NBER WORKING PAPER SERIES

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Working Paper 11948
http://www.nber.org/papers/w11948

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2006

Federal Reserve Board, University of Maryland and NBER, and Federal Reserve Board, respectively. Earlier versions of this paper were presented at the CRIW/NBER Summer Institute (July 2004), the OECD (March 2005), and the BEA (October 2005). We thank Dale Jorgenson and the participants at the Summer Institute, OECD, and BEA workshops for helpful comments. The views expressed in this paper are those of the authors and should not be attributed to the Board of Governors of the Federal Reserve System or other members of its staff. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 11948
January 2006
JEL No. O47, E22, E01

ABSTRACT

Published macroeconomic data traditionally exclude most intangible investment from measured GDP. This situation is beginning to change, but our estimates suggest that as much as $800 billion is still excluded from U.S. published data (as of 2003), and that this leads to the exclusion of more than $3 trillion of business intangible capital stock. To assess the importance of this omission, we add capital to the standard sources-of-growth framework used by the BLS, and find that the inclusion of our list of intangible assets makes a significant difference in the observed patterns of U.S. economic growth. The rate of change of output per worker increases more rapidly when intangibles are counted as capital, and capital deepening becomes the unambiguously dominant source of growth in labor productivity. The role of multifactor productivity is correspondingly diminished, and labor's income share is found to have decreased significantly over the last 50 years.

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I. Introduction and Background

The revolution in information technology is apparent in the profusion of new products available in the market place (goods with the acronyms PCs, PDAs, ATMs, wi-fi), as well as items like the internet, cell phones, and e-mail. These innovations are part of a broader technological revolution based on the discovery of the semiconductor, often called the "IT revolution." However, while its effects are apparent in the market place, its manifestation in the macroeconomic statistics on growth has been slow to materialize. Writing in 1987, Robert Solow, famously remarked that "you see the computer revolution everywhere except in the productivity data." Some ten years later, Alan Greenspan observed that the negative trends in measured productivity observed in many services industries seemed inconsistent with the fact that they ranked among the top computer-using industries.[1] Greenspan also questioned the accuracy of the consumer price index, in part because of its failure to adequately account for the new or superior goods made possible by the IT revolution.[2]

The IT revolution began to appear in the productivity data mentioned by Solow in the mid 1990s. This pick-up has been linked to investment in IT capital in a series of papers (Oliner and Sichel (2000, 2002), Jorgenson and Stiroh (2000), Stiroh (2002), and Jorgenson, Ho, and Stiroh (2002)), all of which estimate the contribution of IT capital to output growth within the

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[1] Chairman Greenspan's concerns about the measured productivity trends in services industries were first expressed in remarks at an FOMC meeting in late 1996 in regard to a staff analysis of disaggregated productivity trends (Corrado and Slifman 1999). Gullickson and Harper (1999) also investigated this issue. The observation that many of the services industries that had negative productivity trends were among the top computer-using industries owes, at least in part, to Stiroh (1998) and Triplett (1999).

[2] Similar views were expressed by Nordhaus (1997), who concluded from his analysis of the history of lighting that official price and output data "miss the most important technological revolutions in history." Also, Hausman (1999) noted that cell phones were absent from the CPI market basket for many years after they appeared in the market place.

Solow-Jorgenson-Griliches sources-of-growth (SOG) framework. However, the productivity pick-up did not remove all suspicion about the ability of official data to accurately capture the factors that affect U.S. economic growth. Both firm-level and national income accounting practice has historically treated expenditure on intangible inputs as an intermediate expense and not as an investment that is part of GDP, although this has begun to change with the capitalization of software in the U.S. National Income and Product Accounts (NIPAs).[3] The capitalization of software alone has had an appreciable affect on the growth of output per worker in the non-farm business sector, and the growing literature on intangibles suggests that this is just the tip of the iceberg.[4]

Our own earlier estimates suggest that, in 1999, software spending was less than 15 percent of a more complete list of intangible business investments that includes spending on innovative property (eg., R&D) and economic competencies as well as software and other computerized information (Corrado, Hulten, and Sichel 2005, hereafter CHS). We found that total business investment in intangibles was approximately one trillion dollars in 1999, an amount that is roughly the same as investment in tangible capital at that time. The magnitude of these estimates suggests that uncounted intangibles have an appreciable effect on the level of GDP, as well as on the rate of investment and level of labor productivity. This paper builds on

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[3] In addition to the capitalization of software expenditures by the Bureau of Economic Analysis (BEA), the capitalization of scientific R&D is under serious consideration for both the U.S. NIPA and the United Nations System of National Accounts. See Grimm, Moulton, and Wasshausen (2005) for a description of BEA's procedures for estimating software.

[4] The recent literature includes work sponsored by the OECD (OECD Secretariat 1998, Kahn 2001), Nakamura 1999, 2001, 2003; Brynjolffson and Yang 1999; Brynjolffson, Hitt, and Yang 2000; Hall 2000, 2001a, 2001b; McGratten and Prescott 2000, Lev 2001. This literature approaches the intangibles problem from a variety of perspectives, building upon previous work that both linked aggregate productivity and stock market performance (e.g., Baily 1981, B. Hall and R. Hall 1993) and constructed firm-level intangible stocks using financial data (e.g., Griliches 1981, Cockburn and Griliches 1988, and B. Hall 1993).

our previous work by examining whether the relative magnitude of the discrepancy in the *level* of investment carries over to the *rates of growth* of capital stock and real output. Our ultimate objective is to examine how the capitalization of intangible expenditures affects the SOG analyses that have played such a prominent role in recent analyses of the productivity pick-up.

We use our new SOG estimates to address the following issues: how much growth in output went uncounted because of the omission of intangibles; what is the contribution of intangible capital to output growth; how does the inclusion of intangibles affect the allocation of output growth between capital formation and multifactor productivity growth; and, does the post-1995 productivity pickup look different when intangibles are taken into account? To our knowledge, this is the first paper to examine these issues in the SOG framework with a more-or-less complete list of intangible assets. We find that the inclusion of intangibles makes a significant difference in the measured pattern of economic growth: the growth rates of output and of output-per worker are found to increase at a noticeably more rapid rate when intangibles are included than under the baseline case in which intangible capital is completely ignored, and capital deepening (when expanded to include both tangibles and intangibles) becomes the unambiguously dominant source of growth in labor productivity. More broadly, the factors typically associated with the growth of the "knowledge economy" assume a greater importance once intangibles are included.

We also find that the inclusion of intangibles has an important effect on the labor share of income. Specifically, in our framework, labor's share of income is lower than implied by conventional NIPA data, and it trends down notably over time. The addition of intangible capital and the associated flow of income from that capital raise the capital share of income and lower the labor share. Moreover, our numbers indicate that intangible investment has grown considerably more rapidly in recent decades than has tangible business investment, and the stock of intangible capital has grown considerably more rapidly than has the stock of tangible business capital. Thus, once intangible assets are incorporated into the calculations, the share of capital income shows a noticeable uptrend in recent decades, and the share of labor income shows a marked downtrend, particularly since 1980.

The paper is organized as follows: We first examine the theoretical basis for the claim that intangibles should be treated as capital rather than as intermediate inputs. We then describe how intangible capital, which is often viewed as qualitatively different from tangible capital, can be incorporated in the neoclassical framework on which the sources-of-growth model is based. Our procedures for estimating the flow of intangible investment and the corresponding stock of intangible capital are then discussed, after which our growth accounting results are presented and discussed.

II. Are Intangibles Really Capital?

A. The Treatment of Intangible Expenditures

The first question to be settled is theoretical: should intangible expenditures be classified as capital or as an intermediate good? The choice between the two alternatives becomes more apparent when the production functions and accounting identities associated with the two approaches are made explicit. This can be accomplished by considering a world of three goods, consumption C, tangible investment goods I, and an intangible N. When intangibles are regarded as being an intermediate good, labor L and tangible capital K are allocated to the production of all three goods, and N is an input to C and I. The production function and flow account for each of the three sectors is then

$$\text{(1a)} \quad N(t) = F^N(L_N(t),K_N(t), t); \qquad P^N(t)N(t) = P^L(t)L_N(t) + P^K(t)K_N(t);$$

$$\text{(1b)} \quad I(t) = F^I(L_I(t),K_I(t),N_I(t), t); \qquad P^I(t)I(t) = P^L(t)L_I(t) + P^K(t)K_I(t) + P^N(t)N_I(t);$$

$$\text{(1c)} \quad C(t) = F^C(L_C(t),K_C(t),N_C(t), t); \qquad P^C(t)C(t) = P^L(t)L_C(t) + P^K(t)K_C(t) + P^N(t)N_C(t);$$

with the adding up conditions $L = L_N + L_I + L_C$, $K = K_N + K_I + K_C$, and $N = N_I + N_C$, as well as the accumulation equation $K(t) = I(t) + (1-\delta_K)K(t-1)$.[5] The production functions in each equation are linked to the accounting identities by the assumption that each input is paid the value of its marginal product. In this formulation, N(t) is both an output and an immediate input to the production of the other products, and therefore nets out in the aggregate. Thus, N(t) does not appear in the GDP identity, which has the form

$$\text{(1d)} \quad P^{Q'}(t)Q'(t) = P^C(t)C(t) + P^I(t)I(t) = P^L(t)L(t) + P^K(t)K(t).$$

This is the approach taken by financial accounts for individual firms, the United Nation's System of National Accounts (1993), and, until the recent move to capitalize software, the U.S. NIPAs. In equation (1d), the apostrophes on the left-hand side of the equation are used to distinguish the

[5] We adopt the convention that intermediates used by the industry that produced them are netted out of final output. We have therefore omitted N_N from the production function and accounts of the intermediate good industry. We also ignore the complication of chain weighting to keep the exposition simple.

case in which intangibles are excluded from the case described below in which intangibles are counted as investment.

A different model of production accounting applies when the intangible is classified as capital. The output of the intangible, N(t), now appears in the production functions of the consumption and tangible investment sectors as a cumulative stock, not as a contemporaneous input as above. An accumulation equation for intangible capital, $R(t) = N(t) + (1-\delta_R)R(t-1)$, parallels the corresponding equation for tangibles. The sectoral equations become

(2a) $N(t) = F^N(L_N(t),K_N(t),R_N(t),t); \quad P^N(t)N(t) = P^L(t)L_N(t) + P^K(t)K_N(t) + P^R(t)R_N(t);$

(2b) $I(t) = F^I(L_I(t),K_I(t),R_I(t),t); \quad P^I(t)I(t) = P^L(t)L_I(t) + P^K(t)K_I(t) + P^R(t)R_I(t);$

(2c) $C(t) = F^C(L_C(t),K_C(t),R_C(t),t); \quad P^C(t)C(t) = P^L(t)L_C(t) + P^K(t)K_C(t) + P^R(t)R_C(t);$

The balance equations set out above are modified to replace the equation $N = N_N + N_I + N_C$ with $R = R_I + R_C + R_N$.[6] Again, the production functions in each equation are linked to the accounting identities by the assumption of marginal productivity pricing. The GDP identity, in this case,

[6] In this second formulation we expand the technology of the intangible producing sector to use the output that it produced in previous years (that is, to use its own stock of accumulated intangibles). In other words, the knowledge investments of past years are allowed to be productive in producing current and future knowledge. This allows investment to be aimed not just at direct product or process innovation, but also at furthering the capability of the innovation process itself. Indeed, this is a key aspect of the R&D process, because research often is done to further the research capability of R&D researchers. Moreover, some firms continue to do research even when a competitor has beat them to the punch, in order to keep up with best practice and perhaps get out in front in the next round. This line of reasoning does not fit well with the preceding formulation (1a)-(1d) in which the accumulated stock of past knowledge is treated as an intermediate input and omitted from the technology for producing knowledge.

must be expanded to included the flow of new intangibles on the product side and the flow of services from the intangible stock on the income side:

$$\text{(2d)} \qquad P^Q(t)Q(t) = P^C(t)C(t) + P^I(t)I(t) + P^N(t)N(t) = P^L(t)L(t) + P^K(t)K(t) + P^R(t)R(t).$$

The price $P^R(t)$ is the user cost associated with the services of the intangible stock and is a source of income that is absent from the conventional intermediate goods case (1d). The concept of GDP in this expanded identity is more comprehensive and larger in magnitude than in the conventional case.

B. Growth Accounting with Intangible Capital

The conventional SOG framework allocates the growth rate of output to the share-weighted growth rates of the inputs plus a residual. Following Solow (1957), the SOG equation is derived from the conventional framework of equations (1a)-(1d) by logarithmic differentiation of (1d):

$$\begin{aligned} \text{(1e)} \qquad g_{Q'}(t) &= s'_C(t)g_C(t) + s'_I(t)g_I(t) \\ &= s'_L(t)g_L(t) + s'_K(t)g_K(t) + g_{A'}(t). \end{aligned}$$

The notation $g_X(t)$ is used to denote the rate of growth of the respective variables; for example, $g_{Q'}(t)$ thus denotes the growth rate of aggregate output (the Divisia index of the growth rates of consumption, $g_C(t)$, and investment, $g_I(t)$), and $g_{A'}(t)$ denotes the growth rate of multifactor productivity. The output shares $s'_C(t) = [P^C(t)C(t)]/[P^C(t)C(t) + P^I(t)I(t)]$, etc., and input shares $s'_L(t) = [P^L(t)L(t)]/[P^L(t)L(t) + P^K(t)K(t)]$, etc., are assumed to be equal to the corresponding output elasticities. Intangible input and output play no role in the formulation of this SOG equation.

When intangible capital is treated symmetrically with tangibles, the structure (2a)-(2d) governs the equations of growth, and the SOG model becomes

$$(2e) \qquad g_Q(t) = s_C(t)g_C(t) + s_I(t)g_I(t) + s_N(t)g_N(t)$$
$$= s_L(t)g_L(t) + s_K(t)g_K(t) + s_R(t)g_R(t) + g_A(t),$$

where the output shares are now $s_C(t) = [P^C(t)C(t)]/[P^C(t)C(t) + P^I(t)I(t) + P^N(t)N(t)]$, etc., and the true input shares are $s_L(t) = [P^L(t)L(t)]/[P^L(t)L(t) + P^K(t)K(t) + P^R(t)R(t)]$, etc.

A comparison of (1e) and (2e) reveals that the alternative view of intangibles involves more than the growth terms $g_N(t)$ and $g_R(t)$, and the associated shares, but also requires a restatement of all shares. The shares are linked by the factor of proportionality

$$(3) \qquad \lambda = (p^C C+p^I I)/(p^C C+p^I I+p^N N).$$

The basic result is that labor's share when intangibles are capitalized is smaller by this factor: $s_L = \lambda s'_L$, and the income share of capital is thus larger. A similar analysis applies to the rates of saving and consumption. Consumption shares with and without intangibles are related by the same proportionality factor as above, $s_C = \lambda s'_C$. The consumption share is smaller and the rate of saving/investment is correspondingly higher. This result is relevant in view of the perception of a low rate of saving in the U.S. economy, particularly because existing measures exclude much of the investment in knowledge capital that is a defining feature of the modern U.S. economy. Finally, the residual estimates of multifactor productivity from (1e) and (2e), $g_{A'}(t)$ and $g_A(t)$, respectively, differ by the factor λ when the economic system is in Golden Rule steady state growth, a result derived from Jorgenson (1966), but the bias due to ignoring intangible capital, $g_A(t) - g_{A'}(t)$, has a more complicated form in other cases.

C. The Criteria for Capitalizing Intangibles

The two approaches set out above give different structural representations of the same economy, and both cannot be simultaneously correct. Fortunately, standard capital theory provides criteria for choosing one over the other. As discussed in CHS, capital theory implicitly defines capital in the context of an optimal consumption plan based on the maximization of an intertemporal utility function subject to the usual constraints (Weitzmann 1976). The solution to this optimization problem determines the optimal path of consumption over time and thus consumer saving behavior, which in turn determines the paths of investment and capital. As discussed in Hulten (1979), the solution to this optimization problem has an important implication for the treatment of intangible capital: *any* use of resources that reduces current consumption in order to increase it in the future qualifies as an investment. This result argues for *symmetric* treatment of *all* types of capital, so that, for example, spending on R&D and employee training should be placed on the same footing as spending on plant and equipment. Moreover, this symmetry principle requires that most business expenditures aimed at enhancing the value of a firm and improving its products, including human capital development as well as R&D, be accorded the same treatment as tangible capital in national accounting systems.

D. Symmetry in Production

The symmetry principle of the preceding section establishes the theoretical equivalence of tangible and intangible capital from the standpoint of consumption. This symmetry between tangible and intangible capital is less apparent from the production side of the economy, which is perhaps one reason that intangibles have traditionally not been counted as capital. Indeed, some have argued – particularly in the accounting world – that several characteristics of intangibles disqualify them from being counted as capital; namely, the lack of *verifiability* for intangible assets that are not acquired through market transactions; the lack of *visibility* of intangible assets after their acquisition that complicates efforts to track past vintages; the *non-rivalness* of some intangible assets; and the lack of *appropriability* of the returns from some intangibles. We discuss each of these issues in turn and argue that such differences between tangibles and intangibles, while generally noteworthy, are no more relevant for the capitalization issue than are differences in the characteristics of equipment, structures, and land.

One source of production asymmetry between tangibles and intangibles arises from the fact that most tangible assets are purchased from other producers. Intangible assets, on the other hand, often are produced within the firm that uses them, and there is thus no arms-length market transaction to generate observable and *verifiable* data with which to estimate the quantity produced, designated as the flow $P^N(t)N(t)$ in the notation of this paper. A related problem arises because it is also difficult to separate $P^N(t)N(t)$ into separate price and quantity components; indeed, sometimes it is even difficult to define the units in which $P^N(t)$ and $N(t)$ ought to be measured (for example, in what units should knowledge be denominated?).

The absence of externally verifiable data is a major reason that accountants are reluctant to capitalize intangibles, preferring instead to treat them as an intermediate expense that arises and disappears internally within the same year. However, the lack of verifiability *per se* does not automatically make intangibles an intermediate input. Some tangible assets are also produced internally (some construction projects, for example) and therefore do not pass through external markets that generate verifiable transactions data. On the other hand, many intangible assets are acquired through external markets (technology licenses, patents and copyrights, and the economic competencies acquired through purchases of management and consulting services). In any case, the real issue of whether intangibles should be classified as intermediates or as capital depends on the economic character of the good, as per the preceding section, and not on the ease with which $P^N(t)N(t)$ can be measured.

Intangibility itself is another source of asymmetry in production. Tangible goods have a physical embodiment that is capable of being observed, and it is therefore possible to observe the ones that have been held over from previous years in the larger stock (they often have serial numbers that identify their vintage). The self-evident durability of a tangible good would immediately qualify it as capital rather than an intermediate good under most reasonable criteria. Intangibles, on the other hand, have no palpable embodiment and, in some sense, lack *visibility.* Thus, it is not feasible to look for a collection of vintages of intangible investments or even a single older vintage as proof that the item in question really is capital. In the case of knowledge capital, for example, it is hard to know which "bit" of knowledge belongs to which vintage of investment. From the perspective of national income accounting methodology, this issue could be characterized as the difficulty of measuring depreciation rates and obtaining stocks, R(t), for intangible assets. However, this concern is not a valid conceptual reason for treating intangibles as an intermediate input rather than as a capital asset. Again, it is how the item is used over time that determines whether or not it should be capitalized, not the ease with which R(t) can be measured.

Yet another asymmetry between tangibles and intangibles arises because of the public good aspects of the latter. Many types of intangible capital, such as R&D knowledge, are *non-rival*. The non-rivalness of pure knowledge implies that it can be employed by many users simultaneously without diminishing the quantity available to any single user. In this situation, the balance equations would be $N = N_N = N_I = N_C$ and $R = R_I = R_C = R_N$. Moreover, each additional unit of output produced would not need an additional "unit" of knowledge, suggesting that the marginal product of R is zero. However, while the marginal product of R used in the direct production of output may indeed be zero, this is the wrong margin to examine, because an increase in R increases the efficiency of production and thus increases output indirectly, or it improves the quality of the product (which is conventionally expressed as an equivalent increase in quantity). Why else would a firm pay to increase its R if it did not yield some benefit? In addition, many types of intangible capital – such as brand equity and organizational and human competencies – are not purely non-rival, but instead have a highly firm-specific character. Indeed, many intangibles are specific to a firm and valuable, at least in part, because the firm is able to exclude competitors from gaining access to key information and technology (the secrecy of the formula for Coca Cola is an example).

The *non-appropriability* of some intellectual property is another aspect of intangibles. The full benefits of R&D and worker training may not be captured by the firm making the investment, and the measured prices $P^N(t)$ and $P^R(t)$ may reflect only private benefits and costs.[7] However, as before, the capitalization issue pivots on whether the provision of R increases future output and consumption, not whether R is partly non-appropriable or non-rival, and these two features do not invalidate the need to capitalize many intangible expenditures.

In sum, the various characteristics that cause tangible and intangible capital to be different – verifiablity, visibility, non-rivalness, and appropriability – are all important features that distinguish one type of capital from the other. However, none of these differences is relevant to the issue of whether to treat intangible expenditures as capital. That is determined by whether or not the expenditure is intended to yield output in some future time period. This is the conceptual analogue on the production side to the symmetry criterion of whether the expenditure was made in order to increase future consumption. Many intangibles satisfy these criteria and must therefore be treated as capital.

Symmetry in production does impose one important restriction on intangible assets. To proceed as we have in the formulation of the equations (2a)-(2d), we assume that the same neoclassical investment rules that apply to tangible capital also apply to intangibles: investment in tangibles is assumed to proceed up to the point that the present value of the stream of future user costs, $P^K(t+\tau)$ just equals the cost of acquiring a marginal unit of the investment good, $P^I(t)$. Applied to intangibles, this assumption implies that investment is made using marginalist principles. An alternative Schumpetarian view of the firm might reject this assumption, but we

[7] Any externalities due to unappropriated benefits from R&D or other investments appear as a shift in the production function and are picked up in measured MFP (Hulten 2001). This is essentially the mechanism of endogenous growth theory when externalities arise from R&D (Romer 1986) and education (Lucas 1988).

adopt the marginalist approach because our objective is to integrate intangible capital into the neoclassical sources-of growth framework of equation (2e), which is based on marginalist principles.

E. Prices and Deflators

The SOG equations of the preceding section are computationally derived from the accounting structure in equations (2a)-(2d) using price deflators to convert nominal values into their real counterparts. As discussed above, a difficult aspect of this computation is measuring the price deflator $P^N(t)$ needed to convert estimates of expenditure $P^N(t)N(t)$ into real estimates. This has proved to be one of the most difficult empirical issues in the study of R&D investment, in large part because of the verifiability and visibility issues described above. The strategy in the R&D literature has been to use input costs to proxy for $P^N(t)$; the most common approach has been to average a wage deflator and a price deflator for a broad measure of output on the grounds that R&D expenditures are roughly 50 percent labor costs and 50 percent supplies.[8]

In contrast to this approach, we opt for a pure output deflator as a proxy for the price of intangibles. Although we consider this proxy only a placeholder until further research develops deflators for specific intangibles, we believe that a price measure is preferred to a wage measure for the following reason. Under constant returns to scale in the technology in (2a), the growth rate of the price of the intangible capital good is:

$$(4) \qquad g_{PN}(t) = s_{LN}(t)g_{PL}(t) + s_{KN}(t)g_{PK}(t) + s_{RN}(t)g_{PR}(t) - g_{AN}(t),$$

[8] This approach to constructing a deflator for R&D was developed and used by Jaffe (1972) and then by Griliches (1984).

where $s_{LN}(t) = [P^L(t)L_N(t)]/[P^L(t)L_N(t) + P^K(t)K_N(t) + P^R(t)R_N(t)]$ is labor's income share in the production of intangible investment. Using the wage $P^L(t)$ as a proxy for $P^N(t)$ is equivalent to assuming that the growth rate of output price is $g_{PN}(t)$ is equal to the growth rate of wages, $g_{PL}(t)$. As can be seen in equation (4), this will occur only if labor is the sole input to the production of the intangible and if the rate of multifactor productivity growth in the production of intangibles, $g_{AN}(t)$, and the shares of tangible and intangible capital, $s_{KN}(t)$ and $s_{RN}(t)$, are all zero. These assumptions are extremely implausible, because, for example, R&D programs require plant and equipment, and knowledge builds on knowledge. Because using a wage deflator tends to give biased results, we adopt the nonfarm business output price deflator as a proxy for $P^N(t)$. This proxy can be rationalized by the fact that much R&D and coinvestments in marketing and human competencies are tied to specific product lines. Integrating the cost of productivity-enhancing investments back into the "using" industries is accomplished generally by adopting the nonfarm business output price as the deflator for intangibles.[9]

The search for an appropriate deflator for the user cost of intangibles, $P^R(t)$, also poses challenges. The corresponding user cost of tangible capital, $P^K(t)$, is not usually observed but can be imputed following Jorgenson (1963) and Hall and Jorgenson (1967). When intangibles are ignored, the conventionally measured rental flow, $P^K(t)K(t)$, is estimated by the residual income not attributable to labor, $P^C(t)C(t) + P^I(t)I(t) - P^L(t)L(t)$. This leads to an error because, when income accrues to intangible capital, the conventionally measured residual term for capital income actually equals

[9] Martin Baily offered this rationale for the deflation of the output of management consultancies (see Triplett and Bosworth 2004, p 260).

(5) $$P^C(t)C(t) + P^I(t)I(t) - P^L(t)L(t) = P^K(t)K(t) + P^R(t)R(t) - P^N(t)N(t).$$

The conventional practice of ignoring intangible capital thus leads, in general, to a biased estimate of the income accruing to tangible capital. There is, moreover, another subtle issue that arises because the total capital income on the right-hand side of (5) is measured by the sum of all property-type income (interest, dividends, retained earnings, taxes, and depreciation). This list accounts for all the non-labor payments accruing to both tangible *and* intangible capital, i.e., to $P^K(t)K(t) + P^R(t)\,R(t)$, leaving no apparent role for the intangible investment, $P^N(t)N(t)$. As the right-hand side of equation (5) illustrates, the answer to this apparent contradiction is that the income accruing to intangible investments is reflected on the input side as uncounted profits. Specifically, when intangibles are treated as an intermediate input, the spending on intangibles is subtracted from revenue as an expense, reducing measured profits. On the other hand, when intangibles are treated as an investment, they are not subtracted from revenue in the period of purchase, and profits are higher. Thus, the symmetric treatment of tangible and intangible capital is not just about $P^N(t)N(t)$ as uncounted output, but also about $P^N(t)N(t)$ as uncounted income accruing to capital.

III. Estimates of Intangible Investment and Capital

A. Measuring Investment in Intangibles

In our earlier work, we developed estimates of a broad range of business investments in intangibles in the 1990s. Our results are summarized in Table 1 for the three broad categories of intangibles included in our analysis, with separate detail for two of the categories. We first estimated expenditures on each type of intangible (the first column in the table), and then, based on available economic research and evidence, we determined how much of each expenditure might be considered business investment according to the criterion of whether the expenditure could be deemed to yield future consumption (the last column). Estimates are the annual average for the period shown (the late 1990s), and the numbers in parentheses indicate how much of each type of investment currently is included in the NIPAs.

The rationale for our choice of categories is discussed in some detail in our the previous paper. We only note here that our choice was driven, in large part, by our desire to go beyond existing categories to develop a more comprehensive list. Our first broad category, business investment in computerized information, is largely composed of the NIPA series for business investment in computer software.[10] Our second category, innovative property, includes the National Science Foundation (NSF) Industrial R&D series. However, the NSF's survey is designed to capture only innovative activity built on a scientific base of knowledge and therefore does not fully capture resources devoted by businesses to innovation and new product/process R&D more broadly.[11] This "other" R&D – we called it nonscientific R&D – includes the revenues of the nonscientific commercial R&D industry, as measured in the Census Bureau's

[10] The NIPA software series is conceptually consistent with our intertemporal criterion for defining capital because the software measure includes both purchased and own-account components. National accountants estimated the own-account component indirectly to overcome the verifiability issue discussed earlier (Parker and Grimm 1999).

[11] The survey asks companies to include "activities carried on by persons trained, either formally or by experience, in: biological sciences, computer science, engineering, mathematical and statistical sciences, and physical sciences (e.g., chemistry and physics)" but to exclude "quality control, routine product testing, market research, sales promotion, ... and other nontechnological activities; ... and research in the social sciences or psychology." In a further clarification, the survey instructs companies to include expenditures for conducting clinical trials for drugs and software development if the application has commercial value, but to exclude "software development intended for within company use only."

Services Annual Survey (SAS), as well as the costs of developing new motion picture films and other forms of entertainment, and a crude estimate of the spending for new product development by financial services and insurance firms.[12] It is apparent from Table 1 that, by the late 1990s, investment in non-scientific R&D was as large as investment in scientific R&D.

Our third general category includes investment in what we have called "economic competencies." This includes spending on strategic planning, spending on redesigning or reconfiguring existing products in existing markets, investments to retain or gain market share, and investments in brand names. Expenditures for advertising are a large part of the investments in brand equity, but as stressed in our earlier work, not all spending on intangibles should be counted as capital spending. Based on results from the empirical literature on advertising, we estimated that only about 60 percent of total advertising expenditures were for ads that had long-lasting effects (that is, effects that last more than one year).

Investment in firm-specific human and structural resources is the second type of economic competency included in our estimates. It includes the costs of employer-provided worker training and an estimate of management time devoted to enhancing the productivity of the firm. Our estimates of the former are based on BLS surveys; the latter are based on SAS revenues for the management consultant industry and trends in the cost and number of persons employed in executive occupations. Without doubt, these spending flows are imprecisely estimated, but business investments in firm-specific human and structural resources through strategic planning, adaptation, reorganization, and employee-skill building are important drivers of innovation and

[12] Many new products in the financial services industry involve computerized information; to avoid double-counting (particularly with the own-account portion of computer software), we deliberately were very conservative in our estimates for this component.

profitability in industry and require treatment as investment to be consistent with capital theory.[13] Moreover, this last category is, by our reckoning, the largest type of business intangible investment. And, total investment in economic competencies is nearly as large as the investment in the other two major categories combined.

Two other facts emerged from our earlier work. First, total investment in intangibles grew more rapidly than investment in tangibles over the decade of the 1990s, although the levels of the two were nearly equal in magnitude for the decade as a whole. Second, investment in the categories of intangibles already included in the NIPAs was only a fraction of our estimated total, even if all scientific R&D were included. Together, these findings suggest that a longer time series on the growth of intangible business investment would indicate a strong dynamic role for intangibles in explaining economic growth and might significantly affect our understanding of the sources of growth of the U.S. nonfarm business sector.

Table 2 reports our new estimates of business investment in the intangibles shown in table 1 by decade starting in 1950. In general, the estimates shown in table 2 were derived using the same methods and sources as used in our earlier paper. Most of the needed source data begin at least by the late 1940s, and the series for spending on scientific R&D and on brand equity begin much earlier. However, for a few components we could not use the same sources for earlier periods, and the components were extrapolated backward in time using related series. This occurred most prominently for the series based on SAS data, which are not available prior to the

[13] Moreover, the micro data evidence of Abowd et. al (2005) suggests that firm-level differences in organizational practices (proxied by firm-level distributions of human capital) are strongly related to outcomes such as revenue per worker and market valuation.

mid-1980s. All SAS series were extrapolated back using a related aggregate in the BEA's gross product by industry system that is available beginning in the late-1940s.[14]

For employer-provided training we made some changes to the estimates for recent years and made some special adjustments to estimates for earlier years. In our earlier work, we used trends in wage costs and the industrial structure of the workforce to extrapolate the results of surveys conducted by the Bureau of Labor Statistics (BLS) in the mid-1990s. For this paper, we improved our extrapolations for more recent years by linking them to estimates from surveys that have been conducted by the American Society for Training and Development (ASTD) since 1997.[15] These new results suggest a slight pullback in firms' per-employee expenditure on training in 2002, perhaps reflecting the cyclical episode in 2001. We know of no similar, survey-based data for business outlays on employer-provided training in earlier periods.

The studies that established the link between training and productivity at the firm level (Bartel 1991, 1994) used data for earlier years (the mid-1980s), but the training measures were qualitative indicators, not actual figures on the amount firms invested in their employees (see also Black and Lynch 1996, whose data were for the early 1990s). The BLS surveys and the more recent ASTD data suggest that per-employee rates of spending on (formal) training increases with the size of the firm.[16] The BLS surveys also show that employees in professional and managerial

[14] Specifically, the rate of change in value added in miscellaneous professional services was used to extend the series for R&D in the social sciences and humanities, market research services, and management consulting services from 1985 back to 1947.
[15] See www.astd.org or Bassi, et. al. 2001 for further information.
[16] See table 1 in the employer survey at www.bls.gov/ept. Only 69 percent of small establishments (fewer than 50 employees) provided formal training in 1995 compared with nearly all medium-sized (50-249 employees) and large (250 or more employees) establishments.

occupations receive the most training (in terms of hours).[17] With the growth of the modern corporation and a rough doubling of the ratio of employees in professional and managerial occupations in the total workforce since the late 1960s, the incidence of employer-provided training likely has also increased by a notable, albeit unknown, amount.[18] Because an extension of the methods used in our earlier work would not build in an increase in incidence (except indirectly through its impact on the distribution of wage costs by industry), we boosted the trend in training implied by an extension of our earlier work by a small amount (less than 2 percent per year) between 1948 and 1988.

All told, business investment in intangibles is a vital aspect of business activity, and the investments shown in table 2 represent a large and growing portion of the overall economy. The extent to which existing nominal output measures are understated owing to the treatment of most intangibles as intermediates in the national accounts is illustrated by Figures 1 and 2. The former shows our measure of total investment as a share of (adjusted) nonfarm business output and indicates that intangibles have accounted for virtually all of the increase over the last five decades. (Note that software is included in "existing" investment, owing to its current treatment the NIPAs). Figure 2 breaks the growth in intangible investment into its major components and reveals that, in recent years, the most dynamic categories of intangibles are firm-specific resources, non-scientific R&D, and computer software. The major period of *relative* growth in

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[17] Employees in professional and paraprofessional occupations received essentially twice the number of hours of formal and informal training as those in other occupational groups, with training most prevalent for computer, professional and technical, and management skills. See tables 1 and 6 in the employee survey at www.bls.gov/ept.

[18] The reported increase in the ratio of professional and managerial occupations in the workforce is based on data from BLS's Current Population Survey (CPS). Nakamura (2001) presents and discusses the increase in this ratio from 1982 to 2000. We developed similar estimates using more limited CPS occupational categories that extend back to 1967.

scientific R&D was the 1950s.[19] Figure 2 also reveals the relative importance of investment in economic competencies as a share of the total investment.

The last four rows of table 2 present data on related series as a basis for further comparisons. The most interesting is perhaps the last row, which presents our estimates of the parameter λ from our equation (3). This parameter is the ratio of output with and without unrecognized intangibles. When nonfarm business output is adjusted to include our estimates of the unrecognized intangibles, the adjusted output is 12 percent ($1/\lambda$) percent higher than the existing measure in the 2000-2003 period. Fifty years ago, the adjusted measure was only about 5 percent higher.

B. Real Intangible Investment and Capital Stocks

The ultimate objective is to estimate the SOG equation (2e). In order to do this, estimates of the real investment in intangibles are necessary, as are the corresponding stocks of capital. Real investment for each new category of intangibles was obtained by deflating the nominal investment estimates of the preceding section by the nonfarm business output deflator.[20] As noted in Section II, we believe this deflator is a plausible placeholder until further research permits better measures. The NIPA price for software is retained and used for that category of intangibles.

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[19] Scientific R&D also bulged in the 1979-1982 period, but this bulge is accounted for by a jump in mineral exploration, which we include in scientific R&D along with the NSF's Industrial R&D series. Expenditures on oil and gas well drilling and mining, the dominant component of mineral exploration, are already capitalized in the NIPAs.

[20] The nonfarm business output deflator begins in 1948. To deflate nominal investment data that begin earlier (scientific R&D and brand equity, for example), the nonfarm business output deflator is linked to the GDP deflator.

To obtain intangible capital stocks, we start with our estimates of real investment series N(t) and apply the capital accumulation identity of Section II, $R(t) = N(t) + (1-\delta_R)R(t-1)$.[21] Two further elements beyond N(t) are needed to implement the identity: a depreciation rate, δ, and a capital benchmark, R(0), for each intangible asset.

Relatively little is known about depreciation rates for intangibles. Based on the limited information available, we made the following assumptions about depreciation rates:

Category	Depreciation Rate (percent)
Computerized information other than software)	33
R&D, scientific	20
R&D, nonscientific	20
Brand equity	60
Firm-specific resources	40

For computerized information, our estimate is based on the BEA's assumptions for own-account software (depreciation rate of 33 percent, five-year service life). Our estimate of the depreciation rate of R&D capital (20 percent) is in the middle of the range of the rates reported in the existing literature on R&D. For R&D, Bernstein and Mamuneas (2004) find that the depreciation rate in the United States is 18 percent. Nadiri and Prucha (1996) obtain a figure of 12 percent. Pakes and Schankerman (1978), using data for several European countries, obtain an

[21]Note that we are assuming that R&D investment becomes productive as soon as it is put in place; that is, we are assuming a gestation lag of zero. In contrast, Fraumeni and Okubo (2005) assumed a one-year gestation lag. We maintained a gestation lag of zero to avoid the complication of different gestation lags for different assets as is done in much of the growth accounting literature. Hopefully, future research will shed further light on this issue.

average rate of 25 percent; in a later paper (1986), they estimate a range from 11 to 26 percent.[22] For advertising, the empirical literature finds the effects of ads to be relatively short-lived (as noted earlier) but reports a wide range of findings on the longevity of advertising capital; our own interpretation of this literature is that advertising capital depreciates by 60 percent per year.[23]

For firm-specific resources, we averaged the rates for brand equity and R&D. As just described, the firm-specific resources category has two components. On the one hand, the discernible and direct link between employer-provided training and firm-level productivity suggests that investments in this component are long-lasting. On the other hand, investments through strategic planning and reorganization reflect business' need to constantly adapt to changing economic conditions. While such investments undoubtedly have a long-lasting "learning-by-doing" dimension (similar to that in R&D), we believe they also have a short-lived "organizational forgetting" dimension (similar to that in advertising).

For each asset, the initial capital stock was set to zero in the year shown below.

Category	Year Initial Stock Set to Zero
Computerized information	1958
R&D, scientific	1928
R&D, nonscientific	1945
Brand equity	1928
Firm-specific resources	1946

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22 The 33 percent figure is the double-declining balance rate for BEA's assumed service life of five years for own-account software, calculated as 1.65/5. This ratio was originally developed by Hulten and Wykoff (1981).

23 We concluded that advertising had a service life of less than 3 years based on work by Landes and Rosenfield (1994) who estimated implied annual geometric rates of decay of advertising for 20 two-digit SIC industries covering manufacturing and many services. The Landes-Rosenfield findings also generated our conclusions on the amount of advertising that should be expensed (about 40 percent; see footnote 21 in CHS).

The literature is not settled on these issues. Some find that all (Comanor and Wilson 1974) or a higher fraction (Hall 1981) of advertising expenditures should be expensed, while others suggest that little or no expensing is appropriate (Lev 2001). Yet another econometric study found the durability of advertising capital to be as high as 7 years (Ayanian 1983).

The assumption that initial capital stocks are zero (rather than an unknown positive value) has little effect on our growth accounting analysis because all of the depreciation rates are relatively high and the true value of the benchmark will have depreciated away by the date that we start our growth accounting analysis (1973).

Table 3 shows our estimate of the nominal intangible capital stock in 2003 (in billions of dollars) and the annual average growth rate of real intangible capital in the 1973-1995 and 1995-2003 periods.[24] In terms of the components of intangible capital, over the period from 1973-95, nonscientific R&D capital is the fastest growing new category of intangibles; over the period from 1995-2003, computerized information is the fastest growing category. In both periods, scientific R&D is the slowest growing category.

C. The User Cost of Intangible Capital

The SOG model (2e) requires both the growth rate of intangible capital and its income share. In order to estimate the income share, it is first necessary to estimate the user cost $P^R(t)$ associated with each type of intangible capital. The standard expression for the user cost of any asset was derived by Jorgenson (1963) and extended by Hall and Jorgenson (1967) to include taxes. The Jorgensonian user cost for intangibles is given by the expression

(6) $$P^R_i(t) = [r(t) + \delta_i - \pi_i(t)]\, P^N_i(t),$$

where r(t) a measure of the net rate of return common to all capital in year t, δ_i is the depreciation rate for asset i, $\pi_i(t)$ is the expected capital gain (loss) on asset i, and $P^N_i(t)$ is the intangible

[24] As indicated in Table 2, two components of innovative property (mineral exploration and a portion of architectural design services) are already included in the NIPAs and are not included as intangibles in Table 3; thus, we are implicitly counting them as tangible assets in the growth accounting results that follow. We left them as categorized by the BEA to simplify the presentation; in any case, these categories are small enough that reclassifying them would make little difference in the sources of growth analysis.

investment price deflator. Except for the real net rate of return r(t), each term on the right-hand side of this expression can be calculated for each new intangible asset from the data described above, with the capital gain term proxied by the three-year moving average of the nonfarm business price deflator. We include the usual Hall-Jorgenson tax terms in our actual calculations although they are not shown in (6) for simplicity of exposition. We estimate the net rate of return r(t) using the procedure developed in Jorgenson and Griliches (1967) that solves for the common value of r(t) in each year that causes the accounting identity in equation (5) to hold for all types of capital, intangible and tangible.[25]

D. Output Measures and Income Shares

The next link in completing the data needed for the SOG equation (2e) is the estimation of output and the associated income shares. Following equation (2d), nominal output in the nonfarm business sector is the sum of our estimates of current dollar intangible investment, $P^N(t)N(t)$, and deliveries of consumption and tangible investment to final demand, $P^C(t)C(t) + P^I(t)I(t)$. The income shares follow immediately by dividing each element on the right-hand side of (2d), $P^L(t)L(t)$, $P^K(t)K(t)$,and $P^R(t)R(t)$ by the value of output. These shares are shown in the last column of table 3 for the periods 1973-95 and 1995-2003.

[25] It is worth emphasizing that the Jorgenson-Griliches procedure for estimating the rate of return results in a common rate of return to both tangibles and intangibles. This assumes that businesses arbitrage their investments across all types of capital, investing in each type until the rate of return for all assets is equal. While this assumption about investment may be disputed by Schumpeterians, we believe that it is the logical starting point for incorporating intangibles into the sources-of-growth analysis because it treats intangibles symmetrically with the way tangibles are treated in the existing SOG literature. In particular, it is symmetric with the way the official SOG estimates are constructed by the BLS. We also note that, as of this writing, the required BLS data extend through 2002. Following Oliner and Sichel, we use a regression equation to project r(t) for 2003; explanatory variables include two lags of r(t), inflation in the nonfarm business sector, the acceleration of real output in the nonfarm business sector, the unemployment rate, and the profit share.

To highlight how the accounting differs when intangibles are counted as investment, table 4 shows the elements of the income identity $P^Q(t)Q(t) = P^L(t)L(t) + P^K(t)K(t) + P^R(t)R(t)$, along with the associated shares. As can be seen in the memo items, including all intangibles lowers the labor share of income from about 70 percent to 60 percent and raises the capital share (the sum of lines 12 and 13) from about 30 percent to 40 percent. Note that intangibles account for 37.5 percent of all capital income (line 13 as a share of line 12 plus line 13).

The full time series of the new labor share is provided in figure 3. The lowering of the labor share is one of the more startling results of the "new view" of intangibles. Not only is labor's share significantly lower when *all* intangibles are capitalized, the "new" share is no longer constant (as it appeared to be before software was capitalized). Rather, the new share trends downward over the past five decades, particularly since 1980. The growing wedge between the old and new views of labor's share reflects the fact that an increasing fraction of capital income has been associated with intangibles.[26]

To obtain an index of real output growth including the new intangibles, we aggregate the existing real nonfarm business output and the real investment series for each of the new categories of intangible assets, $P^N_i(t)N_i(t)$, using a Divisia index procedure.[27] The result is the growth rate of output $g_Q(t) = s_C(t)g_C(t) + s_I(t)g_I(t) + \Sigma_i\, s_{Ni}(t)g_{Ni}(t)$. This is the final data series needed to complete the SOG analysis.

[26] This income appears in the first column of table 4 (and on the income statements of companies in the economy) as retained earnings. Additions to retained earnings translate into a long-run increase in national wealth as corporate share values increase. To the individual investor, it appears as an increase in personal wealth from stocks, pensions, insurance, etc.

[27] Because nominal business investment for each of the new intangible assets is deflated with the nonfarm business deflator, Divisia aggregation and fixed-weight (or simple sum) aggregation yield the same series for real nonfarm business output including business investment in intangible assets.

IV. Growth Accounting Results

The estimates of Section III provide the elements needed to construct growth accounts with intangibles. We can then compare the SOG models with and without intangibles (equations 1e and 2e of Section II). The SOG results are shown in Table 5 for two periods, 1973-1995 and 1995-2003, which were selected in order to analyze the role played by intangible investments in the productivity pick-up that is usually dated from 1995 in the recent SOG literature.[28]

The top panel in Table 5 presents the growth accounts based on equation (1e), the SOG without any intangibles.[29] These results are based on BLS estimates of the growth of labor productivity in the nonfarm business sector, from which we have excluded software.[30] The estimates provide the baseline for comparison with SOG estimates based on equation (2e) with intangibles, shown in the bottom panel of Table 5. A number of conclusions can be drawn from a comparison of the two panels. First, it is apparent that the capitalization of intangibles increases the rate of growth of output per hour in both the 1973-1995 and 1995-2003 periods. Interestingly, the increase in growth rates relative to the baseline is largest in the earlier period (20 percent) compared with the second (11 percent). However, it is worth noting that the second period covers both the technology boom and the subsequent technology bust. Estimates that refer only to the

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[28] The figures here follow the methodology described above, which also coincides with that used by the BLS to produce their estimates of multifactor productivity growth. For a description of their methodology, see BLS (1983).

[29] The figures in table 5 and throughout the paper do not incorporate the 2005 annual revision of the NIPAs.

[30] The items listed under the heading 'Contribution of Components' are the growth rate of each input weighted by the corresponding income share. In moving from one formulation to the other, we make appropriate adjustments to the income shares. As of this writing, BLS's published estimates extend through 2002, and we only had to estimate one year. This was done using the procedure developed in Oliner and Sichel (2000, 2002).

1995-2000 period would show a greater influence of intangible investments on labor productivity growth. The dependence of growth accounting estimates on the period of analysis, and particularly on the endpoints, is a well-known characteristic of this type of analysis.

Second, the relative importance of the factors “explaining” growth changes significantly when intangibles are introduced. In the first period, the portion of top-line growth explained by intangibles goes from 0 percent in the top panel (by definition) to 26 percent with them, and the corresponding numbers for the 1995-2003 period are 0 percent and 27 percent, respectively. Moreover, intangibles moved up to parity with tangible capital in its importance as a source of growth during the second period. Put another way, capital plays a larger role in accounting for labor productivity growth once intangibles are included. In the earlier period, capital accounted for 59 percent of labor productivity growth when intangibles are included, but only 44 percent when they are excluded. In the latter period, the difference is even greater, with capital accounting for 54 percent of growth when intangibles are included but only 35 percent when they are excluded.

Third, a comparison of MFP growth rates reveals that this source of growth declines both in absolute and relative importance when intangibles are included as investment. This is most pronounced for the second period, during which the average annual growth rate of MFP drops from 1.42 percentage points under the “old” view to 1.08 percentage points when intangible investments are included in the analysis. Expressed as a fraction of the rate of growth in output per hour, MFP declines in importance from 51 percent to 35 percent. This result is not particularly surprising in light of Jorgenson and Griliches (1967) and in view of the fact that MFP is measured as a residual.

Fourth, one thing that cannot be claimed for the "new" view is that intangibles affected the size of the mid-1990s pick-up in labor productivity itself. The third column in both panels shows the percentage-point acceleration in each SOG factor between the two periods. It is apparent that the size of the acceleration in labor productivity in percentage points was virtually the same in both panels.

Fifth, the source of the mid-1990s acceleration in labor productivity does change when intangibles are included. In the top panel, the acceleration in MFP accounts for two-third of the total pickup when intangibles are excluded, but accounts for less that half in bottom panel when intangibles are included. Correspondingly, the role of capital in the acceleration of labor productivity is considerably larger when intangibles are included.

In sum, the results shown in Table 5 strongly suggest that intangibles matter not just for national income and wealth accounting, but for growth accounting as well. Indeed, our estimates, rough as they may be, imply that the traditional practice of expensing intangibles results in a seriously distorted picture of the sources of growth.

Table 6 continues the SOG of Table 5 by disaggregating line 6 of that table's lower panel into the separate components shown in Table 1. It is probably not surprising that computerized information (software) is an important factor driving the growth of the total intangible variable in Table 5, but it is perhaps more surprising that firm-specific resources are found to be of equal importance. The rather small role of scientific R&D also is surprising in light of the attention that R&D has been given in the literature on innovation. Scientific R&D accounts for only a modest portion of total intangible capital deepening and is markedly less important than investment in software.[31] It also worth noting that the non-traditional types of intangibles highlighted in this paper – nonscientific R&D, brand equity, and firm-specific resources – together account for nearly 60 percent of total intangible capital deepening since 1995. Because software is already capitalized in the NIPAs, and scientific R&D will probably be sometime over the next decade, our results suggest that growth accountants should not lose sight of these other forms of intangible capital.

This paper highlights the importance of intangibles as a source of economic growth. However, because software is already included in published growth accounts, another question is relevant: how much impact would the capitalization of the other intangibles have on published growth rates? Table 7 addresses this question by showing estimates for the nonfarm business sector, including software but not the other intangibles, for periods shown in Tables 5 and 6. A comparison of the top-line result in Table 7 with the corresponding estimate on line 1 in the lower panel of Table 5 indicates that the growth rate of output per hour is not greatly increased by the inclusion of the other intangibles from 1995-2003 (2.95 percent versus 3.09 percent). However, the composition of the sources of growth is affected, with a significantly greater role for capital deepening with full accounting for intangibles and a proportionately smaller role for MFP. Again, the capitalization of intangibles matters for the understanding of economic growth.

[31] This result hinges, at least in part, on our assumption that the nonfarm business output price is an appropriate deflator for scientific R&D. If we followed the R&D literature and used a deflator with a wage component, the result that scientific R&D played a relatively small role in accounting for recent U.S. economic growth would be, if anything, stronger. On the other hand, if the deflator for ICT investment were used instead (as suggested by Mairesse and Kosoglu 2005), we would find that scientific R&D played a more important role.

V. Conclusion: It's the Knowledge Economy

The rapid expansion and application of technological knowledge in its many forms (research and development, capital-embodied technical change, human competency, and the associated firm-specific co-investments) is a key feature of recent U.S. economic growth. Accounting practice traditionally excludes the intangibles component of this knowledge capital and, according to our estimates, excludes approximately $1 trillion from conventionally measured nonfarm business sector output by the late 1990s and understates the business capital stock by $3.6 trillion. The current practice also overstates labor's share of income by a significant amount and masks a downward trend in that share. Our results also suggest that the inclusion of intangibles both as an input and as an output can have a large impact on our understanding of economic growth. We have found that the inclusion of intangible investment in the real output of the nonfarm business sector increases the estimated growth rate of output per hour by 10 to 20 percent relative to the base-line case which completely ignores intangibles. Thus, the inclusion of intangibles matters for labor productivity growth rates, although it has little effect on the acceleration of productivity in the 1990s. On the input side, intangibles reached parity with tangible capital as a source growth after 1995, and when the two are combined, capital deepening supplants MFP as the principal source of growth. Moreover, the majority of the contribution of intangibles comes from the non-traditional categories of intangibles identified in this paper.

It is also worth noting that the fraction of output growth per hour attributable to the old "bricks and mortar" forms of capital investment (labeled "other tangible" capital in the lower panel of table 5) is very small, accounting for less that 8 percent of the total growth in the period 1995-2003. While it is inappropriate to automatically attribute the other 92 percent to "knowledge capital" or "the knowledge economy," it is equally inappropriate to ignore the association between innovation, human capital, and knowledge acquisition, on the one hand, and investments in intangibles, IT capital, labor quality change, and multifactor productivity, on the other.

That intangibles, and more generally, knowledge capital should be such an important driver of modern economic growth is hardly surprising, given the evidence from every day life and the results of basic intertemporal economic theory. What is surprising is that intangibles have been ignored for so long, and that they continue to be ignored in financial accounting practice at the firm level. The results presented this paper are intended to illustrate the potential magnitude of the bias arising when they are excluded from economic growth accounting. In the process, we have been forced to make a host of assumptions about many empirical issues, in order to measure such items as output deflators and non-market inputs like firm-specific organization and human competencies. Further research will undoubtedly find better ways to deal with these issues, and future data collection efforts will evolve to fill the gaps that this paper only traverses lightly. However, while our results are clearly provisional, we are also mindful of the famous dictum of John Maynard Keynes that it is better to be imprecisely right than precisely wrong.

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Table 1
Business Intangibles: Total Spending and Capital Spending, 1998-2000
(billions of dollars, annual average)

Type	**Total spending**	**Comments on evidence as capital spending**	**Capital spending (incl. in the NIPAs)**
1. Computerized information (mainly computer software)	154	Firms capitalize only a fraction of purchased software in financial accounts. Relatively little is known about the service life of software assets.	154 (151)
2. Innovative property (a) Scientific R&D	201	Research suggests that scientific R&D yields relatively long-lasting returns and is capital spending.	201 (16)
(b) Nonscientific R&D	223	Little is known about nonscientific R&D, but a portion of new product development expenditures in the entertainment industry apparently have relatively short-lived effects.	223 (40)
3. Economic competencies (a) Brand equity	235	Research shows that the effects of some advertising dissipate within one year, but that more than half has effects that last more than one year.	140
(b) Firm-specific resources	407	Research suggests that firm-specific training is investment. Spending for organizational change also likely has long-lived effects, but a portion of management fees probably is not capital spending.	365
Total	1,220		1,085 (205)
Percent of Existing GDP			11.7
Ratio to Tangible Capital Spending			1.2

NOTE—Components may not sum to totals because of rounding.
SOURCE—Corrado, Hulten, and Sichel (2005), table 4. Estimates are based on a one-year service life cutoff for determining capital spending.

Table 2
Business Investment in Intangibles
(billions of dollars, annual average for period shown)

	1950-59	1960-69	1970-79	1980-89	1990-99	2000-03
	(1)	(2)	(3)	(4)	(5)	(6)
1. Total CHS intangibles	19.4	41.9	103.4	349.3	749.8	1,226.2
2. Computerized information (mainly computer software)	--	.8	4.5	23.2	85.3	172.5
3. Innovative property						
(a) Scientific R&D	7.7	16.9	34.0	104.6	157.7	230.5
(b) Nonscientific R&D	.5	1.7	10.9	58.4	145.2	237.2
4. Economic competencies						
(a) Brand equity	5.3	9.5	18.2	54.4	105.7	160.8
(b) Firm-specific resources	5.9	13.0	35.7	108.7	255.9	425.1
Related series[1]						
5. Computer software, NIPAs	--	.7	4.5	22.7	83.6	169.6
6. Industrial R&D, NSF[2]	5.2	14.1	25.3	75.8	136.9	196.0
7. Advertising, Coen report	8.6	15.0	30.6	89.6	165.0	240.3
8. Business fixed investment, NIPAs	38.2	71.5	188.4	485.7	807.1	1,141.9
8a. Tangibles	35.6	67.3	171.4	421.1	676.5	893.4
8b. Intangibles[3]	2.5	4.2	17.0	64.6	130.7	248.5
Memo:						
9. CHS intangibles, ratio to NIPA tangibles	.47	.62	.60	.82	1.10	1.36
10. New CHS intangibles[4]	16.9	37.7	86.3	284.7	619.2	977.7
11. Nonfarm business output, ratio of existing to adjusted for new CHS intangibles (λ)	.95	.94	.94	.92	.90	.89

NOTE–All figures for investments in intangibles are derived using the sources and methods described in Corrado, Hulten, and Sichel (2005), or CHS, based on a one-year service life cutoff.

1. Sources indicated are as follows: NIPAs, the U.S. National Income and Product Accounts; NSF, the National Science Foundation; and Coen report, advertising data developed by Bob Coen for Universal-McCann (see http://www.universalmccann.com/ourview.html).
2. Prior to 1953, the industrial R&D estimates are from N. Terleckyj (1963).
3. Includes computer software, mineral exploration, and architectural and design services embedded in structures and equipment purchases.
4. Intangibles not recognized as capital in the NIPAs.

Table 3
Value, Growth Rate, and Income Share of Business Intangible Capital

	Value, billions of dollars	Growth rate of real capital[1] (percent change)		Share of total income (percent)	
	2003	1973-1995	1995-2003	1973-1995	1995-2003
1. Total	3636.1	6.2	6.9	9.4	13.9
2. Computerized information (includes software)	511.9	16.0	13.0	.8	2.3
3. Innovative property					
3a. Scientific	922.3	3.6	3.9	2.4	2.5
3b. Nonscientific	864.4	12.4	7.2	1.0	2.2
4. Economic competencies					
4a. Brand equity	271.8	4.2	4.6	1.7	2.0
4b. Firm-specific resources	1065.6	5.3	6.2	3.5	5.0
Memo:					
5. New CHS intangibles	3132.9	4.7	4.6	8.6	11.7

1. The rates of change for the total and major categories are built from the individual real stocks using asset-specific user costs as price weights.
SOURCE—Authors' calculations.

Table 4
Value of Output and Inputs, Nonfarm business sector, 2000-2003
(annual average, billions of dollars)

	Conventional, without Intangibles Equation (1d)	This paper, with Intangibles Equation (2d)
1. Conventional nominal output ($P^C C + P^I I$)	7670	7670
2. + Intangible Investment ($P^N N$)	0	1206
3. = Nominal output	7670	8876
4. - Indirect business taxes[1]	736	736
5. - Statistical discrepancy	-52	-52
6. = Total income	6986	8192
7. Total income	6986	8192
8. = Labor compensation ($P^L L$)	4915	4915
9. + Income Accruing to Tangible Capital ($P^K K$)[2]	2071	2046
10. + Income Accruing to Intangible Capital ($P^R R$)	0	1231
Memo: Shares out of total income (percent)		
11. Labor compensation (8)/(7)	70.4	60.0
12. Tangible capital (9)/(7)	29.6	25.0
13. Intangible capital (9)/(7)		15.0

NOTE. The figures in this table are consistent with those used by the BLS in putting together its multifactor productivity estimates for the nonfarm business sector. The figures in the first column, however, exclude software, and thus nominal output (line 3) and total income (line 7) are lower by NIPA estimates for software spending by nonfarm businesses.
1. Estimates of indirect business taxes for the nonfarm business sector (now known as taxes on production and imports) were inferred, given figures for lines 3, 5, and 6.
2. The figure for income accruing to tangible capital in the second column differs from that in the first column because the net rate of return—the term r(t) in equation (6)—changes slightly when intangibles are included.

Table 5
Annual Change in Labor Productivity,
Nonfarm Business Sector

Published data, excluding software

	1973-1995	1995-2003	*Memo*: Accel.[2]
1. Labor productivity (percent)[1]	1.36	2.78	1.42
Contribution of Components:[2]			
2. Capital deepening	.60	.98	.38
3. IT equipment	.33	.70	.37
4. Other tangible capital	.27	.28	.01
5. Labor composition	.28	.38	.10
6. Multifactor productivity	.48	1.42	.94

Published data, including business investment in intangibles

	1973-1995	1995-2003	*Memo*: Accel.[2]
1. Labor productivity (percent)[1]	1.63	3.09	1.45
Contribution of Components:[2]			
2. Capital deepening	.97	1.68	.71
3. Tangibles	.55	.85	.30
4. IT equipment	.30	.60	.30
5. Other[3]	.25	.24	-.01
6. Intangibles	.43	.84	.41
7. Software	.12	.27	.15
8. Other (new CHS)	.31	.57	.26
10. Labor composition	.25	.33	.08
11. Multifactor productivity	.41	1.08	.67

1. Output per hour of all persons.
2. Percentage points. Components may not sum to totals because of independent rounding.
3. Includes mineral exploration and the architectural and design services embedded in equipment purchases that are part of “CHS intangibles included in the NIPAs” in tables 1 and 2.

Table 6
Contribution of Intangible Capital Deepening to the Annual Change in Labor Productivity, Nonfarm Business Sector
(percentage points)

	1973-1995	1995-2003	*Memo:* Accel.
	(1)	(2)	(3)
1. Intangible capital deepening	.43	.84	.41
2. Computerized information	.12	.27	.15
3. Innovative property	.13	.22	.09
3a. Scientific	.05	.08	.03
3b. Nonscientific	.08	.14	.06
4. Economic competencies	.17	.35	.18
4a. Brand equity	.04	.08	.04
4b. Firm-specific resources	.13	.27	.14

NOTE—Components may not sum to totals because of independent rounding.

Table 7
Annual Change in Labor Productivity,
Nonfarm Business Sector

	1973-1995	1995-2003	*Memo:* Accel.[2]
1. Labor productivity (percent)[1]	1.47	2.95	1.48
Contribution of components:[2]			
2. Capital deepening	.73	1.26	.53
3. IT equipment and software	.46	.99	.53
4. Other equip. and structures	.27	.27	.00
5. Labor composition	.27	.37	.10
6. Multifactor productivity	.47	1.32	.85

1. Output per hour of all persons.
2. Percentage points. Components may not sum to totals because of independent rounding
SOURCE—Unpublished update to Oliner and Sichel (2000, 2002) based on data from Bureau of Labor Statistics, *Multifactor Productivity Trends, 2002* (2004).

Figure 1

Investment Shares

(percent of business output)

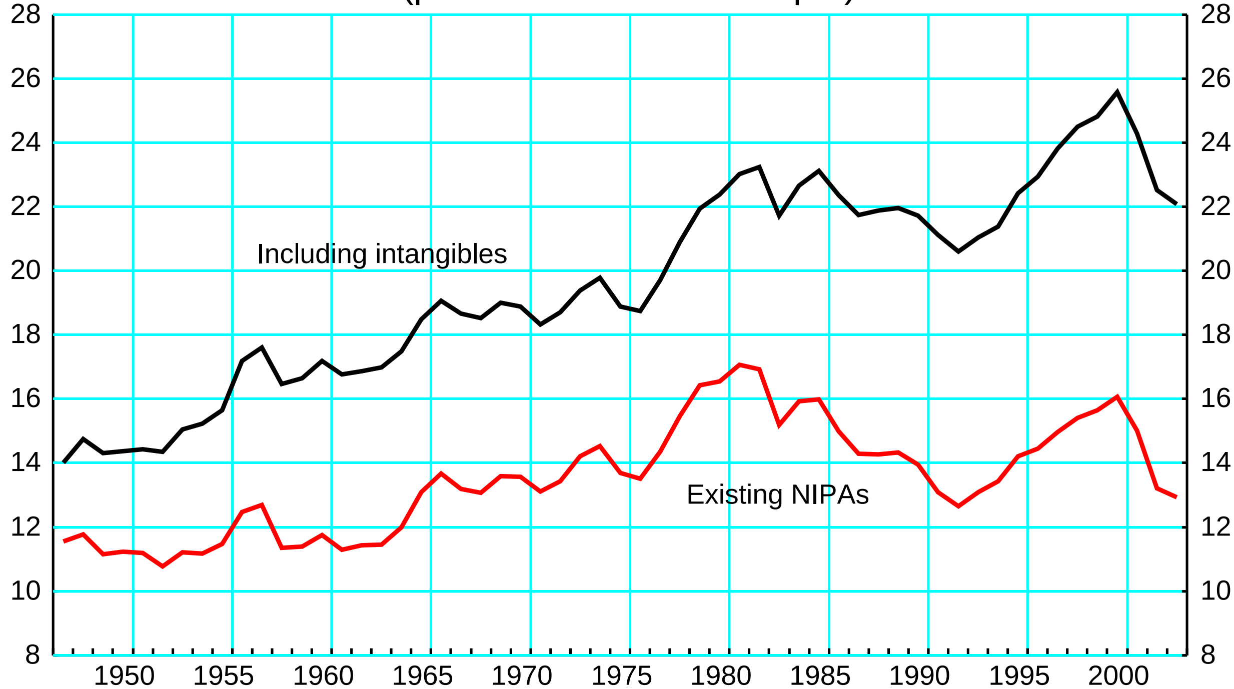
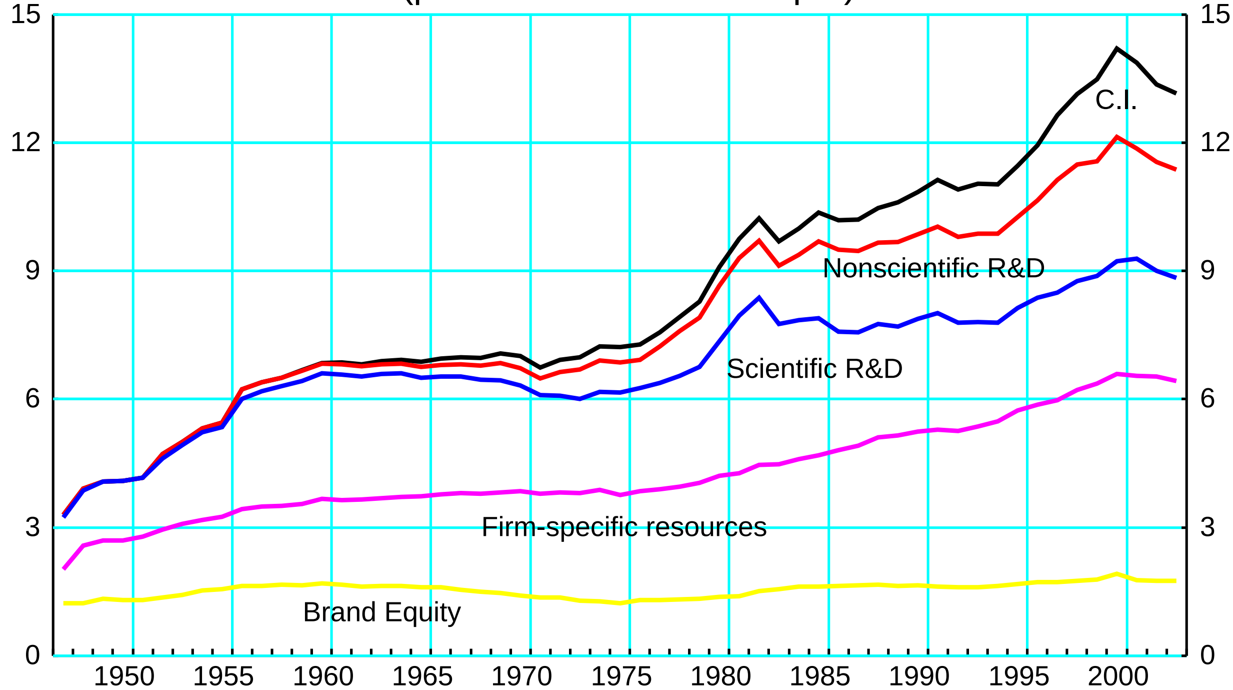


Figure 2

Intangible Investments

(percent of business output)

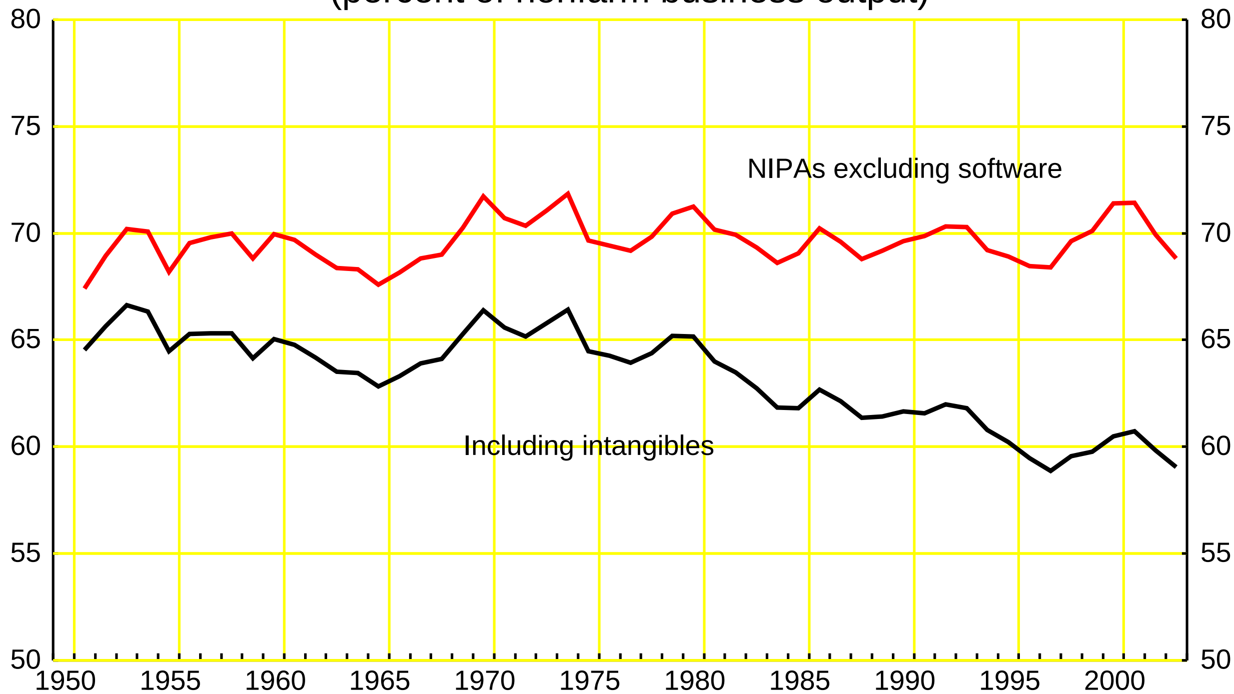


Note: C.I. = Computerized information

Figure 3

Labor Shares

(percent of nonfarm business output)



Note: BLS basis (output excludes government enterprises, labor income includes nonemployees).