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Growth, Productivity, and the Rate of Return on Capital

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Abstract

This paper examines the ability of alternative classes of growth models to explain the historical experience of the U.S. economy. The potential returns to the U.S. from raising its investment rate in terms of both the level and growth rate of future output are then quantified. The long-run growth performance of the U.S. economy is found to be broadly consistent with the predictions of the neoclassical growth model. Endogenous growth models, which suggest a larger contribution of capital to growth and long-run effects of investment on the growth rate, do not seem to be supported by the data.

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Summary

An important public policy question in the United States is the degree to which increasing the savings rate would be expected to lead to an improvement in the economy's long-term growth performance. Alternative views of the relationship between investment and the economy's growth rate suggest different answers to this question. According to the traditional neoclassical growth model, an increase in the investment (saving) rate, would raise the medium-term growth rate (and the level of the path of output thereafter), but would have no long-run effect on the economy's growth rate. Conversely, in some recent models of endogenous growth, strong externalities associated with an individual firm's investments imply that the returns from raising the investment rate could be much larger than suggested by the neoclassical model and that a higher investment rate might place the economy on a permanently higher growth path.

This paper attempts to shed light on which (if either) of these views on the relationship between investment and growth is most applicable to the U.S. economy. It then quantifies the potential returns to the U.S. from raising its investment rate in terms of both the level and the growth rate of future output. After outlining the salient features of the two alternative classes of growth models, the paper examines the long-run growth performance of the U.S. economy with a view to ascertaining capital's contribution to growth. Evidence is presented on: growth accounting measures of the contribution of capital; the time-series relationship between investment and growth; and whether the rate of return on capital has behaved in a manner consistent with the predictions of alternative models.

Based on the review of the growth experience of the U.S. economy, the paper argues that there are no strong reasons for rejecting the central conclusion of the neoclassical model that shifts in investment will have no long-lasting effect on the economy's growth rate. Moreover, given capital's income share, the effects of shifts in investment on growth in the short to medium term can be expected to be small relative to the U.S. economy's underlying rate of growth. The class of endogenous growth models, which suggest a larger contribution of capital to growth and long-run effects of investment on the growth rate, do not seem to be supported by the data. This conclusion does not, of course, imply that efforts to raise the savings (and investment) rate would not lead to an improvement in economic performance in the U.S. The payoff from such efforts would include, in particular, a faster growth rate in the transition to a new long-run equilibrium and a permanently higher level of output and labor productivity.

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I. Introduction

An important public policy question in the United States is the degree to which increasing the savings (investment) rate would be expected to lead to an improvement in the economy's long-term growth performance. Alternative views of the relationship between investment and the economy's growth rate suggest different answers to this question. According to the traditional neoclassical growth model (Solow (1956) and Swan (1956)), an increase in the investment (saving) rate, while raising the medium-term growth rate (and the level of the path of output thereafter) would have no long-run effect on the economy's growth rate. Moreover, to the extent that capital's contribution to growth is reasonably well approximated by its income share, this improvement in economic performance would be expected to be small relative to the economy's underlying growth rate. Conversely, in some recent models of endogenous growth (Romer (1986, 1987 a,b, 1990), Rebelo (1990), Sala-i-Martin (1990 a,b)), strong externalities associated with an individual firm's investments imply that the returns from raising the investment rate could be much larger than suggested by the neoclassical model and that a higher investment rate might place the economy on a permanently higher growth path.

The purpose of this paper is to shed light on which (if either) of these views on the relationship between investment and growth is most applicable to the U.S. economy. The desirability of the U.S. raising its savings rate from current low levels is taken as given and it is further assumed that any increase in saving would be partly reflected in higher (domestic) investment. 1/ With this as background, consideration is given to the potential returns to the U.S. from raising its investment rate both in terms of the level and the growth rate of future output. 2/ After briefly outlining salient features of alternative growth models in Section II, the paper studies in Section III the long-term growth performance of the U.S. economy with a view to determining the size of capital's contribution to growth; the time-series relationship between investment and growth; and whether the rate of return on capital has behaved in a manner consistent

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1/ In a large open economy such as the U.S., an increase in the savings rate would be expected to be reflected partly in an improved current account and partly in higher domestic investment.

2/ The paper does not consider explicitly how much the long-run consumption path would be raised. For a detailed overview of the case for raising the U.S. savings rate, and a discussion of its implications for consumption possibilities, see Evans (1990). Given that much of the existing discussion of the benefits of raising the U.S. savings rate has been based on models in which investment has only a temporary effect on growth rates, there is a presumption that if endogenous growth models are applicable to the U.S. experience the case for a higher U.S. saving would be reinforced (Summers (1990)).

with the predictions of alternative models. Concluding comments are provided in Section IV.

II. Alternative Models of the Relationship Between Investment and Growth

This section outlines two alternative views of the relationship between investment and the economy's growth rate. It begins with a description of the neoclassical growth model--with and without embodied technical progress--and then considers models of endogenous growth associated with Romer (1986, 1987 a,b, 1990). The section highlights that capital's growth contribution can be summarized by its exponent in an aggregate production function--with the major difference between the neoclassical and endogenous growth models being whether there are diminishing returns to capital (i.e., this exponent is less than unity).

1. Neoclassical growth model

In the neoclassical growth model aggregate output is produced according to a well-behaved production function 1/ as given by:

$$Q_t = F(K_t, L_t, A_t) \qquad (1)$$

Where Q_t denotes the flow of (value added) output at time t, K and L refer to the inputs of the services of capital and labor, and A denotes technology or multifactor productivity. The production function F(.) is assumed to exhibit constant returns to scale to capital and labor but diminishing returns to each factor individually. 2/ Improvements in technology--increases in A--are viewed as shifting the production function outward, allowing the economy to produce higher levels of output with given inputs of capital and labor. In the basic neoclassical model, these improvements in technology are assumed to be disembodied. 3/

1/ A well-behaved production function means a function that satisfies all of the standard neoclassical properties, including the Inada conditions (see below). For details, see Burmeister and Dobell (1970).

2/ Diminishing returns refers to the implications for output when the input of one factor (say capital) is changed holding all other inputs constant. Scale returns refers to the implications of simultaneously changing a group of factor inputs. If a production function exhibits constant returns to scale in a group of inputs, a doubling in these inputs will lead to a doubling of output. The production function in the text has constant returns to scale to labor and capital, but increasing returns to a doubling of capital, labor, and multifactor productivity.

3/ Disembodied technical change refers to technical change that does not require an increase in factor inputs to be implemented. For details, see Burmeister and Dobell (1970).

Under the assumptions of (i) an exogenous growth of labor input at the rate n 1/; (ii) exogenous (labor-augmenting) technical change at the rate g 2/; (iii) a fixed savings (equal investment) rate s 3/; (iv) perfectly competitive factor markets; and (v) a Cobb-Douglas production function F(.) where the exponent on capital equals its income share (α) and that on labor equals its income share ($1 - \alpha$) 4/, the key dynamic equation of the neoclassical model can be written as:

$$\dot{k}_t = s\, k_t^{\alpha} - (n + g + d)k_t \qquad (2)$$

where k (lower case) refers to the capital-labor ratio with labor measured in efficiency units (i.e., efficiency augmented labor), a dot indicates a time derivative, α is capital's exponent in the Cobb-Douglas production function, and d is the (assumed) constant depreciation rate on capital. 5/ Given the assumption that capital's contribution to growth (given by α) is below unity 6/, this equation is stable implying that over time the rate of growth of the capital-labor ratio (k) approaches zero.

1/ The growth rate of labor (in manhours) depends on the growth of population of working force age, changes in the participation and employment rates, and growth of (average) hours worked. The assumption that the growth rate of labor input is exogenous and constant is made for simplicity.

2/ Technical progress is labor augmenting (or saving) if, at a given input of capital, less and less labor is required to produce the same output. The rate of growth of labor-augmenting technical change is equal to the growth of multifactor productivity (the shift term in the production function) divided by labor's income share.

3/ The implications of allowing the savings rate to be determined endogenously by utility-maximizing individuals is discussed below.

4/ Under the assumption of a Cobb-Douglas production function, the elasticity of substitution between capital and labor is constant and equal to unity. The production function (in the two factor case) is of the form $Q_t = AK_t^{\alpha} L_t^{(1-\alpha)}$ under these assumptions.

5/ With the depreciation rate on capital equal to d, the proportion of (gross) output devoted to depreciation in any period is equal to d times the capital-output ratio. The depreciation rate in the nonfarm business sector of the U.S. economy has tended to increase over the postwar period; presently, it is around 4 percent (d= 0.04), implying--given a capital output ratio of around 2.5--that 10 percent of output in the nonfarm business sector is needed to replace worn-out capital. Alternatively expressed, a gross investment rate of 10 percent is required just to hold the capital stock constant.

6/ Capital's contribution to growth measures the impact on growth of a one percentage point increase in the growth rate of the capital stock; in the case of the Cobb-Douglas production function this growth contribution is measured by capital's constant income share.

Interpretation of equation (2) is facilitated by noting that the first term on the right-hand side measures the rate of capital accumulation as given by the economy's level of savings, and the second measures the rate of accumulation required to hold the capital-labor ratio constant. 1/ The implication of equation (2) is that the capital-labor ratio is increasing when the rate of capital accumulation exceeds the rate required to stabilize this ratio, and conversely when it falls short.

Given the assumed exogeneity of the growth rates of labor and technical progress--as well as diminishing returns to capital--the neoclassical model reaches a number of conclusions about the determinants of long-run (or steady-state) growth. Along a long-run growth path, the ratio of capital to augmented labor is constant ($\dot{k}_t = 0$ in equation (2)), implying that the following hold: first, output grows at a constant rate determined by the (exogenous) growth rates of labor input and (labor-augmenting) technical change; second, labor productivity grows at a constant rate given by the rate of (labor-augmenting) technical change; third, capital productivity (the inverse of the capital-output ratio) and the rate of return on capital are both constant. 2/

The neoclassical model thus implies that the steady-state growth rate--which occurs when the capital-output ratio is constant--is not affected by changes in the share of resources allocated to investment in physical

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1/ The rate of growth of capital required to hold constant the capital-labor ratio (k) depends on the rate of growth of labor (n: currently around 1.5 percent a year in the nonfarm business sector), and the rate of labor-augmenting technical change (g: currently around 0.7 percent a year in this sector), implying a growth rate of around 2 1/4 percent a year is required compared with an actual growth rate of capital of around 3 1/2 percent a year during the 1980s (see Section III).

2/ Solow (1956) argued that these conditions and, in particular, the stability of the capital-output ratio were reasonable approximations for the long-run growth experience of developed capitalist economies. In a simple one-good model such as the current one, the marginal product of capital and its rate of return depend on the ratio of capital's income share to the capital-output ratio. When capital's income share is constant, the marginal product of capital and its rate of return move inversely with the capital-output ratio. See also Hacche (1979).

capital; 1/ it is influenced only by the exogenous growth rates of labor input and technical change. The reason why changes in the investment rate do not change the long-run growth rate is the existence of diminishing returns to capital as indicated by an exponent on capital in the production function that is below unity. Given diminishing returns, each successive increase in capital has a smaller and smaller effect on output (the rate of return on capital declines) and it is only continuing increases in labor input and (exogenous) improvements in technology that sustain a positive growth rate. Of course, if society were prepared to devote an ever increasing share of its resources to investment, a higher growth rate could be sustained for some time (until the ratio of gross investment to GNP becomes one) but at the expense of a declining rate of return on capital and reduced current consumption.

Even though the neoclassical model implies that (exogenous) changes in the investment rate have no implications for long-run growth, such changes will influence the growth rate in the transition from one steady-state to another, and the transition can take a long time to be completed. In addition, the neoclassical model implies that a change in investment will influence the level of output (and other variables) across different steady state growth paths. 2/ These points can be seen from Figure 1 which graphs the dynamics of the neoclassical model implied by equation (2). In this figure, the curved line marked KK relates the rate of capital accumulation to the capital-labor ratio (the curve is concave due to diminishing returns to physical capital) while the straight line RR indicates the pace of capital accumulation required to keep the capital-labor ratio unchanged. An initial steady state is assumed at point E where the two lines intersect and the ratio of capital to augmented labor is constant.

An exogenous increase in the investment rate shifts the KK line up in Figure 1 leading to a new steady state at point F. In the transition from the old steady state (at E) to the new steady state (at F), the rate of capital accumulation exceeds the rate required to hold constant the ratio of capital to augmented labor; this ratio accordingly is rising. As capital

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1/ Even though the neoclassical model implies that the investment rate has no impact on steady-state growth, the model does not necessarily rule out the possibility of observing a systematic relationship between these variables. Such a relationship can arise when the savings rate is modeled as the outcome of intertemporal choices. Both the life-cycle and overlapping generation models imply that an increase in an economy's growth rate may lead to a higher savings (investment) rate. For further details see Sala-i-Martin (1990 a,b) and Summers (1990). This possibility--noted in Section III--makes the interpretation of any correlation between saving/investment and growth rates difficult; it could reflect causation running in either direction.

2/ For details of the steady-state of the neoclassical model, see Sala-i-Martin (1990 a,b) and Burmeister and Dobell (1970).

deepening occurs, the economy grows faster than its steady-state rate, but the rate of return on capital diminishes. Once the new steady state has been reached, growth returns to its original rate but the level of capital to augmented labor is higher, implying a lower rate of return to capital and a higher level of labor productivity. Provided the economy is not dynamically inefficient, the level of consumption per capita will also be higher in the new steady state. 1/

Using the neoclassical model, some quantification of investment's effects on the level and growth of output can be obtained. 2/ As noted earlier, the exponent for capital in the production function corresponds to capital's income share and also measures its contribution to growth. Capital's income share has averaged around 0.3 in the nonfarm business sector of the U.S. economy. Given an investment rate in this sector over the last five years of 16 percent, a capital-output ratio of 2.5, and a depreciation rate of 4 percent, an (exogenous) permanent increase in the (gross) investment rate of one percentage point 3/ (a 6 1/4 percent increase in the investment rate: the one percentage point increase in the investment rate divided by the share of output allocated to investment) on impact will raise the growth rate of capital by 0.4 percentage points (the 1 percentage point increase in the investment rate divided by the capital-output ratio: 1/2.5) and that of output by 0.12 percentage points (the increase in the growth of capital multiplied by its income share: 0.4*0.3). Over time, however, as noted above, the increment to the growth of output will diminish and approach zero in the new steady state. With the assumed parameter values, the "half-life" of the transition to a new steady state is

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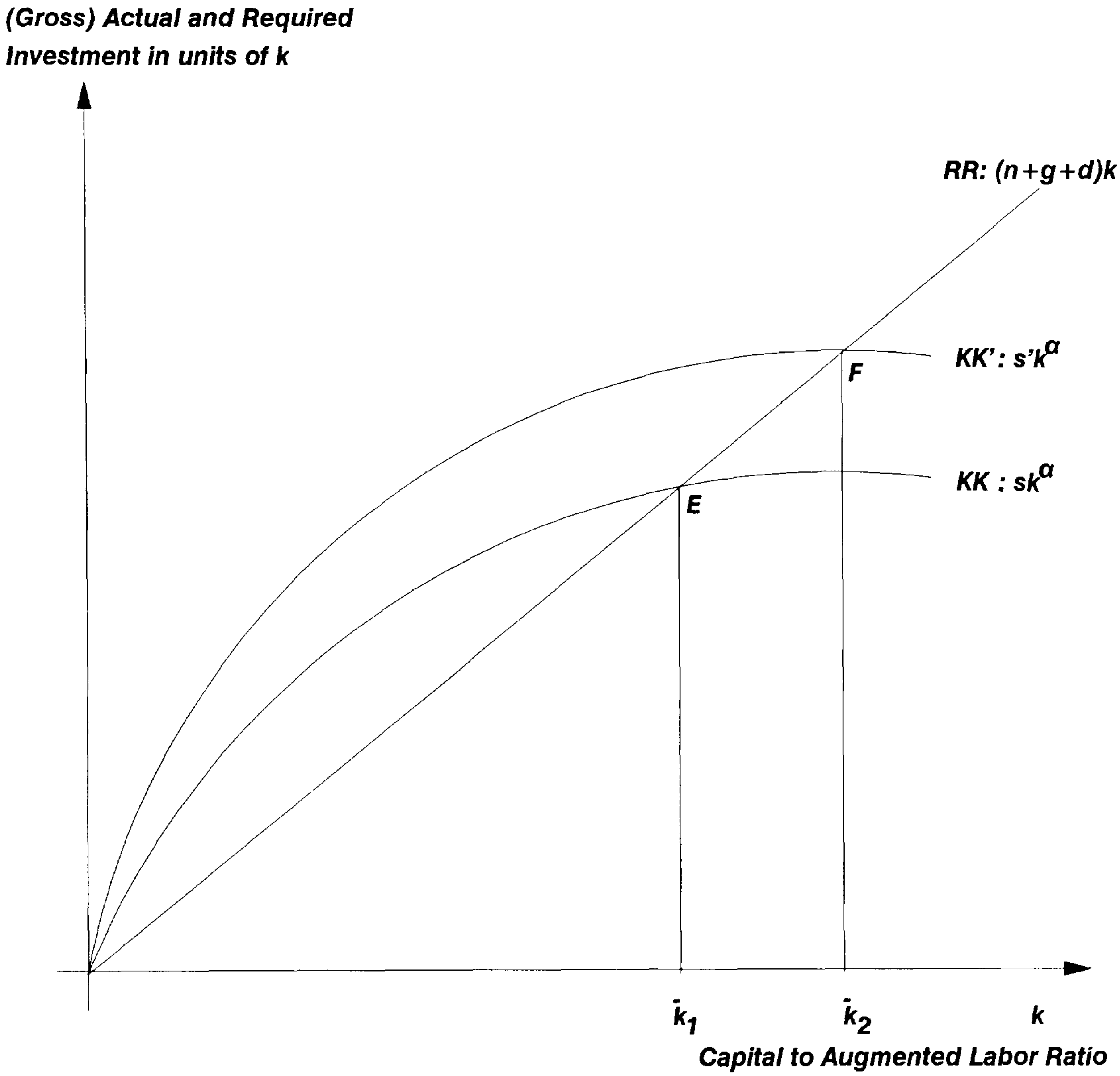
1/ The assumption that the economy is not dynamically inefficient implies that the savings (investment) rate is not above the golden rule rate that maximizes steady-state consumption. (At the golden rule, the real rate of return on capital is equal to the rate of growth of labor). If the economy were above the golden-rule savings rate, an increase in the investment rate--even though it would raise steady-state output--would lower steady-state consumption. Given an exogenous savings rate in the basic neoclassical model, there is nothing to preclude an economy from overinvesting in physical capital.

2/ This, and the following numerical examples, abstract from short-run cyclical effects.

3/ Alternatively, one could consider the impact of a permanent (exogenous) increase in the net investment rate. Given a higher capital stock calls for additional spending on depreciation, this requires a much larger increase in the gross investment rate. Note that it is assumed that the whole of the increase in savings is reflected in higher domestic investment in the nonfarm business sector. In practice, part of any increase in investment would be expected to take place in other sectors of the economy.

Figure 1. Dynamics of the Neoclassical Model.



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about 10 years, 1/ implying over a decade an annual average increase in the growth of output a shade above 0.1 percentage points.

In the new steady state, when growth has returned to its original rate, the level of output (and labor productivity) will be 2.7 percent higher. Reflecting the capital deepening implied by a higher investment rate, the capital-output ratio will have risen by 6 1/4 percent, with an associated decline in the marginal product of capital and its rate of return by 6 1/4 percent, and the rise in the ratio of capital to augmented labor of almost 9 percent. Alternatively expressed, the (gross) rate of return to raising the investment rate is approximately 12 percent, (capital's income share divided by the capital-output ratio) while net of depreciation the rate of return is 8 percent (gross return less the depreciation rate).

Given the apparently small effect of (physical) capital accumulation in the basic neoclassical model, there have been many attempts to determine if an alternative modeling of technology could imply a larger role for investment. 2/ Phelps (1969), Solow (1959), and Nelson (1964) have relaxed the assumption that technical change is disembodied and allowed for the possibility that new capital--which incorporates more efficient technologies--may be more productive than old capital. In these models, even under the assumption of diminishing returns, capital's growth contribution can be larger than in the basic neoclassical model. This possibility is reflected in an exponent for capital in the aggregate production function derived from these models that exceeds capital's income share by an amount related to the (net) additional benefit implied by the introduction of new technologies.

Following Nelson (1964) and Branson (1979), the basic elements of the neoclassical model with capital-embodied technical progress can be illustrated as follows. The production function given by equation (1) is replaced by equation (3) where J denotes an aggregate measure of capital of different vintages. 3/

$$Q_t = G(J_t, L_t) \tag{3}$$

1/ The half-life of the transition refers to the number of years required to complete 50 percent of the adjustment to the new steady state. The length of the transition depends on the depreciation rate on capital, the rates of growth of the labor input and labor-augmenting technical change, and the curvature of the production function. Romer (1987) reaches a similar conclusion regarding the transition time in the neoclassical model.

2/ See Sala-i-Martin (1990 a,b) and Dixit (1975) for a review of some of this work.

3/ Strictly speaking, the model with embodied technical change--which incudes capital with different vintages--does not have an unambiguous measure of the aggregate capital stock. For details, see Solow (1959).

As in the basic neoclassical model, constant returns to scale of capital and labor are assumed as are diminishing return to each factor individually. Aggregate capital input (J) is defined by equation (4) below where h denotes the assumed exogenous rate of capital-embodied (and capital-augmenting) technical progress 1/ and K_m refers to capital of vintage m. By assumption, the only way for the economy to benefit from new technology is to invest in capital goods.

$$J_t = \sum_{0}^{t} K_{mt} (1 + h)^m \tag{4}$$

Using equation (4), the growth of output can be shown to depend on the growth of capital, the rate of capital-embodied technical progress, and the average age of the capital stock (a). This leads to equation (5), where, for simplicity, the production function is assumed to be Cobb-Douglas.

$$\frac{\dot{Q}_t}{Q_t} = \alpha hda + \alpha(1 + ha) \frac{\dot{K}_t}{K_t} + (1 - \alpha) \frac{\dot{L}_t}{L_t} \tag{5}$$

The steady-state growth rate in this model--achieved when the average age of the capital stock is constant--is independent of exogenous shifts in the investment rate. 2/ Embodiment effects make a difference with respect to the growth contribution of capital and the impact of changes in the investment rate between steady states.

As can be seen from equation (5), capital's growth contribution is higher than in the basic model by an amount that depends on the (exogenous) growth rate of capital-augmenting technical change (h) and the average age of the capital stock (a). Intuitively, capital's growth contribution is higher because each new unit of capital means not only that there is more capital but also that there is new technology. However, the introduction of capital with new technology makes part of the existing capital stock obsolete faster. 3/ Under these conditions, the benefits from the introduction of new and more efficient capital are offset to some extent by a faster rate of scrapping of existing capital, leading to a net contribution of capital given by the coefficient attached to $\dot{K}_t/K_t$ in equation (5).

1/ The rate of capital-augmenting technical change is equal to the growth of multifactor productivity divided by capital's income share.

2/ See Solow (1959) and Phelps (1962).

3/ This outcome reflects the additional assumption that labor is mobile and receives the same wage regardless of the vintage of capital with which it works. Under these conditions, the introduction of newer more productive machines draws labor away from existing capital and by virtue of the implied upward pressure on wages makes it uneconomical to continue to operate this capital.

Using the representative parameter values assumed earlier, some quantification of the possible importance of embodiment effects can be obtained. The average age of the capital stock is around 25 years (the inverse of the 4 percent depreciation rate assumed above) 1/ and the rate of capital-embodied technical progress (h) is presently about 2 percent a year. 2/ With these parameters, a one percentage point increase in the investment rate on impact will raise the annual growth rate of capital by 0.4 percentage points. As a result of embodiment effects, however, the annual rate of growth of output immediately rises by 0.18 percentage points (compared with 0.12 percentage points when technical change is not embodied) and over a ten-year period on average rises by 0.15 percentage points a year. Other things remaining unchanged, the effects on growth are larger the older is the capital stock (likely to be the case if investment has been weak for some time) and the more rapid the (exogenous) rate of capital embodied technical progress (h).

Based on the representative parameters for the U.S. economy assumed earlier, it is apparent that an allowance for capital-embodiment effects does not significantly raise the growth contribution of capital. 3/ In addition, embodiment effects do not alter the conclusion that the steady-state growth rate is not affected by changes in the investment rate. To a first approximation, therefore, the neoclassical model--with and without embodied technical change--implies that capital's growth contribution is reasonably well approximated by its income share and that steady-state growth is not influenced by the investment rate. Under these conditions, consideration is given to models which imply that capital's exponent in the aggregate production function could be larger than its income share as implied by the model with embodied technological change, but in which shifts in investment may permanently affect the growth of output.

2. Endogenous growth models

In the last several years growing attention has been paid to models in which increasing returns to scale, learning-by-doing, and spill-over effects

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1/ It must be recognized, however, that both the depreciation rate and the average age of the capital stock in the nonfarm business sector of the U.S. economy have varied considerably over the last 100 years. This is to be expected in a model with capital embodied technical progress; in the basic neoclassical model, the assumption of a fixed depreciation rate is made for convenience.

2/ The rate of growth of capital-embodied (capital-augmenting) technical progress is defined to equal the rate of growth of multifactor productivity divided by capital's income share. For the illustrative calculations in the text, a rate of multifactor productivity growth of 0.6 percent per annum was used, the income share of capital was taken to be 0.3, giving rise to a rate of growth of capital embodied technical progress of 2 percent per annum.

3/ The small role for capital--even in the presence of embodiment effects--has been confirmed by Denison's (1962) work on the U.S. economy.

play important roles. 1/ (See Sala-i-martin (1990 a,b), Rebelo (1990) and Romer (1986, 1987 a,b, 1990)). These models imply that capital's income share may underestimate significantly its growth contribution and that under certain conditions shifts in the investment rate can permanently change the growth rate. However, there are a number of questions concerning their applicability, since they do not appear able to generate the kinds of steady-state growth paths many researchers believe provide reasonable approximations to the long-run growth experience. 2/

For illustrative purposes, a particular endogenous growth model associated with Romer (1986, 1987 a,b, 1990) is considered. 3/ This model stresses the possibility that the returns from (physical) capital accumulation may be larger than in the neoclassical growth model and may not decrease in response to faster rates of capital accumulation. The basic insight is that even though individual firms may perceive diminishing returns to capital accumulation (as in the neoclassical growth model) the economy as a whole may be able to avoid diminishing returns if there are positive externalities associated with firms' investment decisions. Such external effects, which arise if the acquisition of knowledge by one firm expands the knowledge frontier of others or if there are learning-by-doing effects associated with investment, imply that the social rate of return on investment--which will exceed the (perceived) private rate of return--need not necessarily decline as capital input is increased. To the extent that such external effects are important, capital's income share will provide a misleading indicator of capital's contribution to aggregate output growth although it will continue to provide a reasonably good approximation of the return to capital as perceived by an individual firm.

The presence of external effects can be captured through the specification of a firm's (Cobb-Douglas) production function of the form given by equation (6)

$$Q_{it} = A_{it} K_{it}^{\alpha} L_{it}^{(1-\alpha)} K_{t}^{\beta} \qquad (6)$$

where K_{it} and L_{it} refer to the individual firm's inputs of capital and labor, A_{it} is firm-specific multifactor productivity, and K_t denotes the economy's total stock of capital which is the sum of each individual firm's capital stock. The firm's production function has all the properties of the neoclassical production function--diminishing returns to the firm's inputs

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1/ There has also been a growing literature on the roles of human capital accumulation and conglomeration effects in the growth process. For details and a review of recent growth models, see Sala-i-Martin (1990 a,b).

2/ See below.

3/ There are a large number of endogenous growth models that have stressed, inter alia, the importance of learning-by-doing, human capital accumulation, and conglomeration effects. For a review of some of these models, see Sala-i-Martin (1990 b).

of capital and labor, and constant returns to scale to simultaneous increases in these factors--but it is shifted by other firms' investment decisions. Provided the individual firm is small, it is assumed not to take into account the impact of its investment decisions on the economy's aggregate capital stock. 1/ The assumption that factor markets are competitive is retained, so that α and $(1-\alpha)$ continue to represent the income shares of capital and income, respectively.

Aggregating individual firms' production functions gives rise to a production function for the whole economy of the form:

$$Q_t = A_t K_t^{\alpha+\beta} L_t^{1-\alpha} \tag{7}$$

which--in contrast to the neoclassical production function--has an exponent on capital equal to α plus β, implying that capital's growth contribution is different from its income share, α.

The model's implications for the relationship between investment and growth depend on the size of the exponent on the aggregate capital stock $(\alpha + \beta)$. Given the assumption of a positive externality $(\beta > 0)$ 2/ there are two possibilities: (i) $\alpha + \beta < 1$, and (ii) $\alpha + \beta \geq 1$, with alternative implications for the effect of an increase in the investment rate on the growth rate of the economy. When the coefficient on aggregate capital $(\alpha+\beta)$ is below unity, there are diminishing returns to capital and the growth rate of the economy can not be permanently raised by an increase in the investment rate, even though the social returns to investment in this case will exceed the (perceived) private returns. 3/ Conversely, when $\alpha + \beta \geq 1$, there are nondiminishing returns to capital, and an increase in the investment rate will permanently raise the growth rate.

Following Romer (1986), consideration is given to the case where the exponent on capital in the aggregate production function is unity $(\alpha+\beta=1)$, but capital's income share applies to individual firm's production functions $(\alpha<1)$. Labor's exponent in the production function (contribution to growth) is assumed to equal its income share. This case describes a situation in which private firms perceive diminishing returns to their individual investments $(\alpha <1)$, but the social returns to investment are constant

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1/ It is this assumption that creates a wedge between the returns to investment as perceived by any particular firm and the actual returns to society. See Romer (1987 a,b) for further discussion.

2/ Unfortunately, there is little direct evidence on the possible size of the externality. For some suggestive orders of magnitude, see Summers (1990).

3/ As discussed by Sala-i-Martin (1990), the key characteristic of endogenous growth models is that the sum of the coefficients on the augmentable factor (or factors)--here there is one augmentable factor, capital--not be below unity.

$(\alpha+\beta-1)$. In such a case, a once-and-for-all exogenous increase in the investment rate will permanently raise the growth rate because reductions in the (perceived) private rate of return on capital are exactly offset by positive externalities from firms' investment decisions. For the representative parameter values assumed earlier, this model implies that a one percentage point increase in the investment rate on impact will raise the growth rate of both capital and output by 0.4 percentage points, and that output growth will remain at this permanently higher rate. In contrast to the neoclassical growth model, the economy jumps immediately to the new growth path and the social and perceived private rates of return on investment are the same as on the original path.

A difficulty with this growth model is its implication that the capital-output ratio will be constantly changing if labor input is not fixed, and hence that under general conditions a steady state will not be approached. This result, which follows directly from the specification of the production function in equation (7) 1/, implies that the model cannot account for the approximate long-run stability of the capital-output ratio. 2/ Nevertheless, given that the central focus of the paper is on the growth contribution of capital, it is still useful to try to determine whether the rather large role the model ascribes to capital is appropriate in light of historical experience.

III. Capital's Contribution to Growth--The Historical Experience

This section studies the long-run growth performance of the U.S. economy to shed light on which (if either) class of models discussed in Section II provides the most appropriate indication of capital's contribution to growth and the returns from raising the investment rate. The evidence is discussed in three parts: (a) the growth contribution of capital; (b) the time-series relationship between investment and growth; and (c) the behavior of the rate-of-return on capital.

1. Growth contribution of capital

The first question concerns the (proximate) growth contribution of capital which, in the neoclassical model, is reasonably well approximated by its income share. In the endogenous growth model, on the other hand,

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1/ Inspection of equation (7), where the coefficient on capital equals unity, suggests that if the labor force is growing the capital-output ratio must be continually changing.

2/ One possible modification to the model to permit steady-state growth is to re-specify the production function so that the externality derives from the ratio of capital to labor, rather than from the capital stock. Under such a re-specification, the weight on capital in the aggregate production function equals unity while that on labor equals zero, and steady state growth is possible with a constant capital-output ratio.

capital's contribution is higher than its income share and possibly equal to unity. By examining the ability of different models to account for growth with different weights attached to capital, information is obtained on the possible applicability of the models.

Table 1 decomposes output growth in the nonfarm business sector of the U.S. economy over various sub-periods since 1889 according to two different measures of the growth contributions of capital (and labor input) and multifactor productivity. Both decompositions are derived from the total differential of a Cobb-Douglas production function relating the growth of output to the growth of factor inputs and multifactor productivity but differ according to the weights assigned to capital (g_K) and labor (g_L).

$$\frac{\dot{Q}_t}{Q_t} = g_K \frac{\dot{K}_t}{K_t} + g_L \frac{\dot{L}_t}{L_t} + \frac{\dot{A}_t}{A_t} \qquad (8)$$

The first decomposition, based on the neoclassical model and standard growth accounting (Denison (1962)), uses the income shares of capital and labor to measure their growth contributions. In the case of the nonfarm business sector, these shares have not shown sustained change and an average value of 0.31 for capital and 0.69 for labor was used. 1/ The second decomposition follows Romer's (1986, 1987 a, b) endogenous growth model with external effects and has a weight of 1 on capital and a weight of 0.7 on labor. 2/ In both decompositions, the growth of multifactor productivity is defined residually as that part of output growth not accounted for by changes in capital or labor inputs.

1/ Given that these shares have shown some tendency to change over various sub-periods--and, of course, do vary substantially over the business cycle--it was necessary to decide whether to allow for these changes. As discussed in the appendix, it was decided to hold factor shares constant in decomposing the growth contributions of capital and labor. Had these shares been allowed to change, the growth contributions of capital and labor would differ somewhat from those shown in Table 1 but the main conclusions would still hold.

2/ Romer selected a weight of unity on capital on the basis of time-series correlations between capital and output. Romer also considers the implications of allowing the growth contribution of labor to be far less than its income share. Since there are no compelling reasons for such an approach, labor's growth contribution is measured in this paper by its income share.

Table 1. Contributions to Growth, Nonfarm Business Sector, 1889-1989.

(Average Annual Percentage Change)

Period	Output	Neoclassical Model			Endogenous Growth Model		
		Labor	Capital	Multifactor Productivity	Labor	Capital	Multifactor Productivity
1889-1909	4.94	2.08	1.56	1.30	2.08	5.03	-2.16
1909-1929	3.42	1.12	0.96	1.34	1.12	3.09	-0.79
1929-1948	2.61	0.67	0.28	1.66	0.67	0.90	1.03
1948-1968	3.78	0.77	1.20	1.81	0.77	3.88	-0.86
1968-1973	3.31	1.12	1.42	0.77	1.12	4.57	-2.38
1973-1979	2.50	1.31	1.25	-0.05	1.31	4.03	-2.83
1979-1989	2.86	1.21	1.11	0.54	1.21	3.59	-1.94
1889-1989	3.53	1.18	1.06	1.30	1.18	3.40	-1.05

Source: See appendix for data sources.

Several features of the decompositions presented in Table 1 are evident. 1/ Most notable, the neoclassical model attributes only about 1/3 of output growth to measured changes in capital inputs. The remainder is explained by growth in labor input and multifactor productivity with the latter viewed as occurring as a result of (exogenous) improvements in technology and any unmeasured influences on growth. 2/ Second, the endogenous growth model, while attributing a much larger share of growth to changes in factor inputs--particularly capital, which has an exponent of unity in the production function--over explains growth insofar as it tends in most periods to have a large negative residual. 3/

Finally, neither model is very successful in explaining the post-1968 growth slowdown in terms of changes in factor inputs. Consistent with much of the growth accounting literature, both ascribe the bulk of this slowdown to slower multifactor growth and neither assigns an important role to capital, the growth of which picked up after 1968. 4/

The decompositions presented in Table 1 suggest that the endogenous growth model may overstate capital's growth contribution, since it is very difficult to explain negative multifactor productivity growth over long periods, except by appealing to technical regress. The correlations presented in Figure 2 are intended to shed further light on this issue by plotting for various sub-periods since 1889 the relationship between the growth of multifactor productivity (calculated according to the neoclassical model) and the growth of capital input. 5/ If the endogenous growth model is correct--or if capital's contribution to growth is seriously understated for some other reason--there should be a positive relationship between the neoclassical measure of multifactor productivity growth and the growth of

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1/ It is important to note that the decompositions only measure the proximate growth contributions of factor inputs because they abstract from the interactions between changes in factor inputs and technical progress. Given, for example, that a change in the rate of technical progress will change the rate of capital accumulation in the neoclassical model, it is incorrect to regard the decompositions as showing how much of a change in the growth rate was due to changes in capital and how much was due to changes in technical progress.

2/ The work of Denison (1962) has attempted to identify the various influences on multifactor productivity growth.

3/ Had a lower estimate of labor's growth contribution been used (following Romer), the size of the negative multifactor productivity residual would have been lower in absolute value. When a value of 0.3 for labor's growth contribution was used--the value suggested by Romer (1987 a,b)--the residual however was still negative.

4/ There appears to be general agreement that the growth slowdown in the U.S. after 1969 had little to do with measured changes in capital inputs. See Baily and Schultze (1990).

5/ See Adams and Coe (1990) and Baily and Schultze (1990) for a similar approach.

capital. That is to say, if the neoclassical model understates capital's growth contribution, sub-periods when capital is growing rapidly should also be periods when multifactor productivity is growing rapidly. Of course, given that the neoclassical model predicts a positive association between multifactor productivity growth and capital accumulation in the long run, 1/ the finding of a positive correlation does not permit an unambiguous interpretation. Provided, however, that the economy is not always in a steady state, the neoclassical prediction that faster multifactor productivity growth will cause higher capital accumulation should be relatively weak over the periods considered.

The data plotted in Figure 2 do not suggest that the neoclassical model underestimates capital's growth contribution. Rather than implying a positive correlation between capital accumulation and multifactor productivity growth, the figure suggests that there is probably no relation between these variables. 2/ On average, periods when capital accumulation is rapid are not periods of above average multifactor productivity growth as would be suggested by the endogenous growth model associated with Romer (1986, 1987 a,b).

Consideration has thus far been given to the possibility that the neoclassical model may understate capital's growth contribution. Such a focus is appropriate, because the issue has been whether the data are consistent with the large effects of capital on growth implied by the endogenous growth model. Nevertheless, it is also necessary to consider whether the neoclassical model may itself overstate capital's growth contribution, as suggested, for example, by Summers (1990). There are two main reasons why capital's income share may overstate its contribution to growth. 3/ In the first place, part of what is measured as profit in the national accounts may include returns to monopoly power, research and development expenditures, or rents to extraordinary managerial talent. These returns should not be included in measuring the (social) rate of return to physical capital. Second, the fact that investments are risky implies that profits include a reward for taking risk. In determining the contribution of capital to growth, one might not want to include this risk component, but would want to obtain the certainty equivalent rate of return. The difficulty, however, is that, if the (ex post) real rate of return on long-term Government debt is used for this purpose, this rate of return appears to have been very low over much of the post-war period, 4/

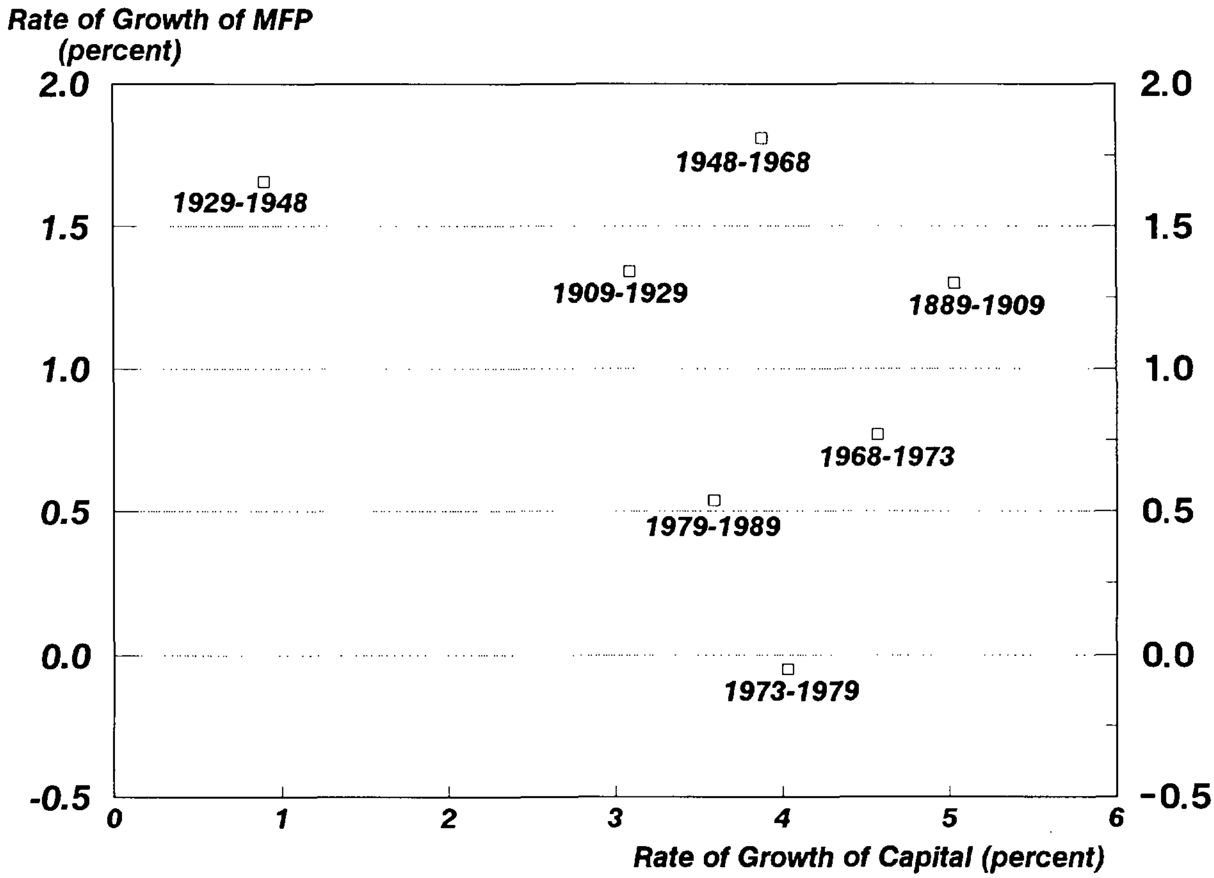
1/ This possibility arises because an (exogenous) increase in multifactor productivity growth--the growth of labor augmenting technical change times labor's income share--raises the long-run rate of capital accumulation.

2/ Given the small number of observations, formal statistical tests cannot be carried out.

3/ See Summers (1990) for more detail.

4/ The (ex post) real rate of return on (federal) government 30-year debt over the postwar period has averaged between 1-2 percent compared with an (ex post) net real rate of return on capital of between 8 and 10 percent.

Figure 2. Rates of Growth of Multifactor Productivity (MFP) and Capital Input, Nonfarm Business, Selected Periods, 1889-1989, United States.



Source: See appendix for data sources.

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implying that capital's income share may overstate its contribution to growth. 1/

There does not at this stage appear to be a satisfactory resolution to these problems. Based on evidence presented by Summers (1990)--notably that Tobin's measure of the ratio of the market value of capital to its reproduction cost in the U.S. has averaged less than unity over the postwar period--there is the possibility that factors such as monopoly may not be very important in the U.S. economy; in short, capital income may not include large monopoly profit elements. As regards the treatment of risk, the situation is a little less clear but--regardless of the fact that capital income presumably includes a return on risk taking--capital's income should still provide a measure of the average but risky rate of return on investment. The problem instead is that the value society places on this income in risk adjusted terms may be much lower than the rate of return on capital. 2/

2. Time series relationship between investment and growth

Another approach to determining the relevance of alternative growth models is to study the time-series relationship between investment and growth (Tables 2a and 2b). Care must be exercised, however, since the neoclassical model--while implying that exogenous shifts in investment have no long-run effects on growth--suggests that a relationship between these variables will arise in the transition between steady states. If these transitions take a long time, one would expect even at relatively low frequencies to observe a relationship between investment and growth rates. In addition, when the assumption of an exogenous savings (investment) rate is relaxed, a long-run relationship could arise between these variables if the savings (investment) rate is affected by the economy's growth rate. Accordingly, if a relationship between growth and the investment rate is uncovered, it is necessary to determine whether it reflects the impact of investment on growth or the consequences of alternative growth rates for the savings (investment) rate. 3/ Nevertheless, given that a major difference between the neoclassical model and the endogenous growth model concerns the impact of exogenous shifts in investment on growth, it is important to study the relationship between these variables. 4/ 5/

1/ The large differential between the rate of return on capital and public debt is well known as the 'equity-premium' puzzle. For further discussion, see Summers (1990).

2/ If the (ex post) real rate of return on public debt--which has averaged between 1 and 2 percent over the post war period--is used to measure the certainty equivalent rate of return, the implied risk-free rate of return on capital is extremely low.

3/ This possibility was discussed earlier in Section II.

4/ A similar approach is adopted by Romer (1990). Based on time-series correlations similar to those considered below, Romer concluded that capital's income share significantly understated its growth contribution.

Interpretation of the equations presented in Table 2--estimated with both period average and yearly observations in order to distinguish longer and shorter-run effects--is facilitated by considering the implications of regressing the growth of output on the investment rate, the growth of labor (in the case of some of the equations), and a constant term (equations (1) through (3)). Such regressions, of course, suffer from all sorts of simultaneity problems but can provide some information about underlying economic relationships. We emphasize that the regressions should not be viewed as rigorous tests of any model. Rather, they are a way of formally examining the correlations in the data.

According to the neoclassical model, the regressions should deliver a coefficient on the investment rate equal to zero over the long run (since investment has no effect on long-run growth). Conversely, the endogenous growth model considered in this paper imply that the long-run coefficient on the investment rate should be positive and--given a growth contribution of capital of unity--equal to the inverse of the (average) capital-output ratio (0.4: unity divided by 2 1/2). The constant terms that are obtained, on the other hand, should depend on whether the growth of labor input is included in the equations 1/ and on whether the rate of technical change is closely associated with the investment rate. In the case of the endogenous growth model, for example, the constant terms in equations that include the growth of labor input would be expected to be close to zero since the rate of technical advance is regarded as being closely associated with the investment rate that is included in the equation. 2/ Finally, the last two equations capture the relationship between the growth of output and that of factor inputs. These equations are included to provide information on the extent to which the growth contributions of factors are related to their income shares.

To the extent of course that one never actually observes the long run, the estimated coefficients in all cases will be influenced by several factors, including the transition dynamics of the neoclassical model and shorter-run cyclical fluctuations.

5/ (...continued)
5/ For a recent examination, along these lines, focussing on Latin America see De Gregorio (1991).

1/ The equations which exclude labor should--in the case of the neoclassical model--have a constant term equal to the sum of the (average); growth rates of labor input and labor-augmenting technical change. This sum has averaged 3.6 percent over the last hundred years (see Table 3 below). The equations that include the growth of labor input should--in the case of the neoclassical model--have a constant term equal to the (average) growth rate of labor-augmenting technical change over the last 100 years (1.9 percent).

2/ A small constant term would also be expected if there are large embodiment effects associated with investment.

Table 2a. Explaining Long-run Growth Using Period Averages, Nonfarm business sector, 1889-1989. 1/

1. $$\frac{\dot{Q}}{Q} = \underset{(1.70)^*}{1.93} + \underset{(1.30)}{0.10}\, i \qquad R^2 = 0.25,\ D.W. = 0.71$$

2. $$\frac{\dot{Q}}{Q} = \underset{(1.74)^*}{1.93} - \underset{(0.009)}{0.001}\, i + \underset{(1.11)}{0.84}\, \frac{\dot{L}}{L} \qquad R^2 = 0.43,\ D.W. = 1.42$$

3. $$\frac{\dot{Q}}{Q} = \underset{(2.51)^*}{1.93} - \underset{(0.39)}{0.02}\, i + \underset{(\ 2/)}{1.00}\, \frac{\dot{L}}{L} \qquad R^2 = 0.66,\ D.W. = 1.90$$

4. $$\frac{\dot{Q}}{Q} = \underset{(2.46)^*}{1.92} + \underset{(1.93)^*}{0.83}\, \frac{\dot{L}}{L} \qquad R^2 = 0.43,\ D.W. = 2.03$$

5. $$\frac{\dot{Q}}{Q} = \underset{(2.35)^*}{2.03} + \quad + \underset{(1.62)}{0.37}\, \frac{\dot{K}}{K} \qquad R^2 = 0.34,\ D.W. = 0.66$$

Table 2b. Explaining Annual Output Growth, Nonfarm Business Sector, 1889-1989.

1. $$\frac{\dot{Q}}{Q} = \underset{(1.79)^*}{1.63} + \underset{(2.86)^*}{0.14}\, i \qquad R^2 = 0.08,\ D.W. = 2.29$$

2. $$\frac{\dot{Q}}{Q} = \underset{(3.20)^*}{1.72} + \underset{(0.081)}{0.003}\, i + \underset{(13.60)^*}{1.04}\, \frac{\dot{L}}{L} \qquad R^2 = 0.68,\ D.W. = 2.68$$

3. $$\frac{\dot{Q}}{Q} = \underset{(3.21)^*}{1.72} - \underset{(0.270)}{0.008}\, i + \underset{(\ 2/)}{1.00}\, \frac{\dot{L}}{L} \qquad R^2 = 0.68,\ D.W. = 2.60$$

4. $$\frac{\dot{Q}}{Q} = \underset{(4.52)^*}{1.75} + \underset{(14.51)^*}{1.04}\, \frac{\dot{L}}{L} \qquad R^2 = 0.68,\ D.W. = 2.68$$

5. $$\frac{\dot{Q}}{Q} = \underset{(1.08)}{0.69} + \quad + \underset{(7.48)^*}{0.83}\, \frac{\dot{K}}{K} \qquad R^2 = 0.36,\ D.W. = 2.37$$

1/ Sample consists of average values for periods: 1889-1909, 1909-29, 1929-48, 1948-68, 1968-73, 1973-79, 1979-89. An asterisk denotes statistical significance at the 5 percent level.

2/ Constrained value. Constraint cannot be rejected at 5 percent level.

Several features of the results presented in Table 2a and 2b are of interest. In the first place, with both period-average and yearly observations, the relationship between investment and output growth is very weak, and in most cases statistically insignificant. 1/ The exception is the annual regression of output growth on the investment rate which shows a small and statistically significant relationship between these two variables. This equation suggests that a one percentage point increase in the investment rate raises the growth of output by 0.14 percentage points a year--approximately the transition effect implied by the numerical estimate of the neoclassical model provided in Section II. Second, adding labor input growth to the equations--unconstrained or constrained to equal unity--weakens the link between investment and growth in both the period average data and the annual regressions. 2/ Third, the constant terms in equations (1)-(3) do not change very much when the right-hand variables are varied; this arises because there is a sizable component of growth that is uncorrelated with investment and the growth of labor input. Many of the constant terms in these equations are around 1.7 - 1.9, approximately equal to the average growth of labor-augmenting technical change over the sample period. 3/

Finally, when separate regressions are run of output growth against the rates of growth of factor inputs, the coefficient on labor tends to exceed (slightly) its income share while that on capital is approximately equal to its income share in period-average data, but considerably above it in the yearly data. At this stage, it is unclear how to interpret the apparently large coefficient on capital in the yearly data and the (related) finding that a statistically significant but weak relationship between investment and growth can be found in the annual regressions. However, because the relationship between growth and investment disappears over the longer runs of the period average data--and is not robust to including the growth of labor input in the regressions--it seems unlikely that it reflects the prediction of the endogenous growth model regarding large and permanent effects of investment on growth.

While one should not, given numerous problems, draw strong conclusions from the regression results it is nevertheless interesting that the data do not generally uncover a strong and lasting relationship between investment and growth as implied by the endogenous growth model. With this as background, some related evidence on the applicability of the alternative models is considered.

1/ A weak relationship was also found when dummy variables were included to take into account the rather large swings in the investment rate during the Great Depression.

2/ This constraint converts the left-hand side of the equations to equal the growth of labor productivity.

3/ Over the last hundred years, the growth of multifactor productivity as measured by the neoclassical model has averaged 1.3 percent implying an average growth of labor-augmenting technical change of 1.9 percent.

3. Behavior of the rate of return on capital

Another approach to assessing the usefulness of the neoclassical model is to examine the behavior of the rate of return on capital and whether there is evidence in favor of diminishing returns. As noted in Section II, a key implication of the neoclassical model is that the rate of return on capital should fall when the ratio of capital to augmented labor is rising. By contrast, the endogenous growth model predicts no necessary relationship between the (social and private) rate of return on capital and the degree of capital deepening. The validity of the neoclassical model therefore can be considered by studying the behavior of the rate of return to capital in periods when the ratio of capital to augmented labor was changing.

Table 3 and Figure 3 summarize how key variables in the neoclassical model have behaved since 1889. 1/ In addition, the table shows a measure of the (gross) rate of return on capital, defined as the ratio of capital income (as given in the national accounts) to capital input. 2/ The presentation differs from that in Table 1 because some of the variables have been expressed in labor efficiency units; in addition, the rate of technical progress is expressed in terms of the growth of labor efficiency, which is the growth of multifactor productivity (calculated according to the neoclassical model) divided by labor's income share. Presentation in efficiency units facilitates the analysis of the data by providing a direct link between the key variables of the neoclassical model and the economy's growth experience. 3/

Of key interest is the relationship between the rate of return on capital and the behavior of the ratio of capital to augmented labor. Abstracting from the Great depression and World War II, 4/ three sub-periods are of interest. The first, from 1889 to 1929, is marked by large swings in the ratio of capital to augmented labor (and the capital-output ratio) but no sustained change in these variables; over this period the (gross) rate of return on capital fluctuated in the 10 to 12 percent range. Between 1948 and 1968 the ratio of capital to augmented labor (and capital to output) again showed no sustained change--notwithstanding substantial year-to-year fluctuations--and there was also no permanent change in the (gross) rate of return on capital which averaged about 16 percent over this period. It is only in the period since 1968 that there have been sustained changes in the capital to augmented labor ratio (and the capital-output

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1/ The sub-periods in the table correspond those selected earlier (see Tables 1 and 2a,b).

2/ This measure--based on the ratio of actual capital income to capital input differs from the direct estimate of the marginal product of capital shown in Figure 3. In practice, the two measures move together closely.

3/ As such, the data shown in Table 3 are a simple transformation of the data for the neoclassical model provided in Table 1.

4/ In what follows, these are treated as unique episodes that no model is likely to fit well.

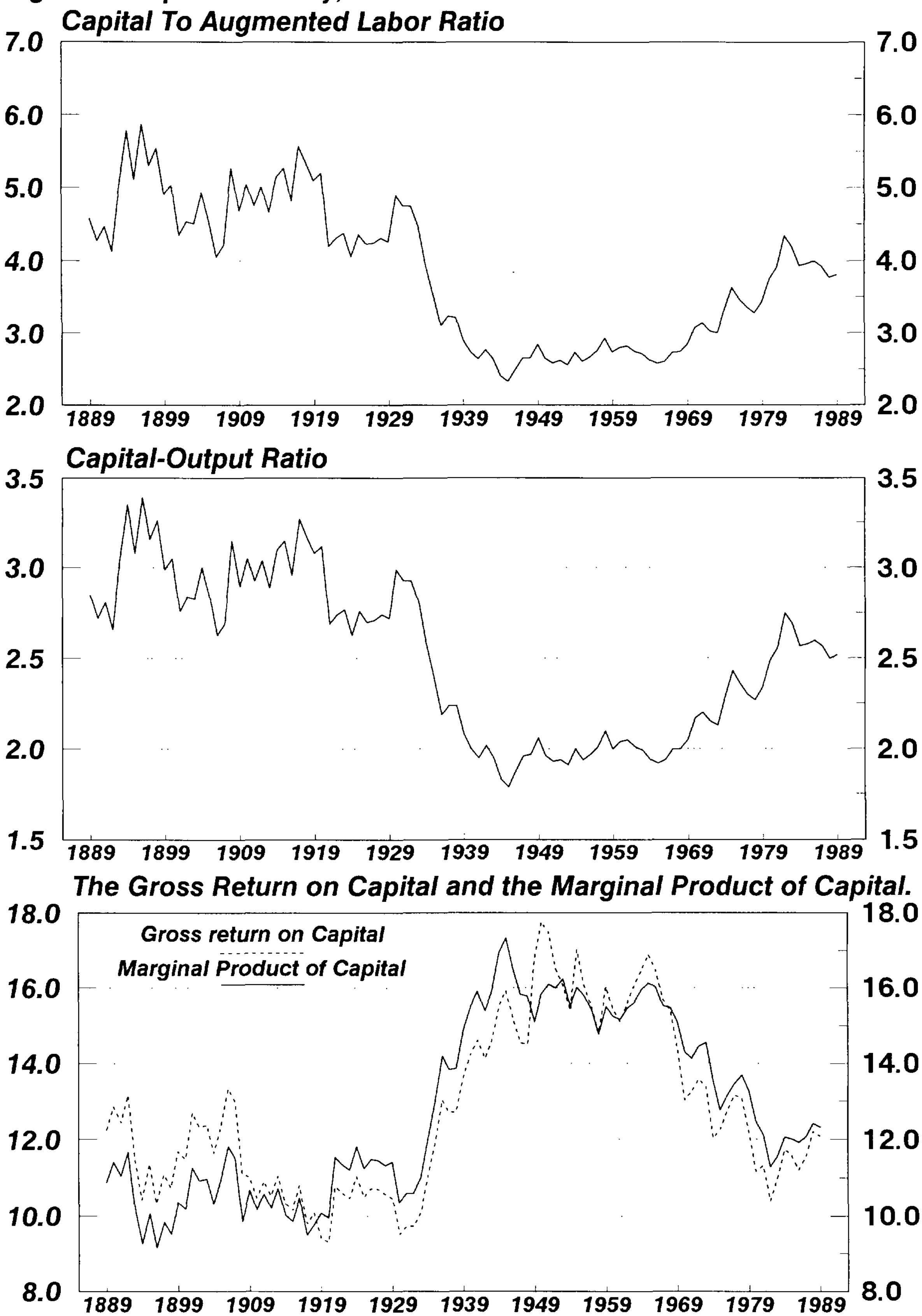
Table 3. Key Variables in the Neoclassical Model, NonFarm Business Sector, 1889-1989.

(Average Annual Percentage Change)

Period	Output	Augmented Labor	Average Labor Productivity	Labor Augmenting Tech. Change	Capital to Augmented Labor Ratio	Capital to Output Ratio	Gross Rate of Return (% per year)
1889-1909	4.94	4.90	1.93	1.89	0.13	0.09	11.87
1909-1929	3.42	3.57	1.80	1.95	-0.48	-0.33	10.47
1929-1948	2.61	3.38	1.63	2.40	-2.47	-1.71	12.90
1948-1968	3.78	3.74	2.67	2.62	0.14	0.10	16.05
1968-1973	3.31	2.75	1.69	1.12	1.82	1.26	13.85
1973-1979	2.50	1.81	0.61	-0.08	2.22	1.53	12.69
1979-1989	2.86	2.53	1.11	0.78	1.06	0.73	11.50
1889-1989	3.53	3.58	1.82	1.88	-0.18	-0.13	12.73

Source: See appendix for data sources.

Figure 3. Capital Intensity, Nonfarm Business Sector 1889-1989.



Source: See appendix for data sources.

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ratio) and that there is a direct test of the neoclassical model's predictions about the rate of return to capital.

The period since 1968 can be characterized broadly as one of a sustained slowdown in the (exogenous) rate of growth of labor augmenting technical progress. 1/ Interpretation of developments over this period is facilitated using Figure 4 which shows--based on the neoclassical growth model--the implications of an exogenous slowing in the rate of labor-augmenting technical change. Beginning in an initial steady state at point E, the slowdown rotates the capital requirements line downward leading to a new steady state at point F. In the transition from point E to point F, there is an immediate slowdown in the rate of growth of output and labor productivity but the rate of capital accumulation only slows gradually. As a result, the ratio of capital to augmented labor (and of capital to output) begins to rise and is higher in the new steady state. As a result of the capital deepening, the rate of return on capital declines and is lower in the steady state at point F.

Consistent with the predictions of the neoclassical model, the data in Table 3 and Figure 3 show that the rise in the ratio of capital to augmented labor since 1968 has been accompanied by a decline in the rate of return on capital. Between 1968 and 1989, the ratio of capital to augmented labor rose by approximately 33 1/3 percent which, according to the neoclassical model, should lead to a decline in the rate of return on capital of 23 percent (the share of labor (0.7) times the percentage rise in the ratio of capital to augmented labor). In fact, the rate of return to capital over this period declined from around 15 percent a year to 12 percent a year--a 20 percent decline--which is broadly consistent with the prediction of the neoclassical model.

In short, the experience of the U.S. economy as regards the rate of return on capital is broadly consistent with the predictions of the neoclassical model and suggestive of the existence of diminishing returns to capital accumulation.

IV. Conclusions

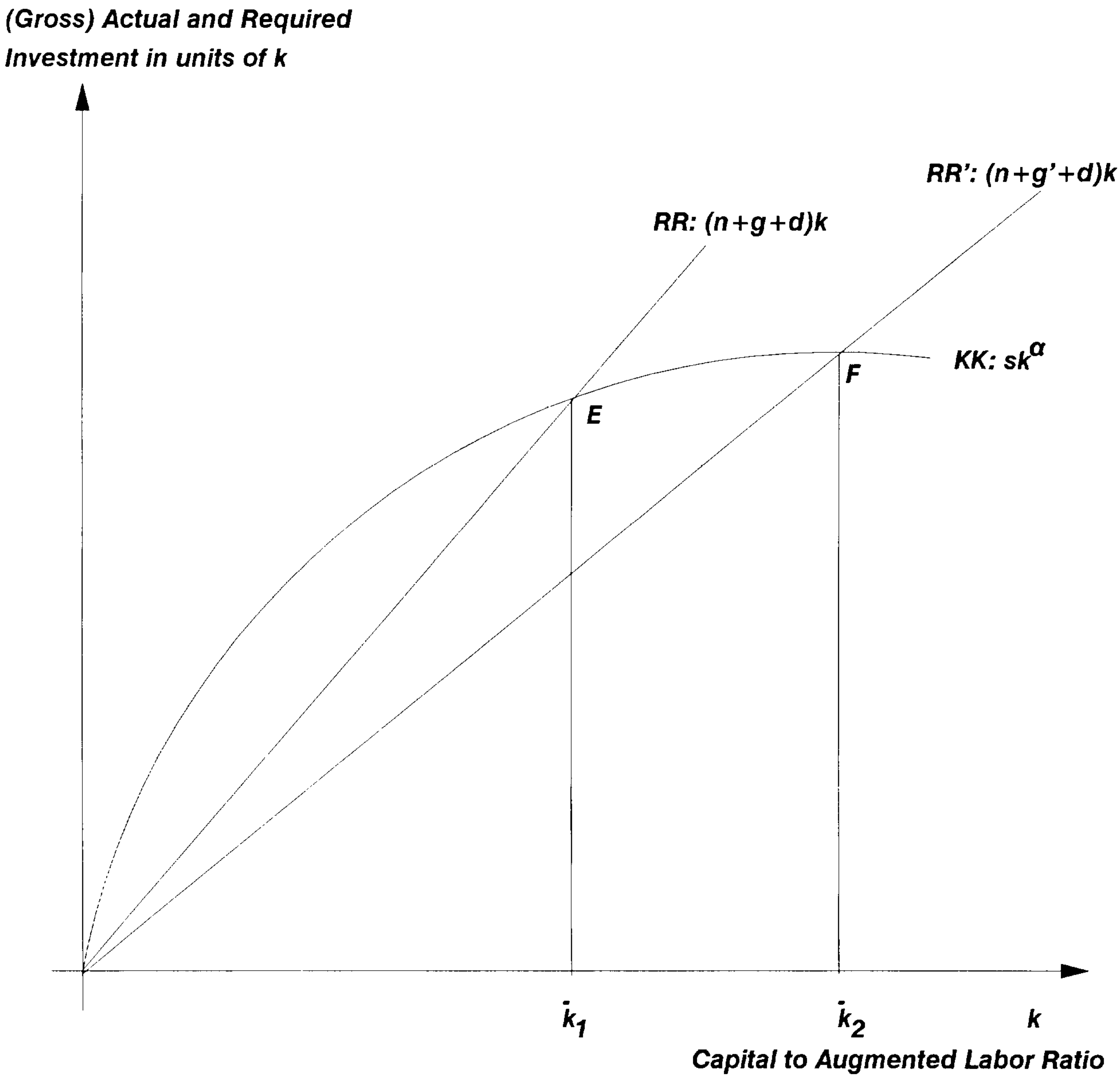
Based on the review of the growth experience of the U.S. economy, there are no strong reasons for rejecting the central conclusion of the neoclassical model that shifts in investment will not have a long-lasting effect on the economy's growth rate. Moreover, given capital's income share, the effects of shifts in investment on growth in the short to medium term can be expected to be small relative to the U.S. economy's underlying rate of growth. The class of endogenous growth models associated with Romer

1/ Over this period--notwithstanding a pickup in the rate of growth of the labor force associated with the baby boom and increased female participation--the rate of growth of labor in efficiency units slowed.

(1986, 1987a, b, and 1990) and others--which suggest a larger contribution of capital to growth and long-run effects of investment on the growth rate--do not seem to be supported by the data.

This conclusion does not, of course, imply that efforts to raise savings (and investment) rates would not lead to an improvement in economic performance in the U.S. The payoff from such efforts would include a faster growth rate in the transition to a new long-run equilibrium and a permanently higher level of output and labor productivity. Rather, the point is that such efforts are unlikely to lead to large and sustained changes in the economy's growth rate and--given diminishing returns--will be accompanied by a decline in the rate of return on capital.

Figure 4. Effect of an Exogenous Slowdown in the Rate of Labor Augmenting Technical Change in the Neoclassical Model.



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Appendix: Data Sources and Description

This appendix describes the construction of the historical series for the nonfarm business sector employed in the paper. Since 1983 the Bureau of Labor Statistics (BLS) has published data that corresponds closely in methodology to the traditional growth accounting approach. These data which have been constructed for the postwar period--with one modification discussed below--are used in the paper for the postwar period. In constructing the prewar data, the methodology employed by the BLS is followed as closely as possible.

In constructing prewar data BLS's real output (in 1982 dollars), labor input, capital services input (in 1982 dollars) series were first extended back to 1889 using (the index numbers for these) series reported by Kendrick (1961, 1973). While the output and labor input series appear to have been constructed in a manner consistent with BLS procedures, the capital input series was first cyclically adjusted since Kendrick reports data for capital stocks while the BLS data attempt to measure the flow of services from the existing capital stock. Following Solow (1957), in an attempt to capture the service flow from the capital stock, the capital stock data were first adjusted by a labor employment index. 1/

The BLS measure of total factor productivity is computed by dividing output by a weighted average of capital and labor inputs, where the weights are (a rolling two year average of) the shares in factor income. We instead impose constant shares, determined by the historical average value of the shares in factor income. The average share of capital was 0.31 for 1889-1989. This constant share is used to construct the series for the marginal product of capital. The (time varying) capital income series was used to construct the gross rate of return reported in Table 3.

The average gross investment rate for the postwar period was provided by the BLS from unpublished data. For the pre-war period it was constructed by positing a constant depreciation rate for various subperiods 2/.

1/ The data employed for the share of the labor force employed are that in Solow (1957). In 1948, the link year, the proportion of the labor force employed was 'normalized' to unity and an index constructed as the ratio of the proportion of the labor force employed in any year to the proportion employed in 1948. This index was then multiplied by the capital stock series to yield a capital services series.

2/ There is an unambiguous upward trend in the (unpublished) depreciation rates computed by the BLS for the postwar data, so a lower rate was assumed for earlier periods.

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