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SUPPLY-SIDE ECONOMICS: AN ANALYTICAL REVIEW

By ROBERT E. LUCAS. JR.*

1. Introduction

WHEN I left graduate school, in 1963, I believed that the single most desirable change in the U.S. tax structure would be the taxation of capital gains as ordinary income. I now believe that neither capital gains nor any of the income from capital should be taxed at all. My earlier view was based on what I viewed as the best available economic analysis, but of course I think my current view is based on better analysis. I thought the story of this transformation, which is by no means mine alone, would make an interesting subject for a lecture. Indeed, I think it makes a particularly suitable subject for the Hicks Lecture, for the theoretical point of view advanced in *Value and Capital* plays the central role in this story, as it has in so many other chapters of our intellectual history.

The framework most of us used, or at least had in the back of our minds, for thinking about taxation, capital accumulation and economic growth in the 1960s was the Solow (1956)–Swan (1956) model in which an economy's savings rate was assumed to be a fixed fraction of income. In this framework, returns to capital are pure rents, so taxing these returns should have no allocative consequences.[1] With progressive schedules and without preferential treatment of returns arbitrarily classified as capital gains, wealthier capitalists could be singled out for the heaviest taxation. Who could ask for a better tax base than this?

The view that an economy's total stock of capital could safely be taken as approximately fixed in tax analysis was forcefully challenged in the 1970s by Feldstein (1978) and Boskin (1978), who argued that the tax treatment of capital and other income in fact had major effects on accumulation and growth. Boskin and others pursued this issue empirically within the

* This paper is a version of the Hicks Lecture, which I had the honor to give in March, 1989. I would like to thank Peter Sinclair for his hospitality on that occasion.

With respect to the analysis of taxation, I am originally a student of Arnold Harberger, and I am grateful for his comments on this paper as well. More recently, I have benefitted from instruction, comments and criticism from Christophe Chamley, Kenneth Judd, Laurence Kotlikoff, Kevin M. Murphy, Edward Prescott, Sherwin Rosen, Nancy Stokey and Lawrence Summers. Peter Sinclair and James Mirrlees provided useful comments after the Hicks Lecture, as did Costas Azariadis and Joan Esteban at the June, 1989 Conference in Santander, Spain. Finally, I thank Chi-Wa Yuen both for his comments and his expert assistance.

[1] Of course, differenital taxation of different kinds of capital has allocative consequences, even when savings are inelastic. Thus the analysis in Harberger (1966) focused on tax-induced misallocation of a fixed total capital stock. Chamley (1981) argues that misallocations due to differential capital taxation are larger than misallocations due to an inappropriate average rate. Jorgenson and Yun (1990) also report estimates of the effects of differential as well as average capital taxation. I will focus here exclusively on the effects of taxation on the total stock of capital, but my doing so should not be interpreted as expressing a position on the relative importance of these two kinds of misallocations.

Solow–Swan framework, by framing it as a question about the magnitude of the interest elasticity of savings. But it is clear enough from the modern theory of consumer behavior that there is no reason to hope that aggregate savings can be represented as a stable function of the contemporaneous return on capital. A savings function will necessarily depend on a whole list of current and expected future returns, and demand functions on infinite dimensional spaces are awkward objects to manipulate theoretically or to estimate econometrically. The Solow–Swan framework, even modified to permit elastic savings behavior along the lines Solow had outlined in his original paper, was simply not suitable for making progress on the questions Feldstein and Boskin raised.

Contributions by Brock and Turnovsky (1981), Chamley (1981) and Summers (1981) provided the framework—really, two frameworks—that proved suitable for this purpose.[2] Each of these papers replaced the savings function of the household with a preference function, the discounted sum of utilities from consumption of goods at different dates. Each used the assumption of perfect foresight, or rational expectations, to deal with the effects of future taxes on current decisions. Each went directly from the first-order conditions for optimal household behavior to the construction of equilibrium, without any need to construct the savings function. In short, all three contributions recast the problem of capital taxation in a Hicksian general equilibrium framework with a commodity space of dated goods. As we will see, this recasting was not a matter of aesthetics, of finding an elegant foundation for things our common sense had already told us. It was a 180 degree turn in the way we think about policy issues of great importance.

The objective of this lecture is to provide a quantitative review of the research on capital taxation that has followed from these contributions. In this attempt, I draw on the contributions of many others, notably Bernheim (1981), Auerbach and Kotlikoff (1987), Judd (1985), (1987) and, especially, Chamley's (1986) normative analysis. But rather than try to mix-and-match conclusions from a variety of different, mutually inconsistent models I will begin by stating a fairly typical example of my own to serve as the basis for a more unified discussion. In Section 3 I follow Chamley (1986) in characterizing the efficient, in the sense of Ramsey (1927), tax structure for this economy. Section 4 uses figures for the U.S. economy to compare long-run behavior under Ramsey taxes to the allocation induced by the existing U.S. tax structure. Section 5 offers some conjectures on transitional dynamics for this model, based on results that have been obtained by others for closely related models.

The result will not be a set of definitive answers, for I will be reviewing on ongoing and active body of research. In any case, the personal experience I

[2] Summers and others acknowledge the stimulus of earlier contributions by Hall (1968) and Miller and Upton (1974).

have described has led me to a certain suspicion of definitive answers to tax questions. But I hope it will be a fair summary of what the best recent research tells us about capital taxation. I hope as well that my story will serve as illustration of the way in which the search for theory at a more fundamental level can revolutionalize our thinking about important practical questions, and hence of the way in which progress at the most purely technical, abstract end of economics serves as the fuel for what Alfred Marshall called our "engine for the discovery of truth."

2. A theoretical framework

As a basis for discussion, I will propose a model suitable for assessing changes in a tax structure consisting of flat-rate taxes on capital and labor income. The model focuses on three margins: the division of production between consumption and investment, the division of time between income-directed activities and all other activities (which I call *leisure*), and the division of income-directed time between the production of goods and the accumulation of human capital (which I will call *learning*). Our interest will be in determining how each of these three margins is affected by changes in the tax structure.

Focusing on some margins means neglecting some others. Thus I will not be studying the division of goods production into private and public goods: government goods consumption and transfer payment obligations will be taken as unalterable givens. I will not analyze the choice of country to invest in, or to acquire capital or consumption goods from: the discussion will be confined to a closed system. Population growth will be mechanically treated, with all demographic choices abstracted from.

By restricting attention to flat-rate taxes (with a small exception to be noted later), in a setting in which, taken literally, lump sum taxes would be both feasible and ideal, I will be evading the fundamental questions on the nature of the tax structure studied in Mirrlees (1971). I consider only tax rates to which the government is fully and credibly committed, though they need not be constant over time, so I am also evading (or at least postponing) the equally fundamental issue of time-consistency raised in Kydland and Prescott (1977) and, in a context very close to the one I will use, in Fischer (1980).

Recent fiscal research based on models with these general features is about evenly divided between work that follows Chamley (1981) in postulating an infinitely-lived typical consumer, interpreted as in Barro (1974) as a family or dynasty, and research that follows Summers (1981) in assuming a succession of finitely-lived overlapping generations. These two classes of models have very different theoretical structures, yet in practice, for the kind of tax problem under study here, seem to yield quite similar results.[3] Nevertheless, a choice must be made, and I will base all of the analysis in this lecture on the relatively simpler dynasty structure. As we will see, many of the ideas and techniques that have been introduced in an overlapping generations context can usefully be adapted to the dynasty context.

In this setting, then, I ask two questions. The first is Ramsey's (1927) normative question: What choice of tax rates will lead to maximal consumer utility, consistent with given government consumption and with market determination of quantities and prices? The second is positive and quantitative: How much difference does it make? To make progress on either question, it will be useful to set out the notation for the model the main feature of which I have just sketched.

There is a single household (representing many) whose objective is to maximize the discounted sum of utilities from the consumption of a single produced good and of leisure, over an infinity of periods:

$$\int_0^\infty e^{-(\rho-\lambda)t} U[c(t), x(t)]\, dt, \tag{2.1}$$

Here $c(t)$ and $x(t)$ stand for per capita consumption of goods and leisure, ρ is the subjective rate of discount, and λ is the rate of population growth. The household is endowed with one unit of time per person per unit of time, so $1-x(t)$ is time spent in income-directed activities.

The production technology is equally simple. Total production of goods (which I will identify with net national product) is a constant returns to scale function of the stock of the per capita capital stock $k(t)$ and effective hours per worker. The latter is just the product of the fraction of time $u(t)$ that each worker devotes to goods production, and his average skill level $h(t)$. Production is divided among consumption, net investment, and government purchases of goods and services, so the technology is described by:

$$c(t) + \frac{dk(t)}{dt} + \lambda k(t) + g(t) = F[k(t), u(t)h(t)]. \tag{2.2}$$

We may think of the average skill level $h(t)$ as growing at an exogenously given rate: Harrod neutral technical change. But I want also to allow for the possibility that human capital accumulation can be affected by the way people allocate their time. Accordingly, let $v(t)$ be the fraction of time

[3] Diamond (1965) demonstrated the possibility of inefficiently large capital accumulation, of a nature that cannot arise in a dynasty structure, in an overlapping generations formulation. Recent work by Kehoe and Levine (1985) and Muller and Woodford (1988) has shown that overlapping generations models can have a continuum of equilibria, and has made some progress in characterizing the circumstances under which this can arise. On the other hand, Laitner (1990) has shown that the overlapping generations equilibria calculated by Auerbach and Kotlikoff (1987) are at least locally unique, for the particular parameter values Auerbach and Kotlikoff assumed.

people spend improving their skills, and assume:

$$\frac{dh(t)}{dt} = h(t)G[v(t)]. \tag{2.3}$$

Of course,

$$u(t) + v(t) + x(t) = 1. \tag{2.4}$$

In this situation, then, we can define a *first-best* allocation as a choice of paths $c(t)$, $u(t)$, $v(t)$, $x(t)$, $k(t)$ and $h(t)$ that maximizes utility (2.1) subject to the feasibility constraints (2.2)–(2.4), given the initial stocks of the two kinds of capital, $k(0)$ and $h(0)$, and the path $g(t)$ of government consumption.[4]

If government activity must be financed by flat-rate taxes, then of course this first-best allocation cannot be attained. To examine the allocations that will arise under flat-rate taxes, we will need explicit statements of the three key marginal conditions.

In a market equilibrium with taxes, households face a budget constraint of the form:

$$\int_0^\infty \exp\left[-\int_0^t (r(s) - \lambda)\, ds\right][c(t) - b(t) - w(t)u(t)h(t)]\, dt \leqslant k(0), \tag{2.5}$$

where $r(t)$ is the interest rate and $w(t)$ the real wage, both expressed net of taxes, and $b(t)$ denotes transfer payments (including coupon payments on government debt) due to households at date t. (Here w is the wage of a worker with a unit skill level, so a worker with skill level h receives wh per unit of time worked.) The right side of this constraint, $k(0)$ is the value (in units of date-0) consumption) of the household's initial capital holdings. In an equilibrium, competition among profit-maximizing firms ensures that both factors are paid their marginal products. Hence:

$$w = (1 - \theta)F_n(k, uh), \tag{2.6}$$

$$r = (1 - \tau)F_k(k, uh). \tag{2.7}$$

where θ is the tax rate on labor income and τ is the tax rate on capital income. Then a competitive equilibrium consists of paths for quantities (c, u, v, x, b, g, k, h), prices (r, w), and taxes (θ, τ) such that (c, u, v, x, h) maximizes (2.1) subject to the constraints (2.3)–(2.5) and $(k, uh, r, w, \theta, \tau)$ satisfy (2.2), (2.6) and (2.7). Note that (2.2) and (2.5)–(2.7) together imply that the government's present value budget constraint is satisfied.

[4] The functions U, F and G are assumed to be twice differentiable. U is strictly increasing in both arguments and strictly concave. F is strictly increasing in both arguments and strictly quasi-concave. G will be assumed either to be a constant function (when I want to treat human capital growth as exogenous) or strictly increasing and strictly concave. These restrictions are sufficient to ensure the uniqueness of the first-best allocation (if one exists) but not to ensure uniqueness of the taxed equilibria I will discuss below. They are not, in general, adequate to ensure existence of first- or second-best allocations. I will not offer a rigorous treatment of these issues in this lecture.

The consumer's problem involves three margins. The marginal rate of substitution between consumption at dates 0 and t must equal the relative prices of these two goods:

$$e^{-(\rho-\lambda)t}U_c(c(t), x(t))/U_c(c(0), x(0)) = \exp\left\{-\int_0^t (r(s)-\lambda)\,ds\right\}. \quad (2.8)$$

The marginal rate of substitution between leisure and consumption must be equal to the real wage:

$$wh = U_x(c, x)/U_c(c, x). \quad (2.9)$$

The allocation of non-leisure time between the two income-directed activities, producing goods and learning new skills, must be such that the value of a unit of time spent producing (and earning) at each date is equal, on the margin, to the value of spending that unit of time accumulating skills that will enhance earnings in the future:

$$w(t)h(t) = G'[v(t)]\int_t^\infty \exp\left\{-\int_t^s (r(\zeta)-\lambda)\,d\zeta\right\}u(s)w(s)h(s)\,ds. \quad (2.10)$$

The left side is just earnings per unit of time for a worker at skill level $h(t)$. The right side is the product of the percentage increment $G'(v)$ to human capital if v units of time are spent in learning and the discounted value of the increased earnings flow that these additional skills will yield. The latter flow depends, of course, on the amount of work effort $u(t)$ one intends to supply in the future.

The marginal conditions (2.6)–(2.10), together with the equations of motion (2.2) and (2.3) for the two kinds of capital, form a system of Euler equations that can be solved for the full dynamics of this model economy given the initial stocks of human and physical capital. I will appeal to them at various points in the argument that follows. By setting the tax rates τ and θ equal to zero, these same equalities also serve to characterize the first-best allocation, a fact I will also cite later on.

With this apparatus in place, I return to the questions I raised a moment ago. What can be said about an optimal tax structure, in Ramsey's second-best sense? This is the subject of the next section. After dealing with it, we will turn to the issues involved in quantifying the gap between current fiscal policy and an ideal one.

3. Efficient taxes

It will provide a useful benchmark for the quantitative analysis to follow to ask first: What is the *best* tax structure for the economy I have just described? One way to frame this Ramsey problem, used in Lucas and Stokey's (1983) analysis of an economy without capital, is to think of the government as directly choosing a feasible resource allocation, subject to constraints that express the assumption that it is possible to find prices such that price-taking households will be willing to consume their part of this allocation. We can then work backward from such an *implementable* allocation to the set of taxes that will implement it.[5]

In an implementable allocation, the household budget constraint (2.5) must be satisfied, and so must the marginal conditions (2.8) and (2.9). Using these marginal conditions to express prices in terms of quantities and substituting back into the budget constraint (2.5) we obtain:

$$\int_0^\infty \mathrm{e}^{-(\rho-\lambda)t}[(c-b)U_c(c,x) - uU_x(c,x)]\,\mathrm{d}t = k(0)U_c[c(0), x(0)]. \quad (3.1)$$

Proceeding in exactly the same way to eliminate prices from the marginal condition (2.10) for human capital accumulation, this condition can be expressed in terms of quantities as:

$$U_x[c(t), x(t)] = G'[v(t)] \int_t^\infty \mathrm{e}^{-(\rho-\lambda)(s-t)} u(s) U_x[c(s), x(s)]\,\mathrm{d}s. \quad (3.2)$$

A feasible allocation (one that satisfies (2.2)–(2.4)) can be implemented by flat rate taxes on capital and labor income if and only if it satisfies the constraints (3.1) and (3.2). Thus choosing time paths of quantities so as to maximize consumer utility subject to these additional constraints determines the Ramsey, second-best allocation. The two associated tax rates can then be read off the marginal conditions provided in the last section. It would be a useful but difficult task to provide a full characterization of solutions to this maximum problem. I have not done so. What I will do instead is to make some observations about the Ramsey taxation of capital income, based on what we know about Ramsey taxes in general and on Chamley's more specific (1986) analysis of a very similar problem.

The nature of efficient capital taxation arises out of the tension between two principles, both of which are familiar from Ramsey's original static analysis. One principle is that factors of production in inelastic supply—factors whose income is a pure rent—should be taxed at confiscatory rates. In the present application, if the value $k(0)$ of consumers' initial capital holdings can be taxed directly via a capital levy, this eases the constraint (3.1) and reduces (or possibly eliminates entirely) the need to resort to distorting taxes. In the same way, defaulting on initial government debt and reducing promised transfer payments from government to households (both summarized in the path $b(t)$ in (2.5) and (3.1)) will reduce the need to resort to distorting taxes and improve welfare. Insofar as the government's ability to obtain capital levies in this general sense is left unrestricted—insofar as $k(0)$ and $b(t)$, $t \geqslant 0$, are regarded as choice variables in

[5] This is, I am taking what Atkinson and Stiglitz (1980), ch. 12, call a *primal* approach, as opposed to the *dual* approach in which tax rates are viewed as governmental decision variables and an indirect utility function is maximized.

formulating the Ramsey problem—it will increase utility to use these tax sources fully. Moreover, insofar as other taxes can imitate such a capital levy, it will be efficient to resort to them. (For example, it is known that a tax on capital income combined with an investment tax credit can imitate a capital levy perfectly.) In my analysis, I will assume that all such capital levy possibilities are already captured in the path $b(t)$ of transfers, so that $b(t)$ and $k(0)$ are taken as givens in the formulation of the Ramsey problem.

A second principle in Ramsey's analysis is that goods that appear symmetrically in consumer preferences should be taxed at the same rate—taxes should be spread evenly over similar goods. In this application, this principle means that taxes should be spread evenly over consumption at different dates. Since capital taxation applied to new investment involves taxing later consumption at heavier rates than early consumption, this second principle implies that capital is a bad thing to tax.

In my formulation there is but one tax rate applied to income from old and new capital alike, so these two principles cannot simultaneously be obeyed. The full solution to the Ramsey problem, then, must involve heavy initial capital taxation followed by lower and ultimately zero taxation.[6] Chamley (1986) provides a very sharp characterization of Ramsey taxes in a model very close to this one that exhibits this tension in a very clear way. In one of his two main results, he showed that if the Ramsey allocation converges to a constant or a balanced growth path, then the tax rate on capital must be zero on this path. It will be illuminating to sketch a proof of this result for our model.

This implication can be developed by examination of the marginal condition for capital only. For a taxed economy with the capital tax rate $\tau(t)$ arbitrarily chosen, this marginal condition is:

$$(1-\tau)F_k(k, uh) = \rho - \frac{d}{dt}\ln[U_c(c, x)]. \tag{3.3}$$

(This equality is obtained by differentiating (2.8) with respect to time and substituting for $r(t)$ from (2.7).) To characterize the Ramsey taxation of capital, then, we simply obtain the analogue of (3.3) for the Ramsey problem and compare the two.

It is easiest to begin with the special case in which the rate of human capital growth is given (the function G is constant with respect to v) so that no time is spent accumulating human capital ($v = 0$) and the time spent producing goods, u, is equal to one minus leisure. In this case, the rate of human capital growth ν, say, is an exogeneously given constant. Then we

[6] Roughly speaking, reducing the right side of the constraint (3.1) eases the excess burden of taxation. If this cannot be achieved by a capital levy that reduces $k(0)$, the next best thing is to reduce the relative *value* of consumers' initial wealth by reducing the initial marginal utility of consumption, $U_c(c(0), x(0))$ and then increasing it rapidly. Since τ cannot exceed unity (no one can be compelled to use his capital in production), the rate of increase in the marginal utility of consumption is (see (3.3) below) bounded by ρ. Chamley shows that on a Ramsey path, this constraint will initially bind, which is to say that $\tau(t) = 1$ for t sufficiently small.

can set aside condition (3.2) and the equality (3.1) completely characterizes the set of allocations that can be implemented with flat-rate taxes. Under these assumptions, the Ramsey problem is: maximize (2.1) subject to (2.2), (2.4) and (3.1). The Lagrangean for the government's maximum problem, in this case, involves the discounted value of the function:

$$W(c, x, \Phi) = U(c, x) + \Phi[(c-b)U_c(c, x) - (1-x)U_x(c, x)],$$

where Φ is a non-negative multiplier, constant over time, and strictly positive if it is necessary to use any distorting taxes. This problem has exactly the form of the first-best planning problem, except that the current period utility function U is replaced by this pseudo-utility function W. The term multiplied by Φ gives a "bonus" to date-t allocations (c, x) that bring tax revenues in to the government, hence relieving other periods of some of their "excess burden", and assigns a penalty to allocations that have the reverse effect.

It is straightforward to show that among the necessary conditions that a solution to the Ramsey problem must satisfy is the equality:

$$F_k(k, uh) = \rho - \frac{\mathrm{d}}{\mathrm{d}t} \ln [W(c, x, \Phi)]. \tag{3.4}$$

It is an immediate consequence of (3.3) and (3.4) that if the Ramsey allocation converges to a steady state—an allocation in which quantities are constant—then the Ramsey tax on capital is zero in that steady state. In this case, the time derivative on the right of (3.4) is zero, and the marginal product of capital is just ρ. From (3.3), this requires $\tau = 0$.

For studying a growing economy, models that converge to steady states are not useful, and the appropriate analogue to a steady state is a balanced growth path, defined in this case as an allocation in which consumption, government spending and both kinds of capital grow at the rate v of technical progress, and the time allocation (u, x) is constant. To ensure that such a path exists for this model, it is necessary to assume that the current period utility function U has the constant elasticity form:

$$U(c, x) = \frac{1}{1-\sigma} [c\varphi(x)]^{1-\sigma}, \tag{3.5}$$

where the coefficient of risk aversion σ is positive. When U takes the form (3.5), then with x constant (as on a balanced path) the growth rate of marginal utility is just the product of σ and the growth rate v of consumption, and the right side of (3.3) is just $\rho + \sigma v$. Moreover, if U has the constant elasticity form (3.5), then a simple calculation shows that for fixed x and Φ, W is also a constant elasticity function with the *same* elasticity σ. Hence along a balanced Ramsey path, (3.4) implies:

$$F_k(k, uh) = \rho + \sigma v. \tag{3.6}$$

Comparing (3.3), which holds for any taxed balanced path, to (3.6), we have shown that if the Ramsey path converges to a balanced path, the tax rate on capital must converge to zero.

This proof of Chamley's result requires modification if human capital growth is assumed to be endogenous, for in that case the government's Lagrangean must incorporate the constraint (3.2) as well as the budget constraint (3.1). But it is not hard to show that (3.6) continues to characterize a Ramsey balanced path even in this more general case. The common sense of this result is clear enough from (2.10): the net-of-tax wage rate appears on both sides of this constraint and it is constant along a balanced path. Thus changes in the labor income tax rate do not distort the learning decision on such a path, except through their effects on leisure demand, and these effects are already taken into account in the constraint (3.1).

Even without working out the details of the Ramsey problem, then, some of the general features of efficient capital taxation are fairly clear. Capital income taxation will initially be high, imitating a capital levy on the initial stock. If the system converges to a balanced path, capital taxation will converge to zero. Chamley (1986) verifies both features for an economy that is very similar to this one. His proof of the long-run result applies to the present model, while the short-run conclusion seems a necessary consequence of the efficiency of capital levies.

The implication that capital should be untaxed in the long run is not sufficient to define the efficient long run fiscal policy, even in a setting in which government spending is given and there is only one other good to tax. This is because the level of debt to be serviced in the long run, which along with the level of government spending will determine what labor income taxes will have to be, will depend on the entire time path of taxes and spending: it cannot be inferred on the basis of balanced-path reasoning alone. Auerbach and Kotlikoff (1987) have emphasized this point in a life cycle context. It is equally important in the kind of dynasty framework I am using here.

4. A balanced growth analysis

According to the analysis of the last section, the best structure of income taxation—for an economy growing smoothly along a balanced path—is to raise all revenues from the taxation of labor income and none at all from capital. To evaluate how interesting a result that is, we need to know just how far away from efficiency, in Ramsey's sense, we now are. I will turn to this issue next, taking the U.S. economy as the case under study. Since I am somewhat familiar with, though by no means an expert on, the U.S. tax structure and national accounts, this will reduce—though not entirely eliminate—the chances of major quantitative blunders.

The general idea will be to view the U.S. economy in the postwar period as though it were a closed economy on a balanced growth path. Then I assume that Ramsey taxes are introduced at some date—I will use 1985—and try to characterize the dynamics of the system from then on. As we have just seen, if this system converges to a balanced path, as I will assume it does, capital will not be taxed on this path. Since the Ramsey path is maximal, consumer utility after this hypothetical reform will exceed what it would have been had the economy continued along the original path. To put the welfare gain in comprehensible units, I would like to calculate the lump-sum, permanent supplement to consumption, expressed as a constant percentage, that would leave consumers indifferent between following the original path and switching to the Ramsey path. In this section, I will work out a rough answer to this question based *only* on a comparison of old and new balanced paths. Transitional dynamics are then discussed in Section 5.

To describe behavior along a balanced path, defined as in the last section, I assume that U is the constant elasticity function (3.5) and that the fiscal variables θ, τ, g/h and b/h are constant. It is convenient to let $z = k/uh$ denote the constant value of the capital to effective labor ratio, and to let $F(z, 1) = f(z)$. Then a balanced path is described by the values of z, c/h, u, v, x and ν that satisfy:

$$u[f(z) - (\nu + \lambda)z] = \frac{c}{h} + \frac{g}{h}, \tag{4.1}$$

$$\nu = G(v), \tag{4.2}$$

$$\rho + \sigma\nu = (1 - \tau)f'(z), \tag{4.3}$$

$$\frac{\varphi'(x)}{\varphi(x)}\frac{c}{h} = (1 - \theta)[f(z) - zf'(z)], \tag{4.4}$$

$$\rho - \lambda + (\sigma - 1)\nu = uG'(v), \tag{4.5}$$

together with the time budget constraint (2.4).

These equations are just specializations of the technology description (2.2) and (2.3) and the marginal conditions (2.6)–(2.10) to the kind of balanced path I have described. One can think of solving them for the balanced path resource allocation, including the endogenously determined growth rate along this path, given the two tax rates τ and θ and the level of government consumption g/h. This procedure would leave the government budget deficit (or surplus) free. A more sensible alternative is to add an equation requiring budget balance along the balanced path:

$$\theta u[f(z) - zf'(z)] + \tau uf'(z) = \frac{g}{h} + \frac{b}{h}. \tag{4.6}$$

The left side of (4.6) is the revenue from the taxes on the two factors of production (deflated by the growing stock of human capital). The right side is government consumption g/h, similarly deflated, plus direct transfers

TABLE 1
Initial Values and Benchmark Parameter Values

Initial output	$F(k, uh)$	1
Initial private consumption	c	0.72
Initial government consumption	g	0.21
Initial government transfers	b	0.18
Initial capital stock	k	2.4
Initial human capital	h	1
Initial employment	u	1
Labor's share		0.76
Capital/labor substitution elasticity	σ_p	0.6
Coefficient of Risk Aversion	σ	2.0
Leisure elasticity	α	0.5
Learning elasticity	γ	0.8
Human Capital Growth Rate	v	0.015
Population Growth Rate	λ	0.014
Labor Income Tax Rate	θ	0.40

b/h, defined to include debt service payments.[7] With equation (4.6) added to the system, we must treat one of the four fiscal variables as endogenous, given the values of the other three.

Tables 2–4 describe numerical solutions to the system (4.1)–(4.6) under various assumptions, based on parameter estimates summarized in Table 1. Let me first describe, very briefly, where these numbers come from. From 1955 to 1985, real output in the U.S. grew at an annual rate of 0.029. (This figure, and all others I cite unless explicitly mentioned, is from the supplemental tables at the back of the 1988 *Economic Report of the President.*) This is also the U.S. growth rate over the entire century: U.S. real growth is amazingly stable, which is why it is attractive to model the system as a balanced path. The population growth rate from 1955 to 1985 was 0.012; employment grew at 0.018, and employed manhours at 0.014. Take the latter figure as an estimate of the parameter λ. Then since I have *defined* all growth in output per person to be human capital growth, the value $0.015 = 0.029 - 0.014$ must be assigned to v. Neglecting imports and exports, net national product was divided in the fractions 0.07 to net investment, 0.72 to private consumption, and 0.21 to government purchases of goods and services. The capital-output ratio consistent with these numbers is 2.4. I normalized initial production (NNP), initial human capital, and initial employment all at unity. These are the sources for the first seven figures in Table 1 (excepting transfer payments, to which I return shortly) and the two growth rates v and λ.

For the production technology, I used a CES function with a substitution elasticity $\sigma_p = 0.6$, a value consistent with time series estimates in Lucas

[7] As remarked at the end of the last section, it is not possible to know the balanced path value of b/h without calculating the transitional dynamics. The provisional assumption used here is that debt is neither accumulated nor decumulated along the transitional path.

TABLE 2

Long-Run Per Capita Capital as a Function of the Capital Tax Rate Expressed as Percentage Change from Benchmark Value

Tax Rate	(A) Inelastic labor Exogenous v	(B) Elastic labor Exogenous v	(C) Elastic Labor Endogenous v	v
0.36	0.0	0.0	0.0	0.0150
0.30	7.0	6.8	7.0	0.0150
0.25	12.4	12.0	12.3	0.0149
0.20	17.4	16.7	17.2	0.0149
0.15	22.0	21.0	21.7	0.0149
0.10	26.4	25.1	26.0	0.0148
0.05	30.5	28.8	30.0	0.0148
0	34.3	32.3	33.7	0.0147

TABLE 3

Long-Run Allocation as a Function of the Capital Tax Rate Expressed as Percentage Change from Benchmark Values

	Case (A)	Case (B): Elastic labor; exogenous v			
Capital 'ax Rate	Consumption	Consumption	Labor supply	Welfare	Labor Tax Rate
0.36	0.0	0.0	0.0	0.0	0.40
0.30	1.6	1.4	−0.2	1.5	0.41
0.25	2.7	2.2	−0.5	2.5	0.42
0.20	3.7	2.9	−0.7	3.3	0.43
0.15	4.6	3.4	−1.0	4.0	0.44
0.10	5.4	3.8	−1.3	4.6	0.45
0.05	6.1	4.1	−1.6	5.1	0.45
0	6.7	4.2	−2.0	5.5	0.46

TABLE 4

Sensitivity of Long-Run Capital, Consumption, Employment and Welfare to Changes in Benchmark Parameter Values Case (B), Capital Tax Rate Equal to Zero
Entries are Percentage Changes from Initial Values

Parameter	Value	Capital	Consumption	Employment	Welfare
σ_p	0.6	32.3	4.2	−2.0	5.5
σ_p	1.0	54.9	7.6	−3.9	10.0
σ	1.0	32.3	4.2	−2.0	5.5
σ	2.0	32.3	4.2	−2.0	5.5
σ	4.0	32.3	4.2	−2.0	5.5
α	0.5	32.3	4.2	−2.0	5.5
α	5	28.1	−1.3	−6.3	2.5
α	50	26.2	−3.8	−8.2	1.2

(1969). Auerbach and Kotlikoff (1987) and most other recent taxation studies use the Cobb-Douglas assumption $\sigma_p = 1$. In Table 4 I will report results based on this higher value for comparison. The share and intercept parameters were then fit to U.S. averages, using a labor share of 0.76.

The utility function has already been assumed to take the form (3.5). I used $\sigma = 2.0$ for the coefficient of risk aversion. Auerbach and Kotlikoff use $\sigma = 4.0$, and even higher estimated values have been reported. But from equation (4.3), one can see that if two countries have consumption growth rates v differing by one percentage point, their interest rates must differ by σ percentage points (assuming similar discount rates ρ). A value of σ as high as 4 would thus produce cross-country interest differentials much higher than anything we observe, and from this viewpoint even $\sigma = 2$ seems high. (I owe this observation to Kevin M. Murphy.) As Table 4 shows, this parameter is not critical for long-run comparisons.

I assumed that φ is the constant elasticity function $\varphi(x) = x^{\alpha}$. The elasticity of substitution between goods and leisure implied by this parameterization is unity, as compared to the elasticity of 0.8 used by Auerbach and Kotlikoff (1987). I assumed that $\alpha = 0.5$, which implies an (uncompensated) labor supply elasticity of 0.11 at benchmark values. Most studies estimate this elasticity to be zero or slightly negative (see Borjas and Heckman (1978)), so this value may be viewed as high. Nevertheless, Table 4 reports results with much higher α values for comparison. I used a time endowment of B (not unity), so that $x = B - u - v$, and chose B so that (4.4) holds at 1985 values. The parameterization and estimation of preferences for goods and leisure, obviously critical for tax problems, is a controversial issue that deserves much more careful treatment.

The learning function $G(v)$ was also assigned a constant elasticity form: $G(v) = Dv^{\gamma}$. I used $\gamma = 0.8$, and chose D and the initial learning time allocation v so that (4.2) and (4.5) hold. The elasticity estimate 0.8 is slightly higher that the value 0.65 that is implicit in the estimates reported in Rosen (1976).

I am imagining that the allocation described in Table 1 arose under a tax structure with two constant flat-rate taxes on labor and capital income. The actual tax structure involves thousands of taxes, many of them with nonlinear schedules, at the federal, state and local levels of government. Viewed at close range, the U.S. tax structure is not a pretty sight. Rather than take you through all the details, I will indicate what the main issues are and how I resolved them, and end up with two numbers: a rate of 0.36 on capital income and 0.40 on labor.

First, I consolidated government at all levels into a single fiscal authority. This matches the share of 0.21 I use for government spending. It should be understood, then, that by eliminating capital taxation I do not mean something that could be brought about by single piece of legislation, like eliminating the federal tax on corporate profits. I mean the far more utopian experiment of eliminating capital taxes at *all* levels. To arrive at these two national tax rates, under this assumption, I calculated the total revenues at all levels from capital taxation in 1985 and divided by total capital income. This produced an estimate of $\theta = 0.36$ for the tax rate, assumed constant, on capital. I imputed all other taxes to labor, an assumption suited to a balanced path, where consumption and labor income taxes are equivalent. Since total tax receipts were 0.36 times NNP, this implies an average tax rate of 0.36 on labor as well.

This flat rate assumption is about right—the U.S. tax structure has never been nearly as progressive as people think. But there is some progressivity in the personal income tax, due mainly to the personal exemption: one is permitted to deduct a fixed dollar amount from one's income in calculating one's tax base. A crude way to take this kind of progressivity into account is to think of all labor income as being taxed at a higher rate and then to treat the difference between labor income tax revenues at this higher rate and actual revenues and a lump-sum rebated back to consumers. I will take the labor tax rate to be $\tau = 0.40$, so that the implicit transfer as a fraction of NNP is $(0.40–0.36)(0.76) = 0.03$ (where 0.76 is labor's share).[8] Since explicit transfers are 0.15 times NNP, the transfers I assume are $b = 0.18$.

To summarize this discussion, we think of an economy in which real output and the stock of physical capital are growing at an annual rate of 0.029, 0.014 due to population growth and 0.015 to human capital accumulation. Fiscal policy in this system is described by four numbers: government consumption is 0.21 and lump-sum consumption transfers to households are 0.18, both expressed as fractions of NNP. The tax rates on labor and capital income are 0.4 and 0.36 respectively. In this situation, we think of reducing the tax rate on capital and keeping both government activity variables g/h and b/h fixed, as ratios to human capital. Let the system adjust to the new balanced path, with the labor tax rate adjusting so as the maintain budget balance in the sense of (4.6).

The long run consequences of this change are displayed in Table 2, for the capital stock, and Table 3, for other variables. (In all of these tables, "percentage change" means a log difference times 100.) The columns of Table 2 refer to different assumptions about labor supply. The first column (case (A)) refers to a case in which human capital growth is exogenous (so $v = 0$ and equations (4.2) and (4.5) can be discarded) and labor is inelastically supplied, so u and x are constant and equation (4.4) can be discarded. Then the tax rate τ determines, via (4.3), the capital-effective-labor ratio z on the balanced path. Given g, one can determine the necessary tax θ on labor given any tax τ on capital. Under these assumptions, labor income is a pure rent, and can be taxed at any level without allocative consequences. This is exactly the first case studied in Chamley (1981).

[8] Joines (1981), Seater (1982) and Barro and Sahasakul (1983) provide careful studies of average marginal federal tax rates in the U.S. My figure of 0.40 for the marginal overall labor income tax rate is loosely based on these.

To calculate the second column of Table 2 (case (B)), I retain the assumption that the growth rate v is given exogeneously (so (4.2) and (4.5) will again not be used) but let labor supply be elastic. Then (4.3) again determines the capital-effective-labor ratio, but the marginal condition (4.4) must be used to determine capital k and labor supply u separately. In this case, the determination of the labor income tax rate θ that will maintain budget balance will not be trivial, and as this tax is varied there will be consequences for resource allocation and welfare that cannot be determined from the marginal condition for capital alone.

For case (C), the last columns of Table 2, I let the growth rate of human capital be endogenously determined, so that the full system (4.1)–(4.6) is needed. In this case neither the growth rate v of the economy nor the capital-labor ratio z can be determined from the marginal condition (4.3) alone. The growth rate v implied by each capital tax rate is given in the last column of the table.[9]

The capital accumulation effects listed under case (A) in Table 2 can just be read off the production function: none of the other equations is needed. Under case (B), there are labor supply effects of the tax changes as well, but they do not much affect the results on capital accumulation. Under case (C), the system's growth rate becomes endogenous, but one can see that the effects of this change are quantitatively trivial. For this reason, Table 3 reports allocation effects for cases (A) and (B) only.

The consumption effects in Table 3 reflect the importance of diminishing returns. In case (B), about half of the potential increase of 4.2 percent is achieved if capital tax rates are reduced from the current 0.36 to 0.25. The required increases in the labor tax rate are modest: Even the complete elimination of capital taxation increases the labor tax rate only to 0.46. Of course, this reflects the much larger share of labor as well as the assumed leisure elasticity.

Table 4 indicates the sensitivity of these results to changes in the assumed values of the critical elasticities. Substitution in production is evidently crucial. With a Cobb-Douglas technology ($\sigma_p = 1$) the capital accumulation effects are far greater than under my assumption of $\sigma_p = 0.6$. The coefficient of risk aversion σ, in constrast, matters not at all in determining the

[9] For comparison, Summers (1981) estimates that the replacement of a tax rate of 0.5 on capital income and 0.2 on labor with a consumption tax would induce a 23 percent increase in the long-run capital stock, using a substitution elasticity of $\sigma_p = 0.5$. (See the last column of Table 2, p. 541.) Auerbach and Kotlikoff (1987) estimate that the replacement of a tax rate of 0.15 on all income with a consumption tax would induce a 19 percent increase in the long-run capital stock, with $\sigma_p = 0.8$. (See Table 5.4, p. 69.) Roughly speaking, Summers' estimate is the overlapping generations counterpart to my Table 2, column (A) estimate, and Auerbach and Kotlikoff's can be compared to my Table 2, column (B). I say "roughly speaking" because there are so many ways in which these models differ from mine (and from each other), but even rough comparisons are useful in making the point that the estimated effects of capital tax reductions are of the same order of magnitude in overlapping generations models and in dynasty models when the technology is parameterized is similar ways. Of course, the dynasty models of Chamley (1981) and Judd (1987) would produce estimates identical to mine if parameterized in the same way, as my formulation is adapted directly from theirs.

balanced path allocation. The leisure elasticity α is also important. As this elasticity increases, so does the distortion entailed in shifting taxes to labor and the welfare effects are correspondingly reduced. Though the Table does not show this, for $\alpha = 5$ or 50, balanced path welfare is not maximized at $\tau = 0$. This does not, of course, contradict Chamley's theorem, but it does illustrate the fact that one cannot give tax regimes a welfare ranking on the basis of their balanced path rankings alone.

To sum up these results, Table 2 certainly provides a resounding confirmation of Feldstein's and Boskin's original intuition. Changes in the tax structure can have enormous effects on capital accumulation. Even under my conservative assumption on capital-labor substitution, capital stock after this hypothetical reform is 32 percent larger than it would have been without any tax change. With a Cobb-Douglas technology, the increase would be 55 percent.

The effects on consumption and welfare reported in Table 3 are also substantial. The consumption effects in case (A) exceed 6 percent—an enormous gain in welfare. With elastic labor supply, the consumption effects are smaller, but increased leisure makes up most of the difference: the welfare effects under case (B) are close to those in case (A). Consumption and capital accumulation effects of similar magnitude have been reported in every study of the last ten years: They do not depend on the details of the particular formulation I am using.

Indeed, they do not depend on anything much beyond the marginal productivity for capital condition (4.3) and the curvature of the production function. Though I have explored other possibilities on the labor side of the model, neither leads to substantial modification of the conclusions one reaches from the simplest model I have called case (A). One could have worked out the key features of these results with pencil and paper in a few minutes!

5. Transitional Dynamics

The balanced growth analysis of the last section gives a good description of the long run allocative consequences of a shift to the efficient tax rate of zero on income from capital, but there is a good deal more to the story than can be told on the basis of balanced path comparisons alone. First, the implication that the efficient long run capital tax is zero does not uniquely define long run fiscal policy, since one needs to know the efficient long run debt level. The comparisons of the last section finesse this issue by taking long run debt service to be unchanged from its original value. Second, and I think quantitatively more crucial, the passage from the current balanced path to an efficient one, since it involves a large increase in the level of physical relative to human capital, will involve a long period of reduced consumption or reduced leisure or both, partially offsetting the welfare gains enjoyed on the new balanced path. How can these considerations be quantified?

I will set up a notation for explaining what I think a sharp answer to this question would be, which will then serve as well for discussing various approximations. Let τ denote a complete description of a tax structure, implying some path $(c_\tau(t), x_\tau(t))$ for consumption of goods and leisure. Let ζ be a fraction that will serve as a compensating consumption supplement, and define the indirect utility function V by;

$$V(\zeta, \tau) = \int_0^\infty e^{-(\rho-\lambda)t} U[(1+\zeta)c_\tau(t), x_\tau(t)]\, dt.$$

Then $V(\zeta, \tau)$ is interpreted as the utility the consumer enjoys under the tax structure τ if he receives, in addition, a non-tradeable consumption supplement $\zeta c_\tau(t)$ at each date t. Then if τ_r denotes the Ramsey tax structure and τ_0 the existing one, I will define the unique, positive value of ζ that satisfies $V(\zeta, \tau_0) = V(0, \tau_r)$ as the welfare gain of moving from the existing structure to the Ramsey structure.

Neither I nor anyone else has calculated this number ζ for the model I am using (though all the ingredients for doing so are in Table 1). But from calculations that have been carried out with closely related models, I think we can get a good idea of what ζ has to be. I will begin with the inelastic labor supply version of the model, the version I called case (A) in the last section, which corresponds very closely to a model studied in Chamley (1981). In this model, the labor income tax is effectively a lump sum tax, so the timing of debt does not matter and the only distortion arises from capital income taxation. In this situation, both the existing and Ramsey tax structures can be characterized by a single number τ, interpreted as the *constant* tax rate on capital, where the Ramsey case corresponds to $\tau = 0$ and the existing case to $\tau = 0.36$. The welfare estimate we seek is then the solution ζ to $V(\zeta, \tau) = V(0, 0)$ when $\tau = 0.36$. Or, if we think of solving this equation for the welfare gain as a function of the tax rate, $\zeta = g(\tau)$, we seek $g(0.36)$.

In dealing with approximations to this welfare gain, I will assume without proof that with fiscal variables constant, or eventually constant, the system converges to a balanced path satisfying conditions (4.1)–(4.6) of the last section. Uzawa (1965) shows that the first-best allocation in a very similar model has this property, provided the learning technology G is so restricted as to keep the system from growing too fast. Under this assumption, Tables 2 and 3 describe the long-run behavior of the economy.

For stable systems, Bernheim (1981) provides a very useful formula for the derivative $V_\tau(0, 0)$ of utility with respect to the tax rate. The derivative $V_\zeta(0, 0)$ is readily calculated, so we can use

$$g(\tau) \approx g'(0)\tau = -V_\tau(0, 0)/V_\zeta(0, 0)\tau$$

as an approximation to the welfare cost $g(\tau)$, valid for small distortions.

Applying Bernheim's formula to the problem at hand yields:

$$g(\tau) \approx \left(\frac{\xi}{\xi+\delta}\right)\Delta \ln (c(0)) + \left(\frac{\delta}{\xi+\delta}\right)\Delta \ln (c(\infty)), \tag{5.1}$$

where $\xi = \rho + \sigma v - (\lambda + v)$, δ is the annual rate of convergence of capital to its post-tax-reform steady state, $\Delta \ln (c(0))$ is the initial percentage change in consumption, and $\Delta \ln (c(\infty))$ is the percentage difference in long-run consumption. The latter difference, for $\tau = 0.36$, is just the last row of Table 3, the long-run welfare measure we have already calculated. Thus Bernheim's formula expresses the overall welfare gain as a simple weighted average of the immediate welfare effect and the ultimate, long-run effect.

To use this formula, we need an estimate of the immediate effect $\Delta \ln (c(0))$. From Table 2, when τ goes from 0.36 to zero, capital will expand by 34 percent, or $(0.34)k_0$. If the fraction δ of this adjustment occurs in the first year, then $\delta(0.34)k_0$ must be added to net investment, which is to say, this amount must be subtracted from initial consumption. The percentage effect on consumption is therefore approximately $\Delta \ln (c(0)) = -\delta(0.34)k_0/c_0 = -(1.14)\delta$, using Table 1 benchmark values. Inserting all of this information into (5.1), we find:

$$g(0.36) = \frac{\delta}{\xi+\delta}[0.067 - (1.14)\xi] = \frac{\delta}{\xi+\delta}(0.027),$$

where the second equality uses the estimate $\xi = 0.035$ which is implied by Table 1 values.

According to this estimate, then, the welfare gain from eliminating capital taxation has a *maximal* value of 2.7 percent of consumption, occurring when the adjustment to the new balanced path is very rapid. Of course, the adjustment implied by very large δ implies infeasibly low initial consumption levels: this experiment strains this local approximation beyond its limits. Chamley (1981) provides an estimate of $\delta = 0.09$ for the actual adjustment rate, using Table 1 parameter values. With $\xi = 0.035$, this implies a welfare estimate of $g(0.36) = 0.019$, or 1.9 percent of consumption.

The Bernheim formula is useful, I think, because it provides such a clear picture both of the way long-run gains and short-run costs are traded off against each other in the kind of tax reform we are assessing, and of the factors on which the terms of this tradeoff depend. Chamley (1981) provides an alternative expansion which, for Table 1 parameter values, yields the estimate $g(\tau) = (0.0322)\tau^2$, so that $g(0.36) = 0.00417$, or only about one-fourth of the estimate obtained using the Berheim formula. Chamley also provides a correction factor for large tax changes, which modifies this estimate to $g(0.36) = (1.76)(0.00417) = 0.0073$, or seven-tenths of a percentage point. I do not have sufficient understanding of the two expansion methods to reconcile these differences, though it would appear to me that

Bernheim's formula as I have applied it overstates the welfare gain for large tax changes (by understating the initial cost).[10] In summary, in the inelastic labor supply case (A), it appears that the welfare gains reported for balanced paths in Table 3 overstate the actual gains by a factor of five, or perhaps more.

As soon as one admits an elastic labor supply, the situation becomes much more complex. From Table 3, one can see that long-run consumption increases are smaller with elastic labor supply, and while this is partially offset by an increased consumption of leisure, the long-run gain in welfare is about 18 percent less. *If* the system were to move to the long-run Ramsey structure at once, increasing θ to 0.46 and decreasing τ to zero, and *if* the present value of tax receipts under both structures were the same, I would expect the overall welfare gain to be reduced about 18 percent as well.

But neither of these two hypotheses is at all likely to be satisfied. From the discussion in Section 3, based on Chamley (1986), the Ramsey structure will surely involve initial heavy taxation of capital combined with an announcement of a future shift to zero taxation. Hence the initial tax on labor income will not have to be raised to anything like its long-run level immediately, and might even be reduced to ease the burden during the transition. The expansions introduced in Judd (1985), (1987) provide an ideal method for assessing the welfare consequences of announcement effects of this kind. By experimenting with different timing possibilities using Judd's method, I think one could find transitional dynamics for the elastic labor case with welfare gains that are closer to the gains in the inelastic labor case than the 18 percent figure implied by Table 3. This would be a much simpler exercise than fully characterizing the Ramsey structure, but I have not carried it out.

Solving for the Ramsey structure would also guarantee that the government's present value budget constraint is satisfied, but this is not ensured in any of the approximations I have discussed or proposed, all of which work by first constructing a tax structure for the balanced path and then piecing this structure together with some transitional dynamics. This issue is addressed computationally in a satisfactory and inexpensive way in Auerbach and Kotlikoff (1987). Their method involves proposing a long-run structure, working out the transitional dynamics, and calculating the resulting government debt (or surplus) that will need to be serviced on the balanced path. This debt service is then used to construct a new long-run tax structure, new transitional dynamics are calculated, and so on. Iterating in this way, Auerbach and Kotlikoff arrive at a mutually consistent characterization of a complete, feasible time path of taxes and spending, where the

[10] Chamley uses a second-order expansion taken about a steady state in which capital is untaxed, so that the coefficient of the first-order term τ vanishes. Bernheim uses a first-order expansion taken about the original, taxed steady state. The approximations used by Judd (1985), (1987) and by Laitner (1990) are conceptually the same as Bernheim's. Of course, there is no reason to expect these different approximations to yield the same answer, especially for the enormous change in the tax rate τ that I am analyzing here.

latter is defined to include debt service. Applied to the present model, this would involve iterating on the value of transfer payments, b/h in Table 1. Again, I have not carried this calculation out.

In summary, there is much to be done to obtain a precise estimate of the overall gain in welfare that would result from a switch from the present U.S. tax structure to an efficient, Ramsey structure. On the other hand, there is available a wealth of analytical and computational methods, all developed and applied in realistic settings in the last ten years, for carrying this estimation out. My summary has been limited to crude pencil and paper calculations and extrapolations from existing studies, and so is little more than an advertisement for the more powerful tools that are now at our disposal. Yet I would be most surprised if the application of these methods to the particular problem I have been discussing should produce estimated welfare gains much outside the range 0.75–1.25 percent of consumption.

6. Conclusions

It is impossible to finish an exercise of this sort without accumulating a long list of issues one would like to address more thoroughly. I will mention just two of these, and then sum up.

I introduced human capital accumulation and endogenous growth into the framework used by Chamley (1981) and others because I thought that, as suggested by Rebelo (1987) and Jones and Manuelli (1988), tax changes might alter long-run growth rates as well as long-run equilibrium levels. For the tax changes I considered, this turned out to be true but quantitatively trivial. Roughly speaking, this is because changes in labor taxation affect equally both the cost and the benefit side of the marginal condition governing the learning decision.[11] Certainly one can think of other fiscal changes, for example increased subsidies to schooling, that would affect this margin directly and have potentially large effects on human capital accumulation and long term growth rates. This was not the subject of my lecture, but it might well be an interesting subject for future research within the framework I have used here.

Second, I have referred to the "efficiency" of such fiscal measures as capital levies and default on government obligations. Within the Ramsey framework as I have applied it, I have no choice: such measures *do* increase efficiency in the sense of reducing the excess burden of taxation. But the time-consistency issue is a very real one, even though I have not addressed it, and there is no point in pretending that, as a practical matter, governments have the ability simultaneously to default on past promises and to issue credible new ones. Serious discussion of the efficient taxation of capital income presupposes a society that is able to commit itself to honoring debt and transfer obligations, and to the avoidance of capital

[11] King and Rebelo (1989) report somewhat larger effects of income tax rate changes on endogenous growth rates, in a setting in which capital as well as labor is used in the accumulation of human capital.

levies, however disguised. This issue is much more important than getting the details of the Ramsey structure just right, and I certainly do not wish my attention to the latter question to suggest otherwise.

I have called this paper an analytical review of "supply-side economics", a term associated in the United States with extravagent claims about the effects of changes in the tax structure on capital accumulation. In a sense, the analysis I have reviewed supports these claims: Under what I view as conservative assumptions, I estimated that eliminating capital income taxation would increase capital stock by about 35 percent. Achieved over a ten year period, such an increase would more than double the annual growth rate of the U.S. capital stock. Translated into an effect on welfare, this change is much less dramatic, for two main reasons. First, diminishing returns to capital implies that a long-run capital increase of 35 percent translates into a long-run consumption increase of something like 7 percent. Second, such an enormous capital expansion requires a long period of severely reduced consumption before this long-run gain can be enjoyed. Taking both these factors into account, I estimated the overall gain in welfare to be around one percent of consumption, or perhaps slightly less.

Now one percent of U.S. consumption is about $30 billion, and we are discussing a flow starting at this level and growing at 3 percent per year in perpetuity. It is about twice the welfare gain that I have elsewhere estimated would result from eliminating a 10 percent inflation, and something like 20 times the gain from eliminating post-war sized business fluctuations.[12] It is about 10 times the gain Arnold Harberger (1954) once estimated from eliminating all product-market monopolies in the U.S. Quantitative welfare economics, seriously practiced, can be a discouraging business. The supply-side economists, if that is the right term for those whose research I have been discussing, have delivered the largest genuinely free lunch I have seen in 25 years in this business, and I believe we would have a better society if we followed their advice. But capital taxation at the levels we have been discussing is not an issue that can make or break a society, and to understand the main discrepancies in the wealth of nations I think we have to look elsewhere.

As a practicing macroeconomist, I must say that I have greatly enjoyed this excursion into public finance. In my area, those of us who advocate structural modeling of aggregate behavior—accounting for observed behavior in terms of preferences and technology—remain very much on the defensive, accused of scientific utopianism and an excessive fascination with mathematical technique. How refreshing it is to spend some time in the company of a group of applied economists who simply take for granted the desirability of using (and extending) the powerful methods of dynamic general equilibrium theory to gain a deeper understanding of policy issues. This research demonstrates its respect for the achievements of past

[12] See Lucas (1981) and Lucas (1987), ch. 3.

economists by building on these achievements, not by preserving them in the amber of methodological and substantive orthodoxy. The result is not conflict between those interested in new techniques and those interested in issues of policy but a unity that delivers the kind of hard, productively debatable results on real questions that traditional macroeconomics has so clearly failed to deliver. The attraction of neoclassical economics is not that it is pretty—though it can be—but that, given half a chance, it works.

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