Project Evaluation and the Folk Principle when the Private Sector Lacks Perfect Foresight

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ABSTRACT
The shadow price algorithm can successfully implement the “Folk” principle when the private sector fails to anticipate a project’s future benefits and costs. Under these conditions the MCF criterion also implements the principle, but the MCF parameter depends upon the timing of the tax increase required to balance the government’s budget. However, the folk principle is a necessary but not sufficient condition for a worthy project. The SOC criterion satisfies the folk principle while also ensuring that tax revenue is spent efficiently.

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Introduction

Liu (2011) argues that when there is a tax-induced wedge between the marginal rate of productivity of capital (SOC) and the marginal rate of time preference (STP) the “folk principle” (which states that a project is worthwhile if its net present value is positive when all benefits and costs are expressed as increments to, or withdraws from, consumption at different points of time and discounted at the STP rate) is valid, but the shadow price of capital (SPC) approach (which converts all benefits and costs into units of contemporaneous consumption by shadow pricing any private investment displaced or induced, then discounts at the STP rate) fails to implement the principle for projects with costs incurred beyond the initial period. This is because the SPC approach assumes that the consumption and investment displaced in any period depend solely on the project’s expenditure requirements in that period, whereas, if the private sector is rational and fully informed what gets displaced depends upon the entire time stream of the project’s costs. The correct implementation of the folk principle, according to Liu, is to discount a project’s benefits at the STP rate, but to discount its costs, plus any indirect revenue effects, at the SOC rate after multiplying them by a parameter reflecting the marginal cost of funds (MCF), which represents the welfare cost of transferring a dollar of revenue to the government’s budget using the marginal tax instrument.

Liu does not consider situations where the private sector fails to anticipate a project's future benefits and costs, responding to a project only period by period as benefits and costs materialize. But this latter assumption underpins the analytical framework behind the SPC approach, so Liu's claim that the SPC approach is "conceptually flawed", and that it "cannot implement the folk principle even theoretically", needs to be seen within the context of a model where agents have perfect foresight.[1]

In this paper I compare how three prevailing criteria for project evaluation perform when the private sector lacks foresight about a project's benefits and costs. The criteria are: the shadow price of capital approach advocated by Marglin (1963), Feldstein (1964), Bradford (1975), Lind (1982) and Dasgupta (2008); Liu's (2003, 2011) MCF criterion; and the social opportunity cost of capital (SOC) criterion proposed by Harberger (1973) and Sandmo and Dreze (1971), which discounts both benefits and costs at the SOC rate. Several questions arise. First, is satisfying the folk principle a necessary and sufficient condition for a worthy project? Second, since Ricardian equivalence fails to hold when the private sector lacks perfect foresight the MCF parameter will depend upon the *timing* of the tax increase as well as the type of tax, and this raises the question as to the appropriate specification of the MCF criterion. Third, can the SPC approach correctly implement the folk principle as its proponents claim? And finally, what is the relevance of the SOC criterion in this context?

Models in which agents fail to anticipate future benefits and costs have their critics (c.f. Diamond (1968)), but so do models in which agents have perfect foresight (c.f. Arrow and Kurz (1970), Kay (1972)). My purpose here is not to defend myopic behavior as a superior working hypothesis than perfect foresight (though those who maintain that the cost of debt finance differs from the cost of (lump sum) tax finance are implicitly taking this position), but simply to examine how alternative project evaluation criteria perform in the absence of perfect foresight.

Modeling Framework

Following Arrow (1966), Kay (1972) and Bradford (1975), I assume that the private sector fails to anticipate a project's future benefits and costs and follows a simple Keynesian rule of saving (dis-saving) a constant proportion of any change in disposable income that arises on account of the project. A rational and fully informed optimizer would adjust her inter-temporal consumption plan to ensure that the marginal rate of time preference (marginal rate of substitution between current and future consumption) is always equal to the after-tax rate of return, but if project-induced changes in the future quantities of the publicly provided good, and the future tax increases required for

[1] The proposition that the social discount rate should reflect the social rate of time preference, with the opportunity cost of any investment that is displaced being accounted for by a shadow price, was put forth by Marglin (1963), and supported by Feldstein (1964), Kay (1972), Bradford (1975), Lind (1982) and Dasgupta (2008). Marglin (1963) looked at projects with only initial period costs, whereas others considered multi-period costs. Feldstein (1964), Arrow (1966), Arrow and Kurz (1970), Kay (1972) and Bradford (1975) are all explicit about the private sector behaving myopically, but others have failed to recognize, or acknowledge, this key qualification.

financing, are not foreseen, this first order condition of optimizing behavior will not be satisfied.

Arrow, Kay and Bradford posit a divergence between the marginal rate of productivity of capital and the marginal rate of time preference appropriate for judging the relative worth of consumption at various dates, but they do not attribute the divergence to any specific cause. I attribute it to a constant rate of tax τ on capital income.[2] To keep the analysis simple, I follow Liu (2011) and assume that the marginal rate of productivity of capital, denoted by ρ, and the marginal product of labor, denoted by w, are both exogenous and constant over time, labor supply is given, and the after-tax rate of return r = $\rho(1-\tau)$ represents the social rate of time preference.[3]

Private consumption in period t is conditional on disposable income y_d^t and, conceivably, the amount of the publicly provided good made available g^t, so $c^t = f(y_d^t, g^t)$. Disposable income is national income minus taxes on labor and capital income plus interest on government debt so $y_d^t = y^t - T^t - \tau\rho K^t + rD^t$. National income equals wages plus returns on capital so $y^t = w + \rho K^t$. Since assets A^t are comprised of capital plus government debt, $A^t = K^t + D^t$. Disposable income can then be expressed as $y_d^t = w - T^t + rA^t$ where T^t is the (lump sum) tax on labor income in period t.

The aim of government is to choose projects that increase "social welfare", which is defined as the present value of private plus public consumption discounted at the social rate of time preference. A project is represented by an output stream $\{dg^t\}$, a cost stream $\{dI_g^t\}$, and a stream of lump sum tax increases $\{dT^t\}$ that are required to maintain inter-temporal budget balance. The project's benefits in period t are valued at $B^t = p_g^t\, dg^t$, where p_g^t is the private sector's contemporaneous willingness to pay for a small increment of g^t in period t. Thus $p_g^t = (\frac{\partial U}{\partial g^t})/(\frac{\partial U}{\partial c^t})$, where $U(c^t, g^t)$ is the utility from consumption in period t.

If in period t the project's output is dg^t (assumed to be available free of charge), which the private sector values at B^t, and if there is also a lump sum tax increase dT^t, saving in period t will change by $sdy_d^t = –s\, dT^t$ if the project's benefits are separable from private

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[2] Under perfect foresight, with a perfect capital market and a uniform tax on capital income, the after-tax rate of return would equal each individual's marginal rate of time preference, which would equal the social rate of time preference in the absence of a saving externality. If the private sector is myopic the after-tax rate of return has no behavioral significance. However, it could be interpreted as the rate of time preference of a social planner who is fully informed about a project's stream of benefits and costs. The key results of this paper do not depend upon the wedge between the SOC rate and the STP rate being fully explained by the capital income tax, only that it accounts for at least part of the divergence.

[3] With a constant after-tax rate of return, a rational and fully informed optimizer would choose consumption conditional on wealth (initial assets plus the present value of after-tax labor income discounted at the after-tax rate), and the time stream of the publicly provided good, as in Liu (2011).

consumption, and by $s(B^t - dT^t)$ if the benefits are a perfect substitute for income. If the benefits are separable the project has no effect on private consumption, $i.e. \frac{\partial c^t}{\partial g^t} = 0.$ Its effect on private plus public consumption in period t is therefore just B^t. On the other hand, if the benefits are a perfect substitute for income a dollar's worth of benefits will affect saving just as a dollar increase in income, so $\frac{\partial s^t}{\partial g^t} = s\, p_g^t$ where p_g^t is the value of dg^t. Since any effect on saving represents an equal and opposite effect on private consumption then $\frac{\partial c^t}{\partial g^t} = -s\, p_g^t$, so $\frac{\partial c^t}{\partial g^t} dg^t = -sB^t$. Thus when the project's benefits are a perfect substitute for income the impact on private plus public consumption in period t is (1-s) B^t, and the impact on saving in period t is sB^t. But the stream of consumption that the saving yields to the private sector (discounted at the STP rate) is worth sB^t, so a project with benefits B^t that are equivalent to income will increase the stream of private plus public consumption discounted to period t by B^t.

The Government Budget Constraint and the MCF Parameter

To finance project spending the government collects revenue from a pre-existing capital income tax plus a tax on labor income, the latter being effectively a lump sum tax because labor supply is exogenous. However, tax revenue need not equal project spending each period. Instead, the government's budget constraint requires that the present value of tax revenue minus project spending discounted at the after-tax rate of return (assumed to equal the government's borrowing rate) must be equal to the initial outstanding government debt D^0. Thus $\frac{\Sigma_{t=0}^{\infty}[T^t + \tau\rho K^t - I_g^t]}{(1+r)^t} = D^0$.
The government's budget constraint can be written in the following alternative form by replacing K^t by A^t and noting that $A^t = K^t + D^t$. Thus

$$\frac{\Sigma_{t=0}^{\infty}[T^t + \tau\rho A^t - I_g^t]}{(1+\rho)^t} = D^0 \qquad (1)$$

Notice that the discount rate in (1) is the pre-tax rate of return ρ. A dollar borrowed to finance project spending in period t has no effect on disposable income in period t, and therefore no effect on consumption, saving or assets in subsequent periods. The borrowing displaces private investment dollar for dollar. The economic opportunity cost of a dollar of borrowed funds, otherwise known as the SOC rate, is therefore the financial cost r plus the capital income tax revenue foregone τρ, which together equals ρ.
If the private sector has a constant marginal propensity to save s, and if capital income is taxed at rate τ, a dollar increase in lump sum taxes in period 0 will increase the present value of government revenue (discounted at the SOC rate) by $1 - \frac{\tau\rho s}{(\rho - rs)}$ dollars.[4]

[4] A lump sum tax increase of a dollar in period 0 will reduce saving by s dollars, so disposable income in period 1 decreases by sr dollars and capital income tax revenue decreases by τρs dollars. In period 2 disposable income decreases by $sr(1 + sr)$ dollars,

The marginal cost of funds parameter is defined as the welfare cost of transferring a dollar of revenue to the government's budget using a lump sum tax increase. For a lump sum tax introduced in period 0, the marginal cost of funds parameter is equal to

$$MCF^0 = [1 - \frac{\tau\rho s}{(\rho - rs)}]^{-1} \quad (2)$$

When the private sector lacks perfect foresight, Ricardian equivalence (RE) fails to hold. If RE fails to hold the MCF parameter for evaluating a project will depend on the *timing* of the tax increase as well as the type of tax. For example, if a lump sum tax increase is deferred from period 0 to period t and all effects are discounted to period t rather than to period 0 the *magnitude* of the effects on government revenue and consumption will be unchanged. But a dollar of government revenue collected in period t is worth $(1+\rho)^{-t}$ dollars collected in period 0, whereas a dollar of consumption in period t is worth $(1+r)^{-t}$ dollars of consumption in period 0. Therefore the cost to present value consumption of increasing the present value of government revenue by a dollar using a lump sum tax increase in period t is

$$MCF^t = MCF^0 \left(\frac{1+\rho}{1+r}\right)^t \quad (3)$$

It follows from the above that postponing a lump sum tax increase to fund a project raises the social welfare cost of funding the project. Financing a project by borrowing rather than by raising lump sum taxes therefore increases the welfare cost of the project. Importantly, the government can minimize the welfare cost of funding a project by raising all the necessary funds in the initial rather than period by period as the costs are incurred, or as the project's benefits accrue.

The MCF Criterion, the Folk Principle, and the Shadow Price Algorithm

Now consider a project with a stream of output $\{dg^t\}$ that is valued at $\{B^t\}$, and a stream of costs $\{dI_g^t\}$ that are financed by a lump sum tax increase dT^0. According to the folk principle, the project is worthwhile if it results in an increase the present value of private plus public consumption discounted at the STP rate, i.e. if

$$\frac{\Sigma[B^t + dC^t]}{(1+r)^t} > 0 \quad (4)$$

where $dC^t = \left(\frac{\partial C^t}{\partial y_d^t}\right) dy_d^t + (\partial C^t / \partial g^t)\, dg^t, \frac{\partial C^t}{\partial y_d^t} = 1 - s$, and $dy_d^t = -sr(1 + sr)^{t-1} dT^0, t = 1,2 \ldots$

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saving decreases by s(1+sr) dollars and capital income tax revenue decreases by τρs (1+sr) dollars. Capital income tax revenue in period t therefore decreases by $\tau\rho s(1 + sr)^{t-1}$dollars. Discounting the stream of capital income tax revenue foregone at the SOC rate, the present value of the net increase in government revenue resulting from the lump sum tax increase is $1 - \frac{\tau\rho s}{(\rho - rs)}$.

Project Benefits that are Separable from Private Consumption

Let us first consider the case where the project's benefits are separable from private consumption. Then $\frac{\partial C^t}{\partial g^t} = 0$, which means that the project's benefits B^t represent the project's effect on the present value of private plus public consumption in period t. Any effect on private consumption depends solely on the reduction in disposable income caused by the lump sum tax increase required to fund the project. The present value of the decrease in consumption that results from a lump sum tax increase of $dT^0$is equal to dT^0.[5] Therefore the project will increase the present value of private plus public consumption discounted at the STP rate if

$$\Sigma B^t/(1+r)^t - dT^0 > 0 \tag{5}$$

The lump sum tax increase must satisfy the government's inter-temporal budget constraint given in (1). Thus

$$dT^0 + \tau\rho\Sigma_t[\frac{\partial A^t}{\partial T^0} dT^0 + \Sigma_i \frac{\partial A^t}{\partial g^i} dg^i]/\,(1+\rho)^t - \Sigma dI_g^t/(1+\rho)^t = 0 \tag{6}$$

The term $\tau\rho\Sigma_t\Sigma_i \frac{\partial A^t}{\partial g^i} dg^i/\,(1+\rho)^t$is the effect of the project's output stream on capital income tax revenue. We refer to this as the project's indirect revenue effect. The indirect revenue effect in period t is therefore $IR^t = \tau\rho\ \Sigma_i \frac{\partial A^t}{\partial g^i} dg^i$. For a project with separable benefits the indirect revenue effect will be zero, but in the general case the lump sum tax increase will satisfy the government's budget constraint if

$$dT^0[1 - \frac{\tau\rho s}{(\rho - rs)}] = \Sigma_t(dI_g^t - IR^t)/(1+\rho)^t \tag{7}$$

Now substitute the expression for dT^0 that emerges from (7) into the expression for the project's effect on present value consumption in (5), setting $IR^t = 0$ because the project's benefits are assumed to be separable from private consumption. We find that the project will increase the present value of private plus public consumption if

$$\frac{\Sigma B^t}{(1+r)^t} - MCF^0\ [\frac{\Sigma dI_g^t}{(1+\rho)^t}] > 0 \tag{8}$$

The first term in (8) is the contribution of the project's output stream to social welfare (present value consumption discounted at the STP rate). The term in square brackets is the project's budgetary cost, which when multiplied MCF^0 is converted into its cost to present value consumption.

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[5] $\frac{\Sigma_{t=0}^{\infty}(dC^t/dT^0)}{(1+r)^t} = -(1-s)[1 + \frac{sr}{(1+r)}\Sigma_{t=0}^{\infty}\left(\frac{1+sr}{1+r}\right)^t\Big] = -1.$

The MCF criterion is an application of the folk principle. Notice that to apply the principle one needs information not only about a project's benefits and costs and the marginal tax instrument, but also the period in which the tax increase occurs.
Since the MCF parameter for a lump sum tax increase in period t is related to MCF^0 by $MCF^t = MCF^0(\frac{1+\rho}{1+r})^t$, a project with a given time stream of benefits and costs might satisfy the folk principle when the tax increase occurs in period 0, but fail to satisfy it if the tax increase is deferred to period 1 or to some later period.
For example, suppose the project is financed by a sequence of lump sum tax increases sufficient to finance the project's expenditure requirements period by period. The MCF criterion for such a project becomes

$$\Sigma B^t/(1+r)^t - \Sigma MCF^t dI_g^t/(1+\rho)^t > 0 \tag{9}$$

The term dI_g^t represents the project's cost to government revenue in period t; dividing this by $(1+\rho)^t$ converts it into the cost to the present value of government revenue; and multiplying by MCF^t converts it into the cost to present value consumption when the marginal tax instrument is a lump sum tax increase in period t. Because the lump sum tax increase is spread over many periods, this version of the MCF criterion is more stringent than the criterion with the marginal tax instrument being MCF^0.
Now make use of equation (3) to express the criterion in the alternative form

$$\Sigma B^t/(1+r)^t - MCF^0 \Sigma dI_g^t/(1+r)^t > 0 \tag{10}$$

Here benefits and costs are all discounted at the STP rate, but costs are converted into their "consumption equivalent" by multiplying by MCF^0. This criterion will be equivalent to the shadow price algorithm proposed by Marglin (1963), Feldstein (1964), Bradford (1975) and Lind (1982) if $MCF^0 = (1-\alpha) + \alpha V$, where α is the proportion of the project's costs that displace investment and V is the shadow price of capital.[6]
Consequently, the STP approach can successfully implement the folk principle for multi-period projects if α and V are specified appropriately, but this may be a big if.
In fact, the validity of the SPC approach requires that the wedge between the SOC rate and the STP be explained by factors other than a capital income tax distortion; or, if there is a capital income tax distortion, the revenue from the capital income tax must be lump sum rebated each period. A lump sum tax increase would then have no "revenue leakage" (so a one dollar increase in lump sum taxes would increase the present value of

[6] The shadow price algorithm requires knowledge of the proportions of project expenditure that displace investment and consumption in each period (α and 1-α respectively) and the shadow price of capital V, which is the present value of the stream of consumption that is foregone when a dollar of private investment is displaced. The shadow price of capital depends upon the marginal propensity to save and how the capital income tax revenue is spent. If the government lump sum rebates the capital income tax revenue each period it becomes part of disposable income, and with the marginal propensity to save being s and the pre-tax rate of return being ρ the implied shadow price of capital is V = ρ(1-s)/(r-sρ).

government revenue by a dollar). And, because the private sector appropriates the full marginal product of capital (whether directly or indirectly through the recycling of capital income tax revenue) a dollar lump sum tax increase would reduce the present value of consumption (discounted at the STP rate) by 1-s +sV dollars, where V= (1-s) ρ/(r-sρ). The marginal cost of funds parameter (reflecting the cost to present value consumption of transferring a dollar of revenue to the government's budget using a lump sum tax increase) would then be equal to 1-s +sV.

Project Benefits Equivalent to Income

Next consider the case where the private sector treats the project's benefits as equivalent to income. Then each dollar of project benefits will have the same effect on the private sector's consumption stream as a lump sum transfer of a dollar. A proportion s of a dollar's worth of project benefits in period t will therefore be saved, generating a stream of consumption that, when discounted to period t at the STP rate, is worth s dollars. A dollar's worth of project benefits in period t therefore increases the value of the consumption stream discounted to period t by a dollar.[7] And because the project's benefits are partly saved there will be an indirect revenue effect that corresponds to the effect on capital income tax revenue of a stream of lump sum transfers equal to the project's benefits. A lump sum transfer of a dollar in period t will increase the stream of capital income tax revenue discounted to period t at the SOC rate by $\frac{\tau\rho s}{\rho - sr}$. Therefore, a project with period t benefits of B^t that are equivalent to income will increase the stream of capital income tax revenue discounted to period t by $\frac{\tau\rho s}{\rho - sr}B^t$. This can be interpreted as the project's indirect revenue effect in period t, so $IR^t = \frac{\tau\rho s}{\rho - sr}B^t$.[8] Making these substitutions, the MCF criterion takes the form

$$\Sigma B^t/(1+r)^t - \Sigma MCF^t(dI_g^t - \frac{\tau\rho s}{\rho - sr}B^t)/(1+\rho)^t > 0 \qquad (11)$$

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[7] Whether or not the project's benefits are equivalent to income, if benefits in period t induce the private sector to increase its saving in period t the value of the consumption stream that the saving generates, discounted back to period t, is exactly equal to the saving. Therefore a project's impact on private plus public consumption is always equal to the private sector's willingness to pay for the project's benefits. Referring to equation (4), $\partial C^t/\partial g^t$ may differ from zero but the discounted sum $\frac{\Sigma_{i=0}^{\infty}\frac{\partial C^{t+i}}{\partial g_t}}{(1+r)^i} = 0$.

[8] More formally, if the project's benefits are equivalent to income then $\frac{\partial A^t}{\partial g^i} + p_g^i\frac{\partial A^t}{\partial T^i} = 0$. Therefore $\tau\rho\Sigma_t\Sigma_i\frac{\partial A^t}{\partial g^i}dg^i/(1+\rho)^t = -\tau\rho\Sigma_t\Sigma_i B^i\frac{\partial A^t}{\partial T^i}/(1+\rho)^t$. But $\frac{\partial A^t}{\partial T^i} = -s(1+sr)^{t-i-1}$ for t > i+1, and $\frac{\partial A^t}{\partial T^i} = 0$ for t ≤ i. Therefore $\tau\rho\Sigma_t\Sigma_i B^i\frac{\partial A^t}{\partial T^i}/(1+\rho)^t = \tau\rho\Sigma_i\frac{B^i}{(1+\rho)^i}\Sigma_t\frac{\partial A^t}{\partial T^i}/(1+\rho)^{t-i}$. But $\frac{\Sigma_t(\frac{\partial A^t}{\partial T^i})}{(1+\rho)^{t-i}} = -\frac{s}{(1+\rho)}\left[1+\frac{1+sr}{(1+\rho)}+\frac{(1+sr)^2}{(1+\rho)^2}\dots\right] = -\frac{s}{\rho - sr}$. Therefore $\tau\rho\Sigma_t\Sigma_i B^i\frac{\partial A^t}{\partial T^i}/(1+\rho)^t = -\frac{\tau\rho s}{\rho - sr}\Sigma_i\frac{B^i}{(1+\rho)^i}$.

Making use of equations (2) and (3) it follows that for a project whose benefits are equivalent to income the folk principle will be satisfied if

$$\Sigma(B^t - dI_g^t)/(1+r)^t > 0 \qquad (12)$$

This is a version of the shadow price algorithm known as the Arrow (1966)-Bradford (1975) rule. If the project's benefits are just like income no shadow pricing of benefits or costs is necessary and the project will satisfy the folk principle if its net present value is positive when benefits and costs are discounted at the STP rate.

In sum, we have found that if the private sector is myopic about a project's benefits and costs and follows a simple Keynesian saving rule the SPC approach to the evaluation of multi-period projects can successfully implement the folk principle, at least in principle, in two important special cases: when capital income tax revenue is lump sum rebated each period and the project's benefits are separable from private consumption; and when the project's benefits are equivalent to income (whether or not the capital income tax revenue is lump sum rebated each period). Indeed, in these two cases the SPC approach is equivalent to an appropriately specified version of Liu's MCF criterion.

The SOC Criterion and the Folk Principle

We now turn to the question: Is satisfying the folk principle a necessary and sufficient condition for a worthy project? Proponents of the SOC criterion maintain that in order to ensure a level playing field for all projects, project evaluation should be kept separate from tax policy. The SOC criterion treats the marginal source of funds for all projects as the capital market. Whenever there is outstanding government debt, tax revenue can be used to redeem government debt rather than to fund project spending. If the rate of return to capital is exogenous, a dollar of government revenue spent on debt reduction will "crowd in" a dollar of private investment yielding an economic rate of return of ρ. All worthy projects should therefore meet or exceed this standard.[9]

By treating the marginal source of funds for all projects as the capital market, the SOC criterion is measuring the effect of a project on the present value of government revenue when the private sector is kept at pre-project utility. Importantly, the MCF criterion can be reformulated to facilitate comparison with the SOC criterion. First note that the private sector will be kept at pre-project utility if lump sum taxes are increased in each period by an amount equal to the private sector's willingness to pay for the project's benefits in that

[9] Arrow (1995, p. 9) states that "… no matter what our view of the value of future benefits is, it remains true that if the marginal productivity of capital in private use were constant (independent of the amount invested) and if the government could invest in the private sector, then public investment should be evaluated at that rate of interest." However, he rules out direct government investment in the private sector as inappropriate in a mixed economy. Direct government investment in particular sectors of the economy may well be inappropriate, but debt reduction allows the private sector to direct the investment. Not being targeted at any particular sector, debt reduction is entirely appropriate and preferable to spending tax dollars on projects with a lower economic rate of return.

period, i.e. if $\{dT^t\} = \{B^t\}$. Since MCF^t measures the welfare cost of raising the present value of government revenue by a dollar using a lump sum tax increase in period t, then $1/MCF^t$ measures the increase in the present value of government revenue per dollar of welfare (present value consumption) foregone. Thus if $B^t/(1+r)^t$ is the contribution of the project's period t benefits to welfare, $\frac{\frac{B^t}{MCF^t}}{(1+r)^t}$ is the contribution of the project's period t benefits to the government's budget (present value of government revenue) when they are appropriated by a lump sum tax increase in period t. If the private sector is kept at pre-project utility by setting $\{dT^t\} = \{B^t\}$, the project will increase the present value of government revenue (discounted at the SOC rate) provided that:

$$\Sigma(\frac{B^t}{MCF^t})/(1+r)^t - \Sigma(dI_g^t - IR^t)/(1+\rho)^t > 0 \tag{13}$$

The second term in (13) is the project's cost to the present value of government revenue, consisting of its direct cost plus any effect of the project on capital income tax revenue. The effect on government revenue of the sequence of lump sum tax increases required to appropriate the project's benefits can be decomposed into the effect on lump sum tax revenue plus the effect on capital income tax revenue. But the effect on capital income tax revenue is equal to the difference between the compensated and the uncompensated effects of the lump sum tax increase.[10] Therefore the first term in (13) is equal to $\Sigma B^t/(1+\rho)^t + \frac{\Sigma(IR_c^t - IR^t)}{(1+\rho)^t}$. Making this substitution, the reformulated MCF criterion in (13) is equivalent to

$$\Sigma(B^t - dI_g^t + IR_c^t)/(1+\rho)^t > 0 \tag{14}$$

A project with benefits $\{B^t\}$, costs $\{dI_g^t\}$ and *compensated* indirect revenue effects $\{IR_c^t\}$ is worthwhile if it results in an increase in the present value of government revenue discounted at the SOC rate when the private sector is kept at pre-project utility. This is Harberger's (1973) SOC criterion, recently extended by Burgess (2013) to projects with

[10] Since $\tau\rho\Sigma_t\Sigma_i \frac{\partial A^t}{\partial g^i} dg^i/\,(1+\rho)^t$ is the effect of the project on capital income tax revenue holding income fixed, (i.e. the *uncompensated* indirect revenue effect), then $\tau\rho\Sigma_t\Sigma_i[\frac{\partial A^t}{\partial g^i} + p_g^i \frac{\partial A^t}{\partial T^i}]dg^i/\,(1+\rho)^t$ is the effect on capital income tax revenue of the project plus a compensating increase in lump sum taxes (i.e. the *compensated* indirect revenue effect). The difference between the compensated and uncompensated indirect revenue effects is therefore $\tau\rho\Sigma_t\Sigma_i p_g^i \frac{\partial A^t}{\partial T^i} dg^i/\,(1+\rho)^t$. But $p_g^i dg^i = B^i$ so the difference is $\tau\rho\Sigma_t\Sigma_i B^i \frac{\partial A^t}{\partial T^i}/\,(1+\rho)^t$, which represents the impact on capital income tax revenue of a stream of lump sum tax increases equal to the private sector's willingness to pay for the project's benefits.

non-zero compensated indirect revenue effects, i.e. projects whose benefits that are not equivalent to income.[11]

The final step is to recognize that the version of the MCF criterion given in (13) is more stringent than the version of the MCF criterion with the marginal tax instrument being a lump sum tax increase in period 0.[12] To see this recall from (3) that $MCF^t = MCF^0(\frac{1+\rho}{1+r})^t$ so the criterion expressed in (13) is equivalent to

$$\frac{\Sigma B^t}{(1+\rho)^t} - MCF^0 \frac{\Sigma(dI_g^t - IR^t)}{(1+\rho)^t} > 0 \tag{15}$$

Thus a project satisfies the SOC criterion if its net present value is positive when benefits, costs and (uncompensated) indirect revenue effects are all discounted at the SOC rate, but costs plus indirect revenue effects are multiplied by MCF^0. Because the criterion expressed in (15) discounts project benefits at the SOC rate, rather than the STP rate which is lower, we can conclude the SOC criterion is more stringent than the MCF criterion with the marginal tax instrument being a lump sum tax increase in period 0.

Concluding Remarks

If the private sector had perfect foresight Ricardian Equivalence would hold and it would be a matter of indifference whether projects were (lump sum) tax financed or debt financed. In particular, Liu's MCF parameter would be time-independent so the *timing* of a lump sum tax increase would not affect the cost of a project. Liu's MCF criterion would not only implement the folk principle but also ensure that scarce tax dollars are spent efficiently. In other words, the MCF criterion would be equivalent to the SOC criterion: a worthy project would be able to increase the present value of government revenue discounted at the SOC rate while keeping the private sector at pre-project utility. However, if the private sector fails to anticipate a project's future benefits and costs and responds to a project only period by period by saving or dissaving a constant proportion of any change in disposable income that results from the project, satisfying the "folk principle" becomes a necessary, but not a sufficient, condition for a project to represent an efficient use of tax revenue. While the STP approach to multi-period project evaluation can successfully implement the folk principle under certain conditions (e.g. when the project's benefits are separable from private consumption and capital income tax revenue is lump sum rebated, or when project benefits are equivalent to income

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[11] For a project whose benefits are equivalent to income the compensated indirect revenue effect will be zero. The project then satisfies the SOC criterion if $\Sigma(B^t - dI_g^t)/(1+\rho)^t > 0$. This is more stringent than the Arrow (1966) - Bradford (1975) rule, and the reason is that the Arrow- Bradford rule merely satisfies the folk principle whereas the SOC criterion ensures that scarce tax dollars are spent efficiently.

[12] For a project with benefits $\{B^t\}$, costs $\{dI_g^t\}$, (uncompensated) indirect revenue effects $\{IR^t\}$, and the marginal tax instrument being a lump sum tax in period 0 the folk principle will be satisfied if $\frac{\Sigma B^t}{(1+r)^t} - MCF^0 \frac{\Sigma(dI_g^t - IR^t)}{(1+\rho)^t} > 0$.

whether or not capital income tax revenue is lump sum rebated), this does not ensure that scarce tax dollars are spent efficiently. The MCF criterion correctly implements the folk principle but, because the MCF parameter for a project depends upon the timing of the tax as well as the type of tax, a project with a given stream of benefits, costs and indirect revenue effects might satisfy the folk principle when the marginal tax instrument is a lump sum tax introduced in period 0 but not if the tax increase is deferred to later periods. The SOC criterion is a more stringent test of a worthy project than the standard MCF criterion or an appropriately specified shadow price algorithm because it avoids circumstances where scarce tax dollars are used to fund projects that yield a lower rate of return than alternative uses of government revenue, namely debt reduction.

Those who accept the validity of the folk principle and simultaneously reject the SOC criterion as overly stringent have a mistaken view about opportunity cost, treating the cost of a project as the consumption foregone from the tax increase necessary to finance the project rather than the highest valued alternative use of the tax revenue. Whenever there is outstanding government debt some tax revenue is being used to service the debt and additional tax revenue could be used to redeem it. The rate of return foregone by redirecting tax revenue away from this task is the SOC rate.

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