Two Perspectives on Growth and Taxes

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R obert Solow's (1956) neoclassical model reigns as the standard theory of economic growth. The Solow model begins with the assumption that capital accumulation is subject to diminishing marginal returns. It attributes sustained growth in national income per capita to technological progress that proceeds at a constant, exogenously given rate. Thus, it is an *exogenous growth model*.

Recently, economists have developed alternatives to the Solow model that build on Frank Knight's (1944) earlier theory of economic growth. These economists follow Knight by adopting an all-encompassing definition of capital that accounts for improvements in land, human capital, and scientific knowledge as well as for physical capital. Again along with Knight, they argue that under this broad definition, capital accumulation should be subject to constant, rather than diminishing, marginal returns. In their models, sustained growth occurs even in the absence of exogenous technological change. Hence, these are *endogenous growth models*.

This article presents versions of both the Solow model of exogenous growth and the Knightian model of endogenous growth. In doing so, it illustrates that the differences between these two models are more than purely technical ones; indeed, the differences are of great relevance to contemporary policy debate in the United States. Specifically, Section 1 shows that in the Solow model, a change in the rate of income taxation affects the level, but not the growth rate, of per-capita output. Section 2 demonstrates that in the Knightian model, in contrast, changes in tax rates do influence long-run growth.

Since the two models have such very different policy implications, determining which more accurately describes growth in the U.S. economy remains an important task. Thus, Section 3 concludes the article with a review of the empirical work on income taxation and economic growth.

1. THE SOLOW MODEL WITH TAXES

In the Solow model, time periods are indexed by $t = 0, 1, 2, \ldots$. Like many other contemporary macroeconomic models, the Solow model considers the behavior of a single, infinitely lived representative agent. This representative agent's individual quantities translate into per-capita quantities when the results are applied to understand actual economies.

The representative agent produces output Y_t with capital K_t during each period t according to a production function of the form

$$Y_t = AK_t^\alpha. \tag{1}$$

Since $0 < \alpha < 1$, equation (1) indicates the presence of diminishing marginal returns to capital accumulation: successive incremental additions to the capital stock yield progressively smaller increases in total output. Figure 1 illustrates this property of equation (1). It shows that the marginal return on capital, equal to $R = \alpha AK_t^{\alpha-1}$, is a decreasing function of the capital stock K_t.

The representative agent saves amount S_t during period t in order to add to his capital stock in period $t + 1$. The Solow model assumes that saving S_t is governed by

$$S_t = S(R - R^*), \tag{2}$$

where S is an increasing function of the marginal return on capital R. Thus, the representative agent saves more when the return on capital is higher. R^* represents the rate of return on capital that is so low that the agent no longer finds it worthwhile to save; when $R = R^*$, $S_t = S(0) = 0$.

Figure 1 traces out the dynamics generated by the interaction between the production function (1) and the saving function (2). With the initial capital stock given by K_0, the marginal rate of return R_0 exceeds R^*, so that saving is positive. The representative agent continues to save and accumulate capital until the marginal return has fallen to R^*. At this point, $K_t = K^*$, and saving stops.

When the government imposes an income tax τ, the representative agent's after-tax income becomes $(1 - \tau)AK_t^\alpha$ and his after-tax marginal return on capital becomes $R^\tau = (1 - \tau)\alpha AK_t^{\alpha-1}$. Thus, the income tax τ induces the parallel downward shift in the marginal return schedule that is also shown in Figure 1. Since the representative agent cares only about his after-tax return, his saving now stops when R^τ reaches R^*. Starting from the initial capital stock K_0, capital accumulation continues only until $K_t = K^\tau$.

Thus, Figure 1 reveals how the income tax affects aggregate output in the Solow model. Since it lowers the effective marginal return on capital, the tax weakens the representative agent's incentives to save. Lower saving translates into a smaller capital stock. Consequently, the level of output ultimately attained with the tax, $A(K^\tau)^\alpha$, is lower than the level of output $A(K^*)^\alpha$ achieved without the tax.

Figure 1 also shows that with or without the tax, the Solow model implies that the marginal return on capital eventually falls to R^*, so that capital accumulation and growth ultimately cease. Historically, many economists have used this implication of the diminishing marginal returns assumption to argue that the growth of the U.S. economy, or indeed any capitalist economy, cannot be sustained. Alvin Hansen (1939), for example, interprets the Great Depression of the 1930s as a symptom of a low rate of return on capital and warns that the U.S. economy might stagnate permanently.

In light of the U.S. economy's recovery from the Depression and its continuing expansion since then, however, Solow augments the production function

Figure 1   Taxes in the Solow Model
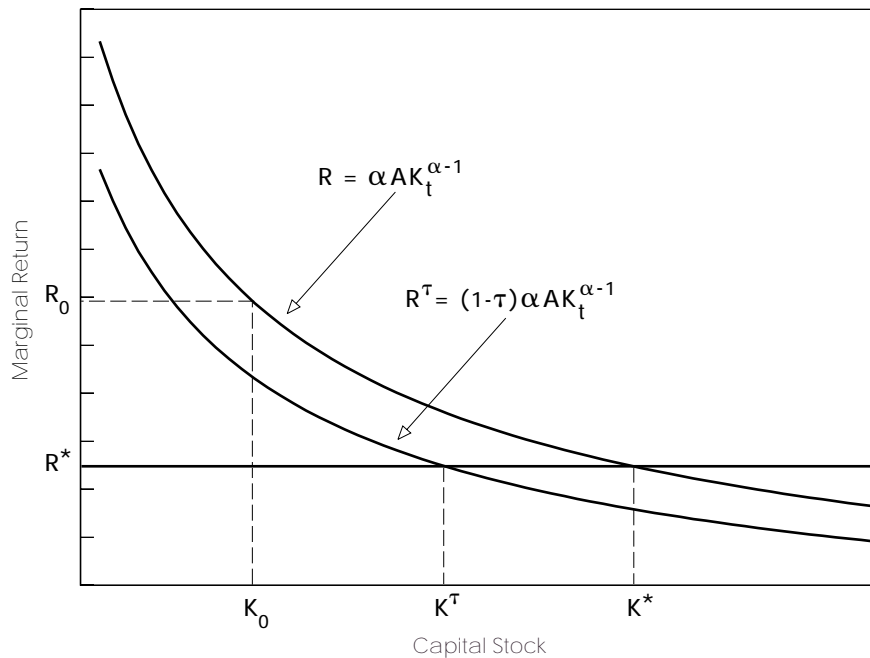
(1) so that his model can account for sustained growth. Specifically, Solow assumes that the parameter A increases steadily over time at the rate μ. Output at time t is then described by

$$Y_t = A_t K_t^{\alpha}, \tag{3}$$

where

$$A_{t+1} = \mu A_t. \tag{4}$$

When A_t increases, the representative agent produces more output with the same capital stock. Thus, equations (3) and (4) capture the effects of constant technological progress.

Figure 2 illustrates the effect of an increase in the parameter A. The government continues to impose the tax τ. At the end of time t, the capital stock K_t^{τ} has reached the level consistent with the minimum rate of return R^*; without technological change, the economy would grow no further. When A increases from A_t at time t to A_{t+1} at time $t+1$, however, the marginal return schedule shifts upward from R_t^{τ} to R_{t+1}^{τ}. The marginal return rises above R^* and capital

Figure 2   Technological Change in the Solow Model
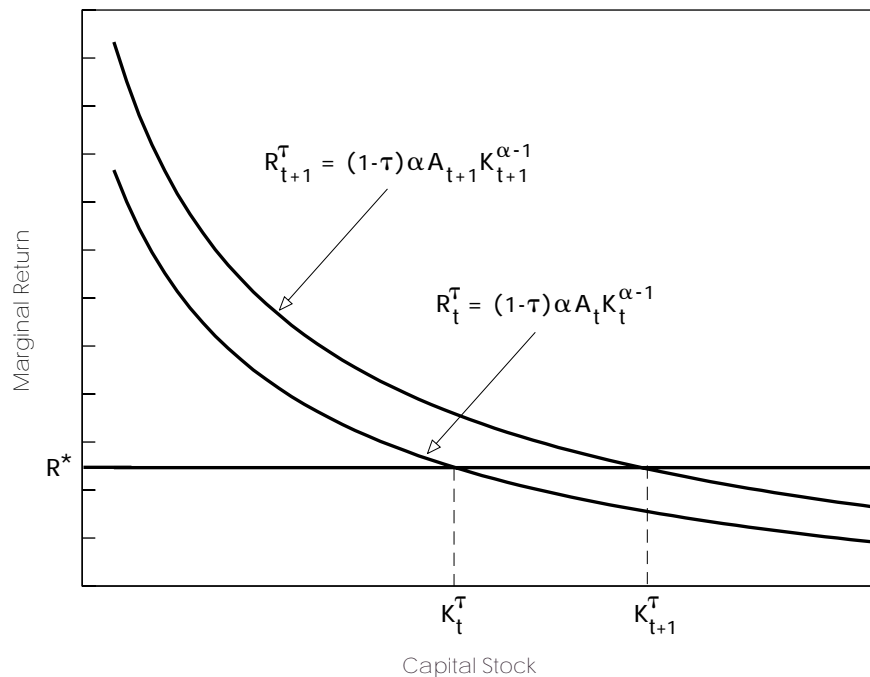
accumulation begins again. The capital stock increases to K_{t+1}^{τ}. Thus, by constantly offsetting the effects of diminishing marginal returns, the kind of continual technological progress described by equation (4) generates sustained growth in the Solow model.

A key assumption behind equation (4) is that μ is completely exogenous. This assumption makes the Solow model an exogenous growth model. Although the tax τ creates adverse effects on incentives that lead to a lower level of output, it has no influence on the process of technological change that determines the economy's long-run rate of growth. Thus, taxes have *level effects* but not *growth effects* in the Solow model.

The Solow model's key implication that tax policies have level effects but not growth effects can also be derived more rigorously with a mathematical treatment of the model. As above, the representative agent produces output according to the production function with exogenous technological change described by equations (3) and (4). The government levies the flat-rate income tax τ.

The government uses its tax revenue to provide the representative agent with a lump-sum transfer of G_t units of output at each date t. The distinction between the flat-rate tax and the lump-sum transfer must be emphasized. The flat-rate tax reduces the agent's effective return on capital and hence weakens his incentives to save. The agent receives the lump-sum transfer no matter how much he saves; the payment G_t has no effect on incentives.

At each date t, the representative agent's total income consists of his after-tax output $(1 - \tau)Y_t$ and government transfer G_t. The agent divides this income between consumption C_t and investment I_t; he faces the budget constraint

$$(1 - \tau)Y_t + G_t = C_t + I_t. \tag{5}$$

From consuming C_t during period t, the representative agent derives utility measured by $\ln(C_t)$, where ln denotes the natural logarithm. His lifetime utility is then

$$\sum_{t=0}^{\infty} \beta^t \ln(C_t), \tag{6}$$

where $0 < \beta < 1$ is a factor that discounts utility in future periods relative to utility in the current period. By investing I_t at time t, the agent adds to his capital stock at time $t + 1$, so that

$$K_{t+1} = (1 - \delta)K_t + I_t, \tag{7}$$

where δ is capital's depreciation rate.

The representative agent maximizes the utility function (6) subject to the constraints (3)–(5) and (7). Cass (1965) demonstrates that the solution to this maximization problem dictates that consumption and capital eventually grow

at the same rate γ and the consumption-capital ratio converges to the constant ξ. Formally,

$$\lim_{t\to\infty} C_{t+1}/C_t = \lim_{t\to\infty} K_{t+1}/K_t = \gamma \tag{8}$$

and

$$\lim_{t\to\infty} C_t/K_t = \xi. \tag{9}$$

Like the representative agent, the government faces a budget constraint that requires that its receipts τY_t equal its expenditures G_t in every period t:

$$\tau Y_t = G_t. \tag{10}$$

Together, equations (3), (5), (7), and (10) imply that the economy's aggregate resource constraint is

$$A_t K_t^\alpha = Y_t = C_t + I_t = C_t + K_{t+1} - (1 - \delta)K_t. \tag{11}$$

That is, output equals consumption plus investment.

In light of equations (8) and (9), equation (11) determines the long-run growth rate that is predicted by the Solow model. Dividing (11) by K_t and taking the limit of both sides yields

$$\lim_{t\to\infty} A_t/K_t^{1-\alpha} = \xi + \gamma - (1 - \delta). \tag{12}$$

Since the right-hand side of equation (12) is constant, this condition implies that A_t and $K_t^{1-\alpha}$ must eventually grow at the same rate. Equation (4) indicates that the growth rate of A_t is μ; equation (8) implies that the long-run growth rate of $K_t^{1-\alpha}$ is $\gamma^{1-\alpha}$. Hence, it must be that $\mu = \gamma^{1-\alpha}$ or, equivalently, that

$$\gamma = \mu^{1/(1-\alpha)}. \tag{13}$$

Equations (3) and (4) then imply that the long-run growth rate of output is

$$\lim_{t\to\infty} Y_{t+1}/Y_t = \lim_{t\to\infty} (A_{t+1}/A_t)(K_{t+1}/K_t)^\alpha = \mu\mu^{\alpha/(1-\alpha)} = \mu^{1/(1-\alpha)}. \tag{14}$$

Equation (14) reveals again the Solow model's key implication: the long-run growth rate is ultimately determined by the rate of technological progress μ. The tax rate τ appears nowhere in equation (14); changes in the tax rate have no effect on long-run growth.

A numerical example illustrates the effects of taxes on growth in more detail. With $\alpha = 0.333$, $\mu = 1.0133$, $\beta = 0.988$, and $\delta = 0.1$, King and Rebelo (1990) show that if each period in the Solow model represents one year, then the model economy's long-run annual growth rate is 2 percent, about the average growth rate of output per capita in the twentieth-century United States.

With these parameter values, Figure 3 plots the growth rates of two Solow economies. Both have constant tax rates, but $\tau = 0.20$ in the first and $\tau = 0.25$ in the second. The economies both start with the same capital stock, set so that

Figure 3   Growth in the Solow and Knightian Models
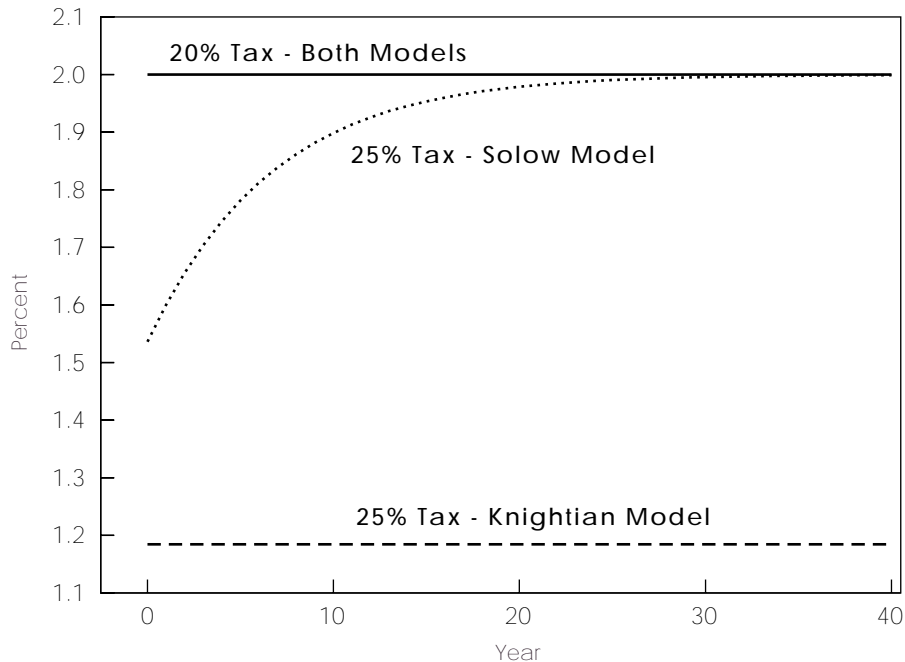
the economy with $\tau = 0.20$ always grows at its long-run rate of 2 percent. Thus, this numerical exercise isolates the effects of an increase in taxes from 20 to 25 percent.

The figure shows that the higher tax rate does slow the economy's growth in the short run. Initially, the growth rate is less than 1.54 percent under the 25 percent tax, compared to 2 percent under the 20 percent tax. Eventually, however, the growth rates of the two economies converge, exactly as required by equation (14). Thus, the results once again illustrate that changes in tax policy have level effects but not growth effects in the Solow model.

2.   A KNIGHTIAN MODEL WITH TAXES

Maddison (1987, Table 1, p. 650) reports that the growth rate of the U.S. economy averaged 4.2 percent annually during 1870–1913, 2.8 percent annually during 1913–1950, 3.7 percent annually during 1950–1973, and 2.3 percent annually during 1973–1984. As the results of the previous section demonstrate, the Solow model attributes all changes in an economy's long-run growth rate to changes in its rate of exogenous technological progress. Thus, according

to Solow's model, the variation in long-run growth documented by Maddison must be due to fluctuations over time in μ. Similarly, among the 92 countries for which complete data are recorded by Summers and Heston (1991, Table III, pp. 356–58), the average growth rate of real per-capita GDP from 1980 through 1988 ranged from 7.8 percent for China to -8.2 percent for Trinidad and Tobago; growth in the United States during this period averaged 2.3 percent. The Solow model also implies that this international variation in growth rates must be due to cross-country differences in μ.

Solow's model does not suggest how μ is ultimately determined, however. Thus, the model essentially leaves unexplained the enormous variation in long-run growth rates that is observed both within countries over time and across countries at any given point in time. This shortcoming of the Solow model has led economists to search for alternative models that do identify sources of variation in long-run growth. One new line of inquiry draws on a theory of economic growth, due to Frank Knight (1944), that predates the formulation of the Solow model.

Knight challenges the conventional view that it is useful to organize factors of production into the three categories of land, labor, and physical capital. According to this conventional view, land is permanently fixed in supply. Labor supply is slightly more variable, but is ultimately limited in the short run by the size of the working population. Only the stock of physical capital can be quickly and easily increased over time.

Knight points out that while land may be fixed in quantity, there is no limit to improvements that can be made in its quality. As a matter of fact, landowners continually develop and improve their property. The productive capacity of an economy's land thereby increases over time, much as the productive capacity of its physical capital stock continually expands as a result of new investment.

Similarly, argues Knight, the quantity of labor may be fixed in the short run, but the quality of the workforce is easily augmented. Just as an entrepreneur invests today to obtain a more productive capital stock tomorrow, a worker allocates time to education and training today so as to become more productive tomorrow. In other words, an economy accumulates human capital as well as physical capital.

In fact, Knight goes on to suggest that the process of technological change is itself just the fruit of another kind of investment. Entrepreneurs and workers search continually for new, more efficient methods of production. Their research and development efforts require resources in the present, but yield a return in the form of increased productivity in the future.

Thus Knight, like Solow, assigns an important role to technological progress in his theory of economic growth. But while Solow assumes that technological progress occurs at an exogenously given rate, Knight views the process as endogenous: the same incentives that induce agents to accumulate physical

capital drive them to search for technological and scientific advances. In light of this distinction, Knight's is an endogenous growth model.

Knight replaces the traditional categories of land, labor, and physical capital with an all-encompassing definition of capital that accounts for improvements in the quality of land, the accumulation of human capital, and the endogenous process of technological change as well as for physical capital. Knight then argues that the various forms of capital he identifies are complements in production. There may be diminishing returns to accumulating one type of capital alone, but there is no tendency for their marginal product to fall as all types are increased together. Under Knight's broad definition of capital, therefore, production features constant, rather than diminishing, returns.

Recent papers by Jones and Manuelli (1990), Barro (1990), King and Rebelo (1990), and Rebelo (1991) incorporate Knight's ideas into contemporary models of economic growth. The simplest of these models differs from Solow's only in its specification of the production function. Here, the representative agent produces output with capital in each period t according to the linear production function

$$Y_t = AK_t. \tag{15}$$

The parameter A is once again constant in equation (15); there is no exogenous technological change. Instead, this model adopts Knight's idea that technological advances occur endogenously and should be accounted for in a comprehensive definition of the capital stock K_t. Equation (15) also drops the exponent α on capital, reflecting Knight's assumption of no diminishing returns.

The implications of Knight's theory can be derived by considering the properties of the production function (15) along with the saving function $S_t = S(R - R^*)$. Consider first the case where there are no taxes. Equation (15) then implies that the marginal return to capital is the constant A; because of the no-diminishing-returns assumption, this return does not depend on the size of the capital stock K_t. Since the return on capital $R = A$ never falls to the critical level R^*, capital accumulation continues forever.

Unlike the Solow model, therefore, this Knightian model accounts for sustained growth in output per capita even in the absence of exogenous technological change. Recalling that Knight's all-encompassing definition of capital accounts for endogenous technological progress, the return $R = A > R^*$ provides the representative agent with an incentive to add continually to the stock of technological knowledge. Economic growth continues as long as this incentive is preserved. The Knightian model therefore contradicts Hansen's (1939) view that an economy will stagnate without exogenous technological change.

The flat-rate income tax τ in the Knightian model shifts the marginal return schedule down from $R = A$ to $R^\tau = (1 - \tau)A$. Sustained growth still occurs if it

is the case that $R^\tau > A$. But since the tax permanently lowers the effective rate of return, it also permanently weakens the agent's incentive to accumulate all types of capital. Hence, unlike the Solow model, this Knightian model predicts that taxes affect the growth rate as well as the level of aggregate output. That is, tax policies have both level and growth effects.

The policy implications of the Solow and Knightian models can be traced back to the different ways in which these two models account for the process of technological change. The Solow model depicts technological change as a completely exogenous process; hence, tax rates do not influence long-run growth. The Knightian model, on the other hand, treats technological change as part of the endogenous process of capital accumulation. Just as higher tax rates weaken the representative agent's incentive to accumulate physical capital, they induce him to slow down his search for more efficient methods of production. Consequently, tax rates do help determine the rate of long-run growth.

In fact, the Knightian model predicts that any economic policy that changes incentives for the accumulation of broadly defined capital will also influence the rate of long-run growth. Since such policies differ widely over time and across countries, this model identifies potential sources of variation in long-run growth rates that the Solow model does not.

As suggested by the analysis above, the mathematical formulation of the Knightian model differs from that of the Solow model only in terms of the production function. Now the representative agent maximizes the utility function (6) subject to the budget constraint (5) and the capital accumulation equation (7) as well as the linear production function (15). King and Rebelo (1990) show that the solution to this maximization problem is such that consumption, capital, and output always grow at the constant rate ω:

$$C_{t+1}/C_t = K_{t+1}/K_t = Y_{t+1}/Y_t = \omega, \tag{16}$$

where

$$\omega = \beta[(1 - \tau)A + (1 - \delta)]. \tag{17}$$

Equation (17) indicates that the economy's growth rate depends negatively on the tax rate τ, so that taxes have growth effects as well as level effects in the Knightian model. Figure 3 illustrates these effects in more detail by repeating its numerical exercise for the Knightian model. As before, $\beta = 0.988$ and $\delta = 0.1$. With $A = 0.165$, output grows at the annual rate of 2 percent under a constant 20 percent tax rate (King and Rebelo 1990). The figure uses these parameter values to plot the growth rates of two Knightian economies, one with $\tau = 0.20$ and the other with $\tau = 0.25$. Thus, as before, the exercise illustrates the effects of a tax increase from 20 to 25 percent.

The figure shows that the growth rate decreases from 2 percent under the 20 percent tax rate to 1.19 percent under the 25 percent tax rate. Moreover,

as equations (16) and (17) imply, there is no tendency for the growth rates of the two economies to converge; the growth rate falls permanently in response to higher taxes. Once again, therefore, the results demonstrate that tax policies have both level and growth effects in the Knightian model.

3.   EMPIRICAL STUDIES OF TAXATION AND GROWTH

Although Figure 3 illustrates that the Solow and Knightian models have different implications for the effects of taxation on long-run growth, this difference may seem to be just a technical matter at first. After all, the tax increase in the Solow model does not permanently decrease growth as in the Knightian model, but it does result in slower growth for more than two decades. When expressed in terms of the level rather than the growth rate of output, however, the difference is enormous. In the Solow model, the increase in the tax rate from 20 to 25 percent decreases the level of output by 3.17 percent over 40 years. In the Knightian model, the same tax increase reduces the level of output by 27.5 percent over 40 years.

Policymakers in the United States have recently called for increases in marginal tax rates, which they argue will help to close the federal budget deficit without significant losses in output. Others disagree, claiming that higher taxes inevitably lead to slower growth. As the results of the previous sections show, competing economic theories lend support to both sides in this debate. On the one hand, the Solow model describes an environment in which tax rates do not affect long-run growth; on the other, the Knightian model confirms the view that higher taxes do hinder growth.

Thus, the next step in applying the theories to understand the U.S. economy is to determine empirically whether or not changes in tax rates actually translate into changes in long-run growth. If taxes do not influence long-run growth, then the Solow model and its policy implications should be taken seriously. If taxes do help determine long-run growth, however, then the Knightian model and its implications are to be preferred.

Figure 4 plots the growth rate of real per-capita GDP (taken from the *Economic Report of the President* 1993) along with Barro and Sahasakul's (1986) tax rate series (updated to run through 1989) for the United States. The graph suggests that there has been a negative relationship between growth and taxes over the postwar period. In fact, a simple regression of the growth rate on the tax rate yields a negative coefficient that is statistically significant at the 10 percent level. Cebula and Scott (1992) use quarterly series from 1957 through 1984 to regress growth in real per-capita GDP on various measures of fiscal policy, including the top personal income tax rate. They also find that changes in taxes have a negative and statistically significant effect on growth.

A problem with using these results to discriminate between the Solow and Knightian growth models arises because even in the Solow model, changes

Figure 4   Growth and Tax Rates in the U.S. Economy
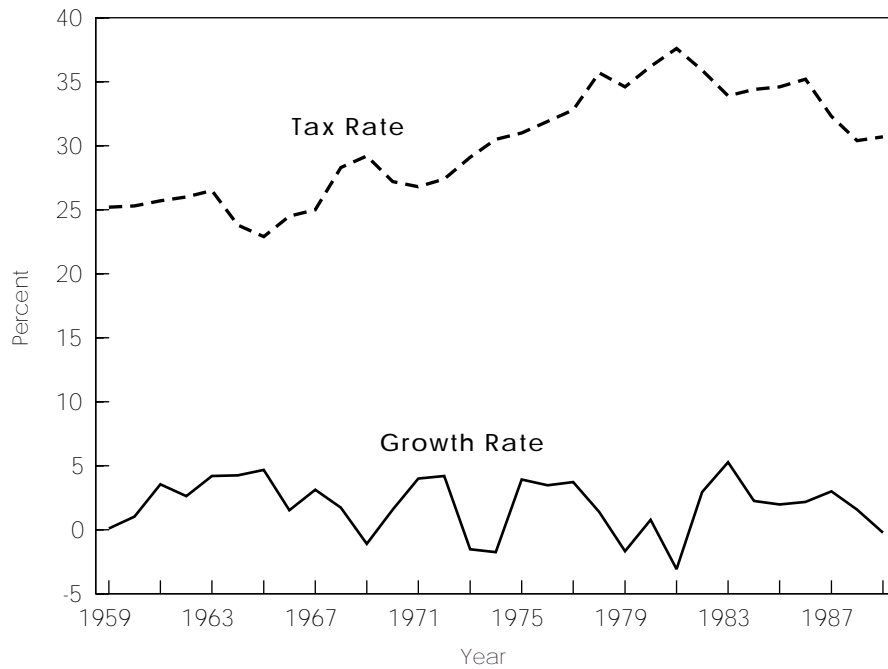
in tax rates affect growth in the short run. As Figure 3 reveals, it is only in the long run that taxes influence growth in the Knightian model but not in the Solow model. Thus, the negative short-run correlation between taxes and growth that appears in Figure 4 is consistent with the implications of both models. Likewise, since Cebula and Scott do not distinguish between short-run and long-run changes in growth, their results cannot be interpreted as decisive evidence against the Solow model either.

Kocherlakota and Yi (1993) recognize the problem of distinguishing between short-run and long-run changes in growth and sidestep this problem by taking a slightly different approach to test the Solow model against the Knightian theory. They note that in addition to having distinct implications for the effects of taxes on the growth rate of output, the two models have different predictions for the effects of taxes on the level of output. Specifically, the Solow model predicts that temporary changes in tax rates have only temporary effects on the level of output. The Knightian model, in contrast, predicts that temporary changes in taxes permanently affect the level of output.

Kocherlakota and Yi assume that all changes in U.S. tax rates, 1917–1983, are temporary ones, and they use a statistical model that distinguishes between temporary and permanent changes in the level of real GNP. Their estimate indicates that temporary increases in tax rates have translated into permanent decreases in the level of output; this result supports the Knightian model. On the other hand, the estimate is not statistically significant, which suggests that the Solow model may be more realistic. Overall, Kocherlakota and Yi's results may simply indicate that even with 65 years of data and with the most powerful statistical techniques, it is very difficult to extract much information about the determinants of long-run growth from the U.S. time series.

Other researchers circumvent the problem of distinguishing between short-run and long-run changes in growth by using international cross-sectional data rather than time series data. With cross-sectional data, growth rates within each country can be averaged over extended periods of time in order to smooth out short-run fluctuations and thereby identify long-run trends. In addition, by drawing on the experiences of many different countries, cross-sectional data bring more information to bear on the question of whether tax rates affect long-run growth. On the other hand, compared to time series studies, those that use cross-sectional data must make the additional assumption that the same mechanisms through which taxes influence aggregate activity in the United States operate in the other countries as well, so that conclusions that apply internationally also hold for the United States.

Existing cross-sectional studies differ in that some use the average tax rate, the ratio of total tax receipts to national income, while others use the marginal tax rate, the additional taxes paid when income rises incrementally, to estimate the effects of taxes on growth. In both of the theoretical models presented above, the simple flat-rate tax is such that the average and marginal tax rates coincide. In reality, however, tax rates differ with the source and level of income, so that average and marginal tax rates diverge. Since economic decisions depend on the marginal tax rate, this measure is more appropriate for investigating the effects of taxes on growth. Data on marginal tax rates are often unavailable, however; average tax rates must then serve as a proxy.

Marsden (1983) takes data from 20 countries, 1970–1979. He organizes these countries into ten pairs; each pair consists of countries with similar levels of per-capita income but different average tax rates. In each pair, he finds that the country with the lower tax rate has a higher rate of real GDP growth. As a matter of fact, all of the ten low-tax countries have higher growth rates than any of the high-tax countries. This pattern also appears in Marsden's regression results, which show that average tax rates have a significantly negative effect on growth across countries.

In Reynolds' (1985) sample, industrial countries with high average tax rates, including Sweden, Belgium, and the Netherlands, grew at an average rate of 1.7 percent between 1976 and 1983. In contrast, those with low average

tax rates, such as the United States, Portugal, and Japan, averaged 4.1 percent growth. About the effects of marginal tax rates, Reynolds notes:

> Supply-side tax theory would predict that economic performance in Ontario, Canada, with a top tax rate of 51 percent, would be superior to that of Quebec, with its 60 percent rate. It would predict that development in Puerto Rico, with a top tax rate of 68 percent, would fall behind that of any U.S. state. It would predict that Australia would outperform New Zealand, that Cyprus would outperform Greece, that the state of New Jersey would grow faster than New York, and so on. All of these predictions are correct.   (P. 557)

Among developing countries, Reynolds finds that those with the highest marginal tax rates have economies that contracted by 1.4 percent annually, 1979–1983. Those with the lowest marginal tax rates, on the other hand, have economies that grew by 4.9 percent annually.

Skinner (1987) uses cross-sectional data from 31 sub-Saharan African countries, 1965–1982. His regression equation shows that the average tax rate has a negative and statistically significant effect on growth.

Average tax rates and growth turn out to be positively correlated in Rabushka's (1987) sample of 49 developing economies, 1960–1982. Rabushka interprets this finding as evidence that governments in more prosperous countries are able to levy more taxes than those in slower-growing nations, rather than as evidence that higher taxes lead to faster growth. Unlike average tax rates, he notes, marginal tax rates are negatively correlated with growth. The country with the lowest marginal tax rate, Hong Kong, has one of the highest growth rates in the sample, averaging 7 percent annually. A group of countries with the highest marginal tax rates, in contrast, grew at the average annual rate of only 1.9 percent.

Most recently, Martin and Fardmanesh (1990) and Engen and Skinner (1992) estimate cross-sectional regression equations and find that average tax rates are significantly and negatively related to growth in real income per capita. Martin and Fardmanesh's sample includes data from 76 countries, 1972–1981; Engen and Skinner's consists of data from 107 countries, 1970–1985.

Thus, many cross-sectional studies appear to support the hypothesis that tax rates influence long-run growth and thereby point to the Knightian model as the more accurate description of the U.S. economy. Only three of these studies, however, use more than ten years' worth of data. The others suffer from the same problem as Cebula and Scott's: by averaging data over a brief time interval, they may not adequately distinguish between short-run and long-run variation in growth. In addition, there are still other cross-country studies that lend support to the Solow model by indicating that changes in tax rates do not affect the long-run growth rate of output.

Using a sample of 63 countries, 1970–1979, Koester and Kormendi (1989) begin by noting that both average and marginal tax rates appear to be negatively

associated with growth. They go on to point out, however, that the level of GDP is negatively related to growth, suggesting that smaller countries grow faster than more developed ones. They note, in addition, that average tax rates are positively correlated with the level of GDP; like Rabushka, they suggest that this correlation indicates that more affluent countries have governments that levy more taxes. Together, these last two correlations raise the possibility that earlier studies may have mistakenly concluded that changes in tax rates have long-run effects on growth, since the negative correlation between taxes and growth may simply reflect the fact that for independent reasons, both tax rates and growth rates are related to the level of income.

To allow for this possibility, Koester and Kormendi add the level of GDP to their growth regressions; by holding the level of income constant, they focus on the direct link between taxes and growth. While the coefficients on both average and marginal tax rates are still negative in the expanded regressions, neither is statistically significant. Garrison and Lee (1992) find that these results continue to hold when the data set is extended through 1984. Thus, these studies suggest that changes in tax rates do not have important growth effects.

Easterly and Rebelo (1993) calculate marginal tax rates for 32 countries in 1984. They regress the growth rate of per-capita consumption from 1980 through 1988 on the marginal tax rate as well as the level of per-capita GDP (following Koester and Kormendi) and measures of two other variables, educational attainment and political instability, that may explain cross-country differences in growth rates. Like Koester and Kormendi, Easterly and Rebelo obtain a negative but statistically insignificant coefficient on the marginal tax rate. Thus, their results also appear to support the Solow model.

Easterly and Rebelo note, however, that they cannot reject the hypothesis that all of their regressors are jointly insignificant. Like Kocherlakota and Yi's time series results, therefore, Easterly and Rebelo's cross-country results may simply indicate that there is insufficient information about the determinants of growth in their sample.

Thus, a review of the literature reveals that no strong conclusions can yet be reached as to which model, Solow's exogenous growth model or the Knightian endogenous growth model, is more appropriate for studying the effects of taxation on growth in the U.S. economy. A number of papers present evidence that tax rates do affect long-run growth, but others find no significant relationship.

The literature points to several problems that need to be overcome in future empirical work. Time series studies must effectively discriminate between short-run and long-run changes in growth, for it is only long-run changes that distinguish the competing models. Cross-sectional studies must distinguish between average and marginal tax rates, since marginal tax rates most directly affect economic decisions but are frequently difficult to measure. Cross-sectional studies must also address the possibility, first raised by Koester and Kormendi, that simple correlations may not reflect the direct effects of taxation

on growth. Finally, Easterly and Rebelo's results suggest that efforts to collect tax and growth rate data from a wider sample of countries than has been previously considered might prove useful in sharpening the statistical results.

The massive federal budget deficit in the United States makes it likely that policymakers will continue to advocate significant tax increases in the years ahead. Since the Solow and Knightian models offer such different predictions for the effects of these tax increases on output, the empirical relationship between taxation and growth remains an important unsettled issue for future research.

REFERENCES

Barro, Robert J. "Government Spending in a Simple Model of Endogenous Growth," *Journal of Political Economy,* vol. 98 (October 1990, Part 2), pp. S103–25.

──────── , and Chaipat Sahasakul. "Average Marginal Tax Rates from Social Security and the Individual Income Tax," *Journal of Business,* vol. 59 (October 1986, Part 1), pp. 555–66.

Cass, David. "Optimum Growth in an Aggregative Model of Capital Accumulation," *Review of Economic Studies,* vol. 32 (July 1965), pp. 233–40.

Cebula, Richard J., and Gerald E. Scott. "Fiscal Policies and Growth: An Extension," *Rivista Internazionale di Scienze Economiche e Commerciali,* vol. 39 (January 1992), pp. 91–94.

Easterly, William, and Sergio Rebelo. "Marginal Income Tax Rates and Economic Growth in Developing Countries," *European Economic Review,* vol. 37 (April 1993), pp. 409–17.

Economic Report of the President. Washington: United States Government Printing Office, 1993.

Engen, Eric M., and Jonathan Skinner. "Fiscal Policy and Economic Growth," Working Paper 4223. Cambridge: National Bureau of Economic Research, December 1992.

Garrison, Charles B., and Feng-Yao Lee. "Taxation, Aggregate Activity and Economic Growth: Further Cross-Country Evidence on Some Supply-Side Hypotheses," *Economic Inquiry,* vol. 30 (January 1992), pp. 172–76.

Hansen, Alvin H. "Economic Progress and Declining Population Growth," *American Economic Review,* vol. 29 (March 1939), pp. 1–15.

Jones, Larry E., and Rodolfo Manuelli. "A Convex Model of Equilibrium Growth: Theory and Policy Implications," *Journal of Political Economy,* vol. 98 (October 1990, Part 1), pp. 1008–38.

King, Robert G., and Sergio Rebelo. "Public Policy and Economic Growth: Developing Neoclassical Implications," *Journal of Political Economy,* vol. 98 (October 1990, Part 2), pp. S126–50.

Knight, Frank H. "Diminishing Returns from Investment," *Journal of Political Economy,* vol. 52 (March 1944), pp. 26–47.

Kocherlakota, Narayana R., and Kei-Mu Yi. "A Simple Time Series Test of Endogenous vs. Exogenous Growth Models: An Application to the United States." Manuscript. University of Iowa, Department of Economics, July 1993.

Koester, Reinhard B., and Roger C. Kormendi. "Taxation, Aggregate Activity and Economic Growth: Cross-Country Evidence on Some Supply-Side Hypotheses," *Economic Inquiry,* vol. 27 (July 1989), pp. 367–86.

Maddison, Angus. "Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment," *Journal of Economic Literature,* vol. 25 (June 1987), pp. 649–98.

Marsden, Keith. "Taxes and Growth," *Finance and Development,* vol. 20 (September 1983), pp. 40–43.

Martin, Ricardo, and Mohsen Fardmanesh. "Fiscal Variables and Growth: A Cross-Sectional Analysis," *Public Choice,* vol. 64 (March 1990), pp. 239–51.

Rabushka, Alvin. "Taxation, Economic Growth, and Liberty," *Cato Journal,* vol. 7 (Spring/Summer 1987), pp. 121–48.

Rebelo, Sergio. "Long-Run Policy Analysis and Long-Run Growth," *Journal of Political Economy,* vol. 99 (June 1991), pp. 500–521.

Reynolds, Alan. "Some International Comparisons of Supply-Side Tax Policy," *Cato Journal,* vol. 5 (Fall 1985), pp. 543–69.

Skinner, Jonathan. "Taxation and Output Growth: Evidence from African Countries," Working Paper 2335. Cambridge: National Bureau of Economic Research, August 1987.

Solow, Robert M. "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics,* vol. 70 (February 1956), pp. 65–94.

Summers, Robert, and Alan Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950–1988," *Quarterly Journal of Economics,* vol. 106 (May 1991), pp. 327–68.