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Interpreting Productivity Growth in the New Economy: Some Agnostic Notes

by

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ABSTRACT

The growth rate of total factor productivity seems to have increased recently, at least in the United States. Higher US productivity growth may justify higher stock market valuations than in the past and thus herald an emerging New Economy. However, the size of the estimated growth rate of total factor productivity depends on an assumption about the factor-augmenting properties of technological change. Simulations based on alternative properties of technological change produce a wide range of implied stock market valuations. As long as the rate of technological change cannot be observed directly, justifying the emergence of a New Economy with residual measures of total factor productivity growth will prove to be a futile exercise.

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1. Introduction

The New Economy can be described as an economy which is increasingly producing digital embodiments of ideas rather than physical entities, which are the domain of the Old Economy. Fueled by new information and communication technologies and based on knowledge-intensive production processes, the New Economy has long been predicted to generate a substantial increase in aggregate productivity growth. Higher productivity growth would not necessarily imply that well-established economic rules no longer apply, but it would mean a higher speed limit for the economy. With higher productivity growth, income and employment could rise faster than before without generating inflationary pressures.

In the United States at least, the New Economy seems to have arrived. Inflation is down, unemployment is at its lowest level for decades, and growth is strong. Gross Domestic Product (GDP) has grown substantially faster since the mid-1990s than in the 15 years before. The strong acceleration in US labor productivity growth, which is unique among industrialized countries up to now, provides the most convincing evidence in favor of the emergence of a New Economy. What remains debatable are the sources of the observed increase in labor productivity growth, which may provide hints on whether it can last for long.

Higher labor productivity growth can result from additional factor inputs or from faster technological change. Higher productivity growth will not last for long if it is due to additional investment in physical and human capital, which both cannot increase forever. But higher productivity growth may be sustainable if it is due to a persistently higher rate of technological change. Thus the empirical question is whether technological change can be identified as the major source of the observed surge in labor productivity growth. If that is the case, it may indeed be justified to speak of a New Economy. Stock markets around the world seem to agree as they priced in a substantially higher future rate of growth.

Unfortunately, a clear-cut empirical distinction between changes in technology and changes in factor accumulation remains impossible by conventional methods of growth accounting. This problem is well known in the literature, but it has consistently been ignored in most of the recent discussion. The point to note is that non-parametric accounting has to use an identifying assumption, which a priori specifies the unobservable factor-augmenting properties of technological change.[1] Hence different technology assumptions necessarily lead to different accounting results. Moreover, the very notion of a New Economy seems to suggest that the factor-augmenting properties of technological change may have changed. Growth accounting exercises have not considered the possibility that a New Economy may be based on a different kind of technological change than the Old Economy.

Simulations based on alternative factor-augmenting properties of technological change demonstrate the extreme sensitivity of implied stock market valuations with regard to the actual size of the measured growth rate of total factor productivity. As long as the rate of technological change cannot be observed directly, justifying the emergence of a New Economy with residual measures of total factor productivity growth will prove to be a futile exercise. This is because non-parametric accounting can only identify whether a given concept of total factor productivity displays a higher rate of growth. But non-parametric

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[1] In priciple, parametric estimation methods could solve the identification problem. However, as noted by Hulten (2000), such a solution is purchased at a cost. An econometric approach may require a priori restrictions to guarantee the consistency of the parameters estimates with economic theory. Hence questions about the robustness of certain restrictions would arise, in addition to questions regarding the appropriateness of non-linear econometric procedures required to estimate models with flexible functional forms. Moreover, the possible endogeneity of physical and human capital accumulation would most likely result in biased parameter estimates.

accounting cannot identify whether the a priori chosen concept of total factor productivity is appropriate or whether it has changed over time.

The next section summarizes some evidence about recent changes in economic growth in selected developed economies. Section 3 highlights the methodological ambiguities which arise in accounting for the relative contributions to observed GDP growth of factor accumulation and technological change. Section 4 discusses alternative concepts of technological change, which are all compatible with the stylized facts of growth but imply rather different measures of total factor productivity growth. Section 5 links the observed increase in US labor productivity growth to stock market valuations and shows that alternative interpretations of total factor productivity growth lead to widely diverging predictions with respect to the increase of the price-earnings ratio.

2. Recent Growth Experience

Recent debates about the empirical relevance of the New Economy paradigm have mainly focused on the question whether output (GDP) and labor productivity (GDP per hour worked) grow significantly faster than in the past and if so, how upward changes in growth rates could be interpreted. The available evidence for a number of industrialized countries may be summarized as three stylized facts (Table 1).

- The US economy has grown at a substantially higher rate in recent years than other large industrialized economies. Average GDP growth of more than 4 percent in the United States was only exceeded by Finland, Ireland, and Australia in 1996-1999.

- The recent acceleration in growth has been more pronounced in the United States than elsewhere, again with Finland, Ireland, and Australia as the exceptions.

- In the United States, faster GDP growth has been accompanied by faster labor productivity growth. GDP per hour worked increased on average by 2.3 percent in 1996-99, compared to 1.3 percent in 1981-89 and 1 percent in 1990-95. The strong acceleration of labor productivity by more than 1 percentage point is what separates the United States from other industrialized countries, which almost all experienced a decline in average labor productivity growth relative to the 1980s and the early 1990s. A comparison with average labor productivity growth in 1950-73 shows that a rate of 2.3 percent is not necessarily high by historical standards, but may prove to be sustainable for a relatively long time span.

These stylized facts reveal that the United States is probably the only economy which up to now shows a growth record compatible with the predictions of the New Economy paradigm. Finland and Ireland, which outstripped the US economy in terms of GDP growth and in terms of labor productivity growth, do not show a recent acceleration but rather a deceleration of both measures. Germany, France, and Japan, which achieved a growth rate of labor productivity comparable to the United States, lag behind in terms of GDP growth. The Netherlands has almost grown as fast as the United States in the late 1990s, but its growth mainly reflects rising employment since its labor productivity barely changed. In Australia, which comes closest to the recent US growth record, the good performance in the 1990s appears to be due to deregulation and privatization of Old Economy sectors like wholesale trade, retail trade, and construction rather than to advances in New Economy sectors like information technology (Gruen and Stevens 2000).

There has been some discussion in the literature whether measured GDP and measured labor input actually track what is going on in the presumed New Economy. Proponents of the New Economy view have argued that due to the intangible nature of many new knowledge-based products and due to rapid increases in the quality of established products, traditionally measured GDP figures may underreport the true increase in economy-wide output. Critics of the New Economy paradigm have pointed to possible measurement errors on the input side, especially with regard to changes in the numbers of hours worked by high-skilled workers. Hence measured labor productivity growth may be downwardly biased if output is underreported, and it may be upwardly biased if rising work schedules of better qualified workers are not appropriately captured by official statistics. However, both possible effects do not seem to matter much in the case of the United States, as discussed in Gust and Marquez (2000).

There is more or less consensus in the literature that the *production* of computers has significantly contributed to the acceleration in US labor productivity growth in the second half of the 1990s. Less clear is whether the increased *use* of computers and computer-related technology in other sectors has also contributed to US productivity growth, as would be expected according to the New Economy paradigm. Oliner and Sichel (2000) find that the production of computers and the use of information technology together account for two-thirds of the observed pick-up of labor productivity growth. Gordon (2000) is more skeptical about a trend increase in labor productivity, but also concedes that the pick-up in labor productivity originated from more sectors than just the production of computers. Jorgenson and Stiroh (2000) are more optimistic. They find that information technology appears to be the driving force in the growth resurgence since the mid-1999s. Hence if the diffusion of information technology improves business practices, generates sectoral spillovers, and raises productivity, average labor productivity growth could be substantially higher in the future than in the past.

3. Methodological Ambiguities

Leaving measurement issues aside, the observed acceleration in labor productivity growth in the United States can only result from two sources. One is faster capital accumulation and the other is faster technological change. If history is any guide, the rate of technological change may jump to a higher level at distinct points in time and remain at the higher level for long time periods. For instance, the increase in the rate of technological change at about the end of the 19th century appears to explain why output per worker in the United States grew faster in the 20th century than in any century before.

By contrast, faster factor accumulation cannot go on forever since the rate of investment is bounded through the fraction of GDP which is required for consumption. In the long run, a given rate of investment can only contribute to rising output per worker if the law of diminishing returns does not apply. Yet there is very little empirical evidence supporting the view that physical as well as human capital accumulation should not run into diminishing returns. Hence the recent surge in US labor productivity growth could in fact be regarded as evidence of a New-Economy-in-the-making if it were due to a higher rate of technological change.

However, the notion of technological change proves to be an elusive concept when it comes to empirical estimation. The reason is that estimating the relative roles of factor accumulation and technological change with non-parametric measures necessarily encounters methodological ambiguities. In growth accounting it is often neglected that there is no way to identify the *size* of the rate of technological change from a given set of data without implementing an a priori assumption about the way technological change might shift the underlying production function over time. Hence any empirical estimate of the residual rate of technological change implies a basically untestable assumption about certain factor-augmenting properties of technological change. Since these assumptions may reasonably differ, interpreting productivity growth often means different things to different people. Figure 1 tries to explain why this is the case.

Points *A* and *B* are assumed to be generated by a production function, which describes the relation between factor inputs and output. Both points may represent observed combinations of output per hours worked (labor productivity *y*) and capital per hours worked (capital intensity *k*) at different points in time. The question is how the observed increase in labor productivity from *y(A)* to *y(B)* can be explained in terms of factor accumulation, which is represented as a movement along a given production function, and in terms of technological change, which is represented as a shift of the production function to a higher level.

Three stylized facts of economic development can be incorporated into Figure 1 to shed more light on the prospective roles of factor accumulation and technological change. First, capital productivity has only slightly declined with increasing labor productivity in most industrialized countries. Capital productivity, which is the inverse of the capital-output ratio, is reflected by the slope of the straight line through the origin and A. Hence B, with a higher capital-output ratio than A, lies to the right of the straight line through the origin, but not by much (see below).

Second, capital's and labor's share in factor income have remained fairly constant in the course of economic growth in industrialized countries (Maddison 1987, Gust and Marquez 2000). A constant labor share implies that there is a fixed relation between labor productivity and the real wage *w*. In Figure 1, *w(A)* and *w(B)* are fixed at 70 percent of *y(A)* and *y(B)*, which approximately equals the size of labor's share in factor income in industrialized countries.

Third, the rate of return to capital *r* has remained more or less constant in industrialized countries over the long run. Since the rate of return to capital equals the slope of a tangent to a production function in the *y*, *k*-space, it follows that

(1) $r = \tan a = \overline{wy} / k$,

where $\overline{wy}$ indicates the distance between *w* and *y*, and hence

(2) $r \cdot k = \overline{wy}$.

Since total factor income adds up to

(3) $y = r \cdot k + w$,

it follows by inserting (2) into (3) that *w* must lie on a tangent to a production function. This suggests that *A* and *B* must lie on different production functions as long as the tangents through *A* and *B* have about the same slope. This will indeed be the case as long as *A* and *B* are close to a straight line through the origin.

Hence given the stylized facts of growth with regard to capital productivity, factor shares, and the rate of return to capital, at least part of the increase in labor productivity would have to be interpreted as due to a shift of the production function. But since the shift of the production function cannot be observed directly, it is principally impossible to know from data on labor productivity and capital intensity alone which part of the change in labor productivity is due to a change in technology and which part is due to a change in factor accumulation. This problem is well known for more than a quarter century (Nelson 1973). But, as Hulten (2000) notes, it has generally been ignored in the productivity literature.

4. Concepts of Technological Change

The major methodological problem of any growth accounting exercise is that a decomposition of labor productivity into factor accumulation and technological change requires an untestable identifying assumption about the specific nature of technological change. In terms of Figure 1, the basic methodological question is *how* a production function through *A* should be shifted to end up as a production function through *B*. For instance, there could be a vertical upward shift, a shift along the straight line through the origin, or a horizontal leftward shift. Under certain additional conditions to be discussed below, shifts of the production function along these lines would be neutral with regard to the functional distribution of income, i.e., they would be compatible with the observed constancy of factor shares.[2] However, each of the three neutral shifts of the production function would imply rather different interpretations of the relative roles of factor accumulation and technological change in a decomposition of labor productivity.

Following the seminal paper by Solow (1957), the traditional growth accounting literature has mainly relied on an intuitively most appealing concept which interprets technological change as a vertical upward shift of the production function. This concept is called Hicks-neutral technological change and is defined as a shift of the production function which leaves unchanged capital intensity *k* for any constant factor price relation *w/r*. Such a shift is represented by a movement from *A* to *A*' in Figure 2. Hicks-neutral technological change is both capital and labor augmenting as it is equivalent to a proportionate increase in capital and labor. This is probably why Hicks-neutral technological change appears to conform most naturally to the notion of neutrality.

Given that the production function is of the Cobb-Douglas type (which guarantees constant factor shares due to a unit elasticity of substitution between capital and labor), Hicks-neutral technological change can be incorporated into a production function as

(4) $$Y = A_{Hicks} K^{a} L^{(1-a)} ,$$

[2] For a textbook discussion of neutral shifts of the production function see, e.g., Allen (1967).

where Y is output, K is capital, L is labor, and A_{Hicks} is (Hicks-neutral) technology which grows at a constant exogenous rate. Using small letters to indicate per capita terms, it follows that

(5) $$\Delta y = \Delta A_{Hicks} + a\Delta k \ ,$$

where Δ indicates a rate of change.

Equation (5) is the standard formula used in the literature to account for the sources of labor productivity growth, where $a\Delta k$ is called capital deepening and ΔA_{Hicks} is called (residual) multifactor productivity growth (see, e.g., Gust and Marquez 2000). Hence US labor productivity growth of 2.3 percent in 1996-1999 (Table 1) would be decomposed into a contribution of „capital deepening“ of 0.5 percentage points, which equals the product of capital’s share in factor income of about 1/3 and the observed rate of change of capital intensity of 1.5 percent, and a contribution of „multifactor productivity change“ of 1.8 percentages points, which equals the residual difference between the change in labor productivity and capital deepening. As a result, 80 percent of the observed increase in labor productivity would be attributed to a Hicks-neutral rate of technological change of 1.8 percent.

This comes close to the initial finding by Solow (1957), who reported that even more than 80 percent of the growth in output per man hour in the United States in 1909-49 was attributable to Hicks-neutral technological change. Most subsequent applied research attempted to reduce the estimated contribution of technological change (the residual), which was held to be a measure of ignorance. Yet a growth theoretic perspective would suggest to expect a 100 percent contribution of technological change to labor productivity growth in the long run, given the three stylized facts of growth mentioned above. That is, starting with Solow (1956) one would have used a different concept of technological change, which may be less easily accessible but which has a clearer foundation in growth theory. This concept is called Harrod-neutral technological change.

Except for the special case of a Cobb-Douglas production function where factor shares are fixed, only Harrod-neutral technological change is compatible with steady state growth (see, e.g., Allen 1967). Steady state growth means that output, capital, consumption, and investment all grow at the same long run rate, so that the ratios between these variables and the factor shares remain constant. In the steady state, only the rate of technological change would determine the growth of labor productivity, which is why one would expect a 100 percent contribution.

The concept of steady state growth may appear as a theoretical curiosity at first sight, but it is at least a reasonable approximation to the average long-run growth experience of the United States in the 20th century (Mankiw 1992). Although Hicks- and Harrod-neutral technological change are both compatible with steady state growth if a Cobb-Douglas production function is used, as in almost all applied work, it matters for the weights given to factor accumulation and technology in the decomposition of labor productivity which identifying technology assumption is used.

Harrod-neutral technological change is defined as a northeast shift of the production function which leaves unchanged the capital output ratio for any constant rate of return to capital *r*, for instance from *A* to *A*'' in Figure 3. Harrod-neutral technological change is labor augmenting in the sense that it is equivalent to an increase in the labor force. Hence Harrod-neutrality assumes that changes in technology cause changes in capital intensity in order to maintain a constant capital-output ratio in face of a rising labor force. In this interpretation, changes in capital intensity would only result because of changes in technology and, therefore, should be counted as such. Starting with the premise that observed long-run growth comes close to steady state behavior, one would expect that labor productivity growth should be almost entirely due to (Harrod-neutral) technological change.

The quantitative difference between Hicks- and Harrod-neutrality in growth accounting can be demonstrated by incorporating Harrod-neutrality into a Cobb-Douglas production function as

(6) $$Y = K^{a}\left(A_{Harrod}\,L\right)^{(1-a)} \quad ,$$

so it follows that

(7.1) $$\Delta y = \Delta A_{Harrod} + \frac{a}{(1-a)}\Delta\left(k/y\right) \quad \text{or}$$

(7.2) $$\Delta y = \left(1-a\right)\Delta A_{Harrod} + a\Delta k \quad .$$

Equating (7.2) and (5) reveals that

(8) $$\Delta A_{Harrod} = \frac{1}{(1-a)}\Delta A_{Hicks} \quad .$$

By definition, Harrod-neutrality gives a larger weight to technological change than Hicks-neutrality. With a capital share in factor income of 1/3, assuming Harrod-neutrality implies that the fraction of labor productivity growth attributed to technological change would rise by a factor of 1.5 as compared to assuming Hicks-neutrality. For the example of the United States that would mean a Harrod-neutral rate of technological change of 2.7 percent. Hence about 120 percent of the observed increase in labor productivity in 1996-99 would be attributed to technological change. This would leave a negative contribution from the change in factor intensity as long as the steady state is not reached.

However, Harrod- and Hicks-neutrality are not the only concepts of technological change which would leave the functional distribution of income unchanged. An unchanged factor distribution can either be defined as a constant relation between capital intensity and relative factor price (Hicks), as a constant relation between capital-output ratio and rate of return to capital (Harrod), or, accordingly, as a constant relation between labor-output ratio and real wage. The latter concept is called Solow-neutral technological change, which is defined to shift the production function to the left along a constant labor productivity (the inverse of the labor-output ratio), for instance from *A* to *A'''* in Figure 4. Based on the econometric estimation of an aggregate meta-production function, Boskin and Lau (2000) find for G7 countries in 1960-97 that technological change may indeed be represented as "generalized Solow-neutral".

Solow-neutral technological change is capital augmenting in the sense that it is equivalent to an increase in the capital stock. Solow-neutrality assumes that changes in technology cause reductions in capital intensity in order to maintain a constant labor-output ratio in face of a rising capital stock. In this interpretation, technological change per se would result in a decline of capital intensity without changing labor productivity. Hence assuming a Cobb-Douglas production function and starting with the premise of approximate steady-state growth, one would expect that Solow-neutral technological change would always account for more than the actually observed change in labor productivity.

Solow-neutral technological change would be incorporated into a Cobb-Douglas production function as

(9) $$Y = \left(K\,A_{Solow}\right)^{a}\,L^{(1-a)} \quad ,$$

so it follows that

(10) $$\Delta y = a\;\Delta A_{Solow} + a\Delta k$$

Hence by definition, Solow neutrality gives an even larger weight to technological change in a decomposition of labor productivity growth than Harrod-neutrality:

$$(11) \quad \Delta A_{Solow} = \frac{(1-a)}{a} \Delta A_{Harrod} = \frac{1}{a} \Delta A_{Hicks}$$

For $a = 1/3$ as before, using Solow neutrality as the identifying assumption would imply for the case of the United States a rate of technological change of 5.4 percent, which amounts to attributing about 240 percent of the observed change in US labor productivity to technological change, twice as much as compared to using Harrod-neutrality as the identifying assumption and three times as much compared to using Hicks-neutrality as the identifying assumption.

These three accounting exercises are meant to demonstrate that there is no way to decide on the basis of non-parametric methods which concept of technological change is the most appropriate. Neoclassical growth theory would suggest that Harrod-neutrality is the only plausible concept if the production function is not of the Cobb-Douglas type. The growth accounting literature uses Hicks-neutrality as the standard concept.[3] Recent econometric estimates seem to suggest that Solow-neutrality may also be a reasonable technology assumption. The bottom line of this discussion is that the specific factor-augmenting properties of technological change cannot be determined by growth accounting methods, but rather have to be imposed as an a priori assumption.

5. Productivity Growth and the Stock Market

Stock markets in most industrialized countries, and especially in the United States, have risen substantially in recent years notwithstanding a significant correction in the second half of 2000. The most plausible reasons for higher stock market valuations than in the past are first that investors may have

[3] For a recent survey of growth accounting, see Barro (1999). The papers by Oliner and Sichel (2000), Gordon (2000), and Jorgensen and Stiroh (2000) use Hicks-neutrality as the identifying asumption. Klenow and Rodriguez-Clare (1997) is an exception in suggesting to use Harrod-neutrality in growth accounting.

reconsidered the risk premium because returns on equities have on average consistently outperformed other less risky forms of financial investment, and second that investors expect rising stock dividends as a result of higher growth in the New Economy. In any case, stock markets should finally approach a level at which the new price-earnings ratio reflects revised expectations about risk free long-run growth. Questions are, then, how much future growth is already priced in current stock markets and how expected growth compares with estimated higher growth rates of total factor productivity.

The link from stock prices to expected growth is based on the premise that stock dividends tend to rise more or less in line with the aggregate growth rate of the economy, which would happen in an economy close to its steady state. If so, the current as compared to the historical price-earnings ratio may be used to derive a measure of the implicit aggregate growth expectation of the stock market. This reasoning follows from the simple rule that the present value and hence the price of stocks equals

$$(12) \quad p = Div \cdot \frac{1}{r-(g-b)} \quad ,$$

where p is the price of stocks, Div is stock dividends, r is the real interest rate, g is the risk-free rate of growth of stock dividends (which should proxy the expected average growth rate of the economy), and b is a risk premium attached to the rate of growth. Dividing both sides by earnings per stock (e),

$$(13) \quad p/e = \frac{Div}{e} \cdot \frac{1}{r-(g-b)} \quad ,$$

it follows that the rise of the price-earnings ratio from its historical level of about 15 to levels of about 30, as happened in 1999, requires either a doubling of the share of stock dividends in corporate earnings or a doubling of the second term. For the economy as a whole, a higher share of stock dividends in corporate earnings would mean a lower share of investment and, therefore, would undermine the steady-state assumptions that are the basis of equation (12) and the growth models discussed in the previous section. Hence for the economy as a whole, the first term of equation (13) can be considered as a constant. A more plausible interpretation of the observed doubling of the price-earnings ratio should focus on higher growth expectations or on a reduced risk premium, as captured by the second term of equation (13).

However, a high presumed risk from buying stocks in the past implies that average stock returns were high and that small variations in the interest rate or in the growth rate did not change the price-earnings ratio by much. If today's investors think that stocks have become a less risky option and buy relatively more stocks than in the past, even small variations in interest rates or growth should have a large impact on stock valuations. That is, believing in lower risk premiums to justify higher stock market valuations runs into a self-defeating prophecy, since the new valuations will necessarily be more unstable than the old variations (Krugman 1999). This is not to deny that lower risk premiums may in fact contribute to high stock market valuations, but the idea that lower risk premiums will be sustainable in the long run independent of the total amount of stock market investment appears to be implausible. Hence rationalizations for higher stock market valuations have to be based on the main promise of the New Economy: higher growth.

What matters for the sustainable long-run growth rate of the economy is the rate of technological change, measured as residual total factor productivity change. As discussed above, the Hicks-concept of technological change suggests that the steady state growth rate of the US economy could have accelerated by about 0.8 percentage points in 1996-1999 relative to 1981-1995. By implication, the Harrod-neutral and the Solow-neutral rate of technological change would have accelerated by 1.2 and 2.4 percentage points (see Table 2, first panel). For a constant risk premium of, say, 2 percent and a given real interest rate of 6 percent, which is the figure used in the growth literature (see Barro et al. 1995), the estimated acceleration in Hicks- and Harrod-neutral growth would only account for modest increases in stock market valuations between 13 percent and 23 percent (Table 2, second panel, no. 1). By contrast, the observationally equivalent acceleration in Solow-neutral technological change would imply that the stock market valuation should almost double. Hence depending on the identifying technology assumption, a relatively small difference in measured total factor productivity growth could account for a wide range of implied gains in stock market valuations from slightly more than 10 percent to slightly less than 100 percent.

However, accounting exercises based on equation (13) ignore that the steady state real interest rate cannot be considered as independent from the steady state growth rate. Growth theory suggests that the steady state real interest rate equals (Barro et al. 1995)

(14) $r = r + q g$,

which reproduces the previous estimate of 6 percent if the rate of time preference r equals 2 percent, the inverse of the intertemporal elasticity of consumption q equals 2, and the rate of technological change g equals 2 percent. This is the standard parameterization of preferences and technology used in the empirical growth literature. However, inserting equation (14) into equation (13) reveals that faster growth will only lead to a higher valuation of stocks if q is smaller than 1:

(15) $$p / e = \frac{Div}{e} \frac{1}{r + b + g(q - 1)} \quad .$$

All other things constant, higher growth would lead to a lower price-earnings ratio as long as q is larger than 1, because a higher g means an increase in the real interest rate by qg. Without assuming a compensating change in any of the other parameters, higher total factor productivity growth would mean lower, not higher stock market valuations. One possibility is that a decline in q could compensate for the rise in the real interest rate due to higher growth.

Empirical evidence by Ogaki and Atkeson (1997) suggests that the intertemporal elasticity of substitution may rise with rising wealth. Hence q, the inverse of the intertemporal elasticity, may decline if the steady-state growth rate increases. Nevertheless, the parameterization of q is bounded from below because lower estimates than 2 would imply a higher steady state saving rate. For instance, Barro et al. (1995) show that the previous standard parameterization of preferences and technology implies a steady state saving rate of about 40 percent, which looks plausible for a broad concept of investment that includes human capital. If q falls from 2 to 0.9 in an otherwise unchanged parameterization, the implied saving rate rises to about 50 percent. If q falls further to 0.5, the implied saving rate would rise to about 56 percent, which looks like an upper bound of a plausible figure for a broad investment rate.

Using the ad hoc assumption that q declines from 2 in 1981-95 to 0.9 in 1996-99, faster Hicks-neutral technological change would account for a rise in stock market valuations of about 30 percent and faster Harrod-neutral technological change would account for a rise in stock market valuations of about 50 percent. In this setting, the observed acceleration in Solow-neutral technological change of 2.4 percentage points would again roughly account for a doubling of the price-earnings ratio (Table 2, second panel, no. 2). Thus by and large, the previous results would be reproduced. But using a stronger assumption about the decline in q, say from 2 to 0.5, would substantially increase the implied change in stock market valuations to about 60 percent (Hicks), 110 percent (Harrod), and 440 percent (Solow).

A further theoretical problem may result from the very notion of a New Economy which seems to suggest that not only the speed but also the nature of technological change could have changed. This possibility is also consistent with the reported data on labor productivity growth and with the stylized facts of economic development, but the implications for stock market valuations would again be inconclusive depending on the specific technology assumptions being made. For instance, if technological change has changed from Hicks- to Harrod-neutrality, the observed increase in the growth rate of labor productivity would imply that the stock market valuation could rise by 34 percent or by 89 percent, depending on the assumption about the decline in the inverse of the intertemporal elasticity of substitution. But if technological change has changed from Harrod- to Solow neutrality, the stock market valuation could rise by 59 or by 323.1 percent for an otherwise identical set of parameters. All other possible combinations of technological change imply stock market valuations within this range (Table 2, second panel, no. 3), which is much too broad to allow for any meaningful conclusions.

Overall, these simulations demonstrate that almost any result can be produced with more or less plausible parameterizations of preferences and technology. By focusing on the rather narrow question whether Hicks-neutral technological change has accelerated in a small or in a broad number of sectors in the second half of the 1990s, the growth accounting literature misses an important point. Non-parametric empirical methods cannot distinguish between shifts of the production function caused by technological change and movements along a production function caused by factor accumulation, even if there were perfect data to be had. Growth accounting analyses simply cannot answer the question whether we actually witness a surge in technological change, which in turn would justify substantially higher stock market valuations than in the past. This is because technological change, the driving force of growth, cannot be observed directly but has to be estimated as a residual.

6. Conclusion

Recent debates about the empirical relevance of a New Economy have mainly focused on the results of growth accounting studies, which have identified an acceleration of total factor productivity growth in the United States since the mid-1990s. However, it appears that the discussion about the size and the sustainability of the identified effect misses a fundamental methodological problem. The non-parametric concept used to estimate the rate of total factor productivity growth requires an identifying assumption about the factor-augmenting properties of technological change. Alternative assumptions are also consistent with the data at hand, but give rise to different interpretations of the relative roles of factor accumulation and technological change in growth. Furthermore, the factor-augmenting properties of technological change may not be the same in the New Economy as in the Old Economy. These implications are ignored in most applied work. The New Economy may produce a substantially higher rate of technological change and hence a higher sustainable long-run growth rate. But residual measures of technological change cannot reveal just how large such a new growth rate may be.

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Table 1 – In Search of New Economy Effects, Selected Industrialized Countries

	Growth rate[a], 1996-99		**Change in growth rate[b], 1996-99 vs. 1981-95**		**Note:** Growth rate[a], 1950-73	
	GDP[c]	Labor productivity[d]	GDP[c]	Labor productivity[d]	GDP[c]	Labor productivity[d]
United States	4.43	2.30	1.40	1.11	3.7	2.5
France	2.53	1.61	0.57	-1.34	5.1	5.1
Germany	1.72	2.14	0.10[e]	-0.12[e]	5.9	6.0
Italy	1.38	0.67	-0.67	-1.82	-	-
Japan	1.31	2.07	-2.00	-0.96	9.4	7.7
United Kingdom	2.78	1.47	-0.29	-1.26	3.0	3.2
Australia	4.78	3.12	1.16	1.53	-	-
Denmark	2.74	0.86	0.41	-2.13	-	-
Finland	5.51	3.10	3.57	-0.77	-	-
Ireland	9.87	3.96	5.19	-0.76	-	-
Netherlands	3.65	0.35	1.39	-2.88	4.7	4.4
Sweden	2.47	1.96	0.53	0.20	-	-

[a]Average annual growth rate of GDP, in percent.
[b]Difference in average annual growth rates, in percentage points.
[c]Real Gross Domestic Product.
[d]Real Gross Domestic Product divided by labor hours worked.
[e]1996-99 vs. 1992-1995.

Source: OECD data as reported in Gust and Marquez (2000); Maddison (1987).

Table 2 – Back of the Envelope: Total Factor Productivity Growth and Implied Change in Stock Market Valuations

	Total factor productivity growth (g)		
	1981-95	1996-99	Difference
Hicks	1.0	1.8	0.8
Harrod	1.5	2.7	1.2
Solow	3.0	5.4	2.4

Implied change in stock market valuations

	1. Constant real interest rate[a] ($r = 0.06$)		
	1981-95	1996-99	Change (in percent)
Hicks	14.3	16.1	12.9
Harrod	15.4	18.9	22.6
Solow	20.0	38.5	92.3

	2. Endogenous real interest rate, declining inverse of the intertemporal elasticity of substitution[b]				
	1981-95 ($q = 2$)	1996-99 ($q = 0.9$)	Change (in percent)	1996-99 ($q = 0.5$)	Change (in percent)
Hicks	20.0	26.2	30.9	32.3	61.3
Harrod	18.3	26.8	47.5	37.7	107.5
Solow	14.3	28.9	102.3	76.9	438.5

	3. Endogenous real interest rate, declining inverse of the intertemporal elasticity of substitution, and changing technological change[b]				
	1981-95 ($q = 2$)	1996-99 ($q = 0.9$)	Change (in percent)	1996-99 ($q = 0.5$)	Change (in percent)
Hicks vs. Harrod	20.0	26.8	34.0	37.7	88.7
Hicks vs. Solow	20.0	28.9	44.5	76.9	284.6
Harrod vs. Hicks	18.2	26.2	44.0	32.3	77.4
Harrod vs. Solow	18.2	28.9	59.0	76.9	323.1
Solow vs. Harrod	14.3	26.8	87.7	37.7	164.2
Solow vs. Hicks	14.3	26.2	83.2	32.3	125.8

[a]Calculated as $1/(r-(g-ß))$, with $ß = 0.02$ (see equation (13)).

[b]Calculated as $1/(r+ß+g(q-1))$, with $ß = r = 0.02$ (see equation (15)).

Figure 1 – Stylized Facts About Growth: From A to B

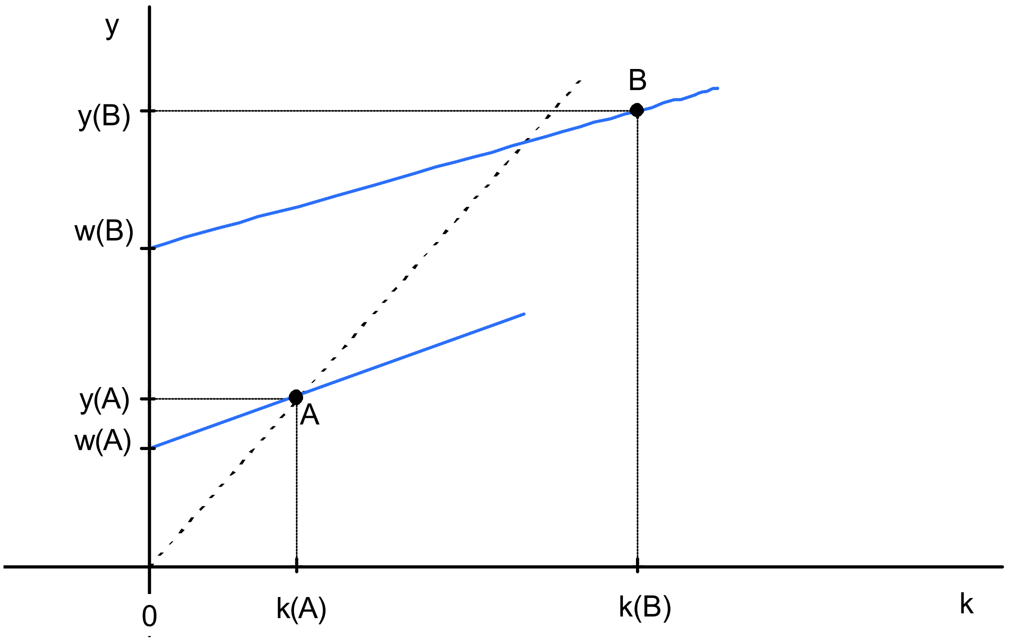

Figure 2 – The Hicks Interpretation of Growth: From A to A' to B

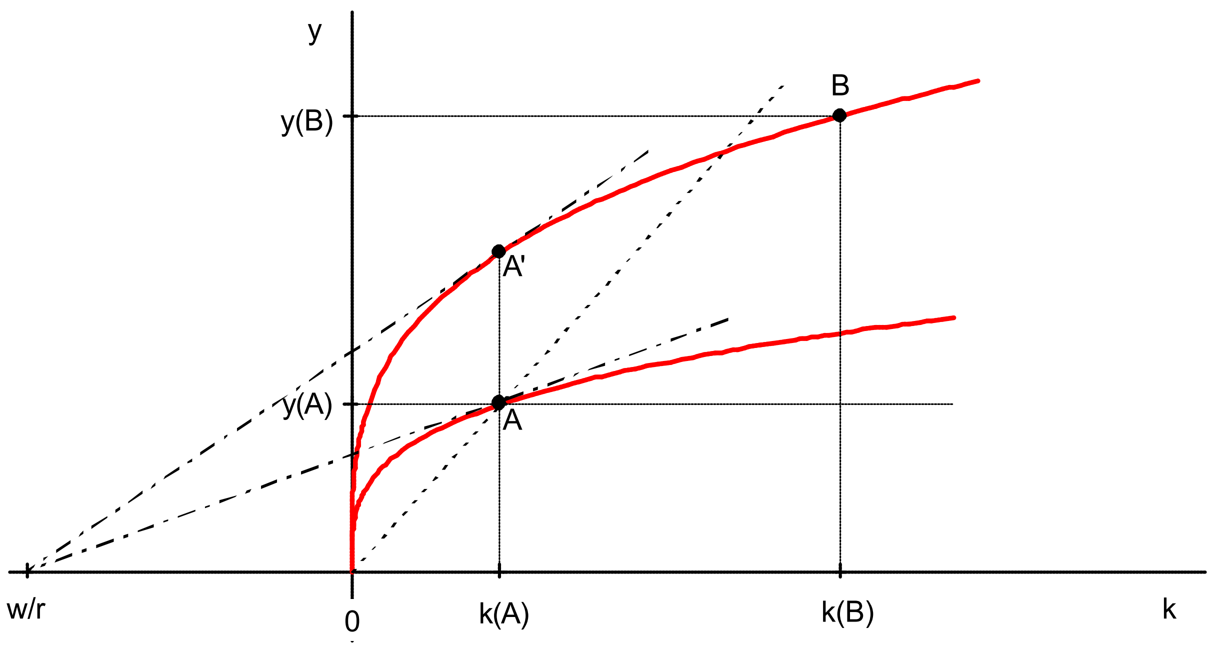

Figure 3 – The Harrod Interpretation of Growth: From A to A" to B

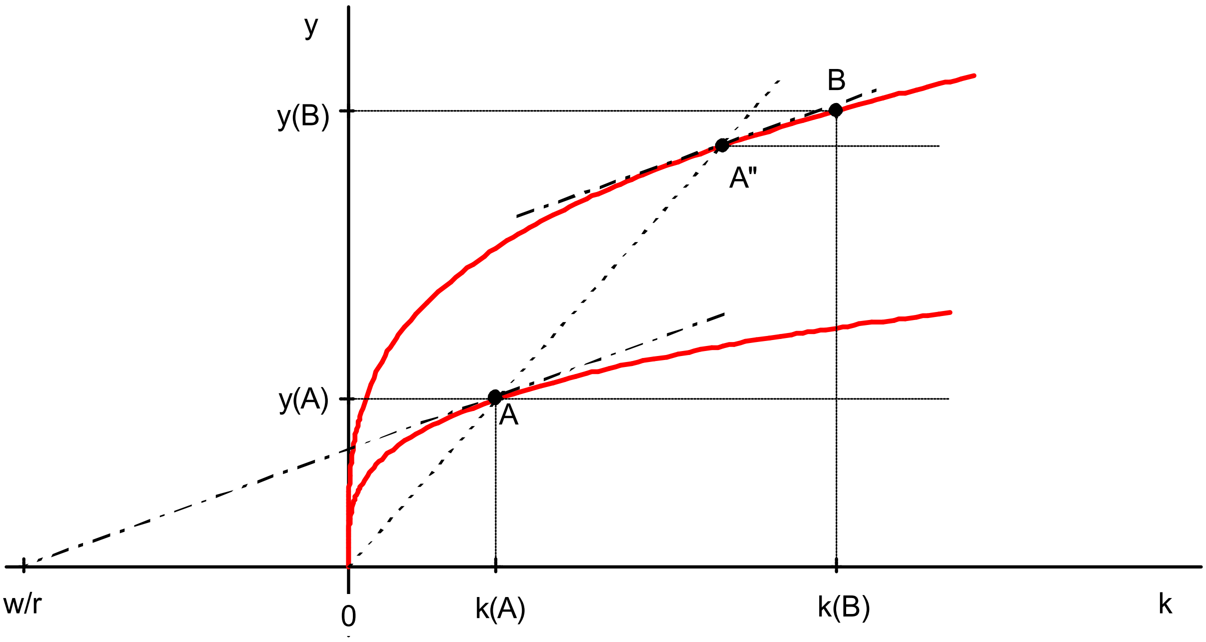

Figure 4 – The Solow Interpretation of Growth: From A to A''' to B