1

Measuring Capital and Technology
An Expanded Framework

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1.1 Introduction and Background

The last two hundred years have witnessed dramatic gains in the standard of living in the United States, driven by the technological innovations introduced by the Industrial Revolution and carried forward by the evolution of technology since then. This evolution is reflected both in the development of new products (electric lighting, automobiles, open-heart surgery) and in the improved efficiency of production processes (the assembly line, just-in-time inventory controls, computer-aided design). Growth economists have undertaken the important task of quantifying these developments and of sorting out the relative importance of the factors that drive sustained increases in real output. This effort has increased in recent years with the debate over the "new economy" and the question of whether living standards will continue to rise at the accelerated pace of the late 1990s.

The "sources of growth" model has been the main empirical tool in tracking and explaining growth trends. This model, developed in the 1950s and 1960s by Solow (1956, 1957, 1960), Kendrick (1961), Denison (1962, 1964), Jorgenson and Griliches (1967, 1972), and others, allocates the growth rate of measured output to the growth rate of labor and capital inputs, each

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weighted by their share of output, and a residual factor associated with the efficiency with which output is produced from a given set of inputs ("total factor productivity," or TFP). A large academic literature has evolved using this framework, reviewed recently in Hulten (2001), and TFP has become an official statistic produced regularly by the Bureau of Labor Statistics (BLS). An updated version of the BLS decomposition is shown in the upper half of table 1.1, which indicates that output per hour worked rose about 1.25 percentage points per year faster since 1995 than it did during the period of lackluster growth from 1973 until then. These figures have lent support to the "new economy" view about prospective growth trends.

Although great progress has been made in applying the sources-of-growth framework to the analysis of economic growth, doubts have nevertheless been raised about our ability to understand and measure fully the fundamental sources of growth. For example, despite several decades of rapid technological advance in information technology, one of the originators of the sources-of-growth model, Robert Solow, famously remarked in 1987 that "you see the computer revolution everywhere except in the productivity data" (Solow 1987). Alan Greenspan observed about ten years later that many services industries displayed implausibly negative trends in

Table 1.1 Annual change in labor productivity, nonfarm business sector

	1948 to 1973	1973 to 1990	1990 to 1995	1995 to 2002
Labor productivity[a] (percent)	2.9	1.4	1.5	2.7
Components (percentage points)				
Capital deepening	0.8	0.8	0.5	1.3
IT equipment and software	0.1	0.4	0.5	1.0
Other equipment and structures	0.7	0.4	0.1	0.3
Labor composition	0.2	0.2	0.5	0.3
Multifactor productivity	1.9	0.4	0.6	1.1
R&D[b]	0.2	0.2	0.2	0.2
Excluding software				
Labor productivity (percent)		1.3	1.4	2.5
Components (percentage points)				
Capital deepening		0.7	0.3	0.9
IT equipment		0.3	0.3	0.6
Other equipment and structures		0.4	0.1	0.3
Labor composition		0.2	0.5	0.3
Multifactor productivity		0.4	0.6	1.3

Note: Components may not sum to totals because of rounding. IT = information technology.

Sources: Bureau of Labor Statistics, *Multifactor Productivity Trends, 2001* (2003; http://www.bls.gov/news.release/prod3.nr0.htm); unpublished update to Oliner and Sichel (2000, 2002).

[a]Output per hour of all persons.

[b]The research and development (R&D) component extends only to 2001.

measured productivity despite being among the top computer-using industries.[1] Also, Nordhaus (1997) concluded from his analysis of the history of lighting that official price and output data "miss the most important technological revolutions in history." The recent debate over the accuracy of the consumer price index (CPI) has raised similar questions: Studies have shown that the failure to capture the full effect of improvements in product quality and the benefits of new goods and services created an upward bias in the CPI of more than 0.5 percentage point (Lebow, Roberts, and Stockton 1994; Advisory Commission to Study the Consumer Price Index 1996; Shapiro and Wilcox 1996) and implied a corresponding downward bias in the rate of increase in the consumption component of total real output.

Some of the foregoing concerns can be traced to problems inherent in the data used to study economic growth, but many key data concerns have been addressed in relatively recent work at the major statistical agencies. These include, among others, the renewed emphasis on quality change in the measurement of prices at the BLS, the capitalization of software expenditures by the Bureau of Economic Analysis (BEA), and the expanded coverage of service industries by the Census Bureau. However, no parallel theoretical advance has emerged, within or beyond the sources-of-growth framework, to guide further empirical advances and tell us what we need to know to understand economic growth in the "new economy."

The first goal of this paper is to expand the conceptual framework of the sources-of-growth model by linking it to a variant of the standard model of intertemporal choice developed in Hulten (1979). In the expanded framework, the determination of what expenditures are current consumption and what are capital investment is governed by consumer utility maximization, and any outlay that is intended to increase future rather than current consumption is treated as a capital investment. When this deferred-consumption rule is applied to one of the most important "new economy" questions—whether business intangible outlays and knowledge input should be expensed or capitalized in national accounting systems—an unambiguous answer is obtained: there is no basis from the consumers' point of view for treating investments in intangible capital differently from investments in plant and equipment, or tangible capital.[2]

1. Chairman Greenspan's concerns about the measured productivity trends in services industries were first expressed in remarks at a Federal Open Market Committee meeting in late 1996 in regard to a staff analysis of disaggregated productivity trends (Corrado and Slifman 1999). A BLS study reached a similar conclusion (Gullickson and Harper 1999).

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 Triplett (1999); see also Stiroh (1998) and Bosworth and Triplett (2003).

2. The focus of this paper is on the macroeconomic debate over role of intangible capital in the growth process. There is a parallel debate in the financial accounting literature over the expensing of intangibles (Lev 2001; Blair and Wallman 2000). Although the objectives of

We then turn to the question of how much difference the theoretically appropriate treatment of intangible capital might make to the productivity estimates shown in table 1.1. Competing approaches have emerged in the current literature on the measurement of intangibles. One prominent approach uses the value of securities, primarily stocks, to infer the quantity of intangible capital held by U.S. corporations to help interpret recent changes in productivity (R. Hall 2000, 2001a,b).[3] Our work, however, follows another branch of the literature. Rather than appealing to the stock market, we pull together disparate pieces of spending data and related evidence to gauge the plausible magnitude of the additional business investment (and thus gross domestic product [GDP] and output per hour) if expenditures on intangibles, or knowledge capital, are treated symmetrically with investments in traditional fixed capital. The estimates we develop build on the studies by Nakamura and others who have examined the undervaluation of measured business investment and capital in the late 1990s (Nakamura 1999, 2001, 2003; Brynjolffson and Yang 1999; Brynjolffson, Hitt, and Yang 2002; McGratten and Prescott 2000), as well as earlier work sponsored by the Organization for Economic Cooperation and Development (OECD; OECD Secretariat 1998).

Our effort differs from previous work, however, by applying the theoretical classification and accounting principles that follow from the expanded framework we introduce in the next section. Not only does this framework lead us to cast a wider net to identify the possible components of business investment in intangibles, but it also leads us to distinguish spending flows that generate relatively long-lasting revenue streams from those whose returns dissipate too quickly to count the associated asset as fixed capital. The latter consideration has not been an explicit aspect of others' efforts to gauge the plausible undervaluation of business investment. We also are careful to separate assets that are already included in the national accounts from those that are not.

All told, our framework for the economic measurement of capital suggests that, if business intangibles are fully recognized in national accounting systems, the move will significantly change measures of economic activity. We estimate that business spending on long-lasting knowledge capital—including intangibles broadly—grew relative to other major components of aggregate demand during the 1990s. As a result, our estimates show that, by the end of the decade, business fixed investment in intangibles was at least as large as business investment in traditional, tangible

growth accounting differ from those of financial accounting, the macroeconomic symmetry principle applies at the firm level as well.

3. The link between productivity and stock market performance has been examined in earlier literature (e.g., Baily 1981; B. Hall and R. Hall 1993), and financial data have long been used to value R&D and patent assets to construct intangible stocks at the firm level (e.g., Griliches 1981; Cockburn and Griliches 1988; B. Hall 1993).

capital. When the unrecognized portion of this spending is viewed in relation to existing measures, our framework portrays the U.S. economy as having had higher gross private saving and, under plausible assumptions, fractionally higher average annual rates of change in real output and real output per hour, particularly from 1995 to 2002.

1.2 Theory

1.2.1 The Production Function Approach to Growth Accounting

Contemporary growth accounting is organized around the concept of the aggregate production function. Aggregate real output is assumed to be related to inputs of labor and capital via an aggregate production function, with provision for changes in the productivity of the inputs. When efficiency change has the Hicks-neutral form, the production function can be expressed as

$$Q_t = A_t F(K_t, L_t), \tag{1}$$

where Q_t denotes real output, K_t and L_t are capital and labor, and A_t is an index of the level of TFP. In econometric studies of growth, the production function is given a specific parametric form, and the parameters of $F(\cdot)$ are then estimated using a variety of techniques. In the index-number (nonparametric) approach of Solow (1957) and Jorgenson and Griliches (1967), the growth rate of output is equal to the shared-weight growth rates of labor and capital:

$$g_Q = s_K g_K + s_L g_L + g_A. \tag{2}$$

(The g terms are growth rates, and the s terms are factor shares.) Under constant returns to scale and marginal-cost pricing, Solow showed that the factor shares are equivalent to output elasticities, and the term g_A was associated with a shift in the production function in equation (1) (illustrated as the move from a to c in figure 1.1), while $s_K g_K + s_L g_L$ was a movement along the function (c to b in the figure). Each item in equation (2) can, in principle, be estimated from national accounting data, except for the growth rate of TFP, g_A, which must be inferred as a residual—Abramovitz's famous "measure of our ignorance."

The sources-of-growth equation is the basis for the estimates in table 1.1, which are expressed in labor-productivity terms: $g_Q - g_L = s_K(g_K - g_L) + g_A$.[4] The estimates in this table highlight the slowdown in productivity growth in the early 1970s and the pickup in the mid-1990s. The table also reveals the important role played by TFP in these swings in productivity growth.

4. This variant follows from equation (2) under constant returns to scale, in which case $s_K + s_L = 1$ and g_L is subtracted from both sides of the equation.

The acceleration in labor productivity since 1995 has generated the "new economy" view that the U.S. economy has entered an era of higher productivity growth. As can be seen in the table, the 1.25 percentage point improvement in labor productivity growth after 1995 was driven both by a pickup in TFP and by the increased capital deepening of information technology (IT) equipment and software.[5]

The potential importance of investment in intangible assets is borne out by the lower panel of table 1.1, in which the sources of growth estimates exclude the effect of capitalized software (i.e., they exclude investment in software as a component of both output and capital input). Here the pickup in labor productivity growth is seen to be only about 1 percentage point, about one-quarter percentage point less than when software is included.

These results for software point to the potential importance of capitalizing other intangibles, like R&D. In the treatment shown in the upper panel of table 1.1 (the part taken from the BLS release), R&D is added as a "memo" item explaining a portion of the residual; it does not play an explicit role as a capital input. Unfortunately, the traditional sources-of-growth framework treats capital and labor inputs as determined outside of the framework and therefore does not provide guidance as to whether to treat R&D as a memo item or as an investment good and thus as part of output. This problem is addressed in the following section by embedding the sources-of-growth framework in a more complete dynamic model in which investment decisions are made explicit. Our extended framework shows that no basis exists for treating intangible capital differently from traditional forms of fixed capital. Indeed, the asymmetrical treatment of the two types of capital could have the effect of suppressing some of the most dynamic factors driving economic growth.[6]

1.2.2 Capital in a Complete Model of Economic Growth

The sources-of-growth model, derived from the production function as illustrated in figure 1.1, evolved as a period-by-period analysis of the factors determining output along the growth path of an economy. This model treats capital as predetermined and cannot fully describe the growth process because saving and investment are choice variables in a complete model of growth. Not only is this choice dimension important because it determines the quantity of capital available at each point in time, but it also determines what should be counted as capital. The answer to the question

5. Table 1.1 shows data on actual productivity growth through 2002. Because the table shows actual data, the averages shown over selected periods reflect changes in factor utilization as well as the underlying trend pace of growth.

6. Our analytical framework also highlights the shortcomings of the prevailing view in the accounting literature. Despite some dissenting views (e.g., Lev 2001), this literature holds that intangible investments should be expensed and not capitalized.

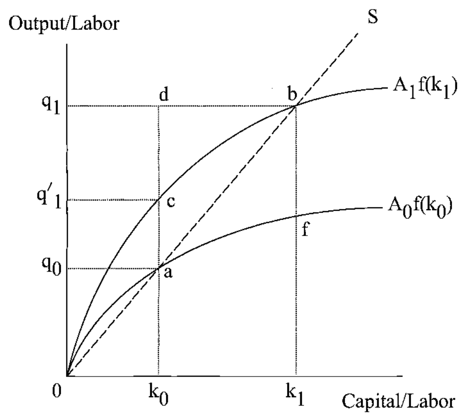

Fig. 1.1 The production function

of whether intangibles should be treated as capital is therefore a matter of embedding the production function–based sources-of-growth analysis in a larger model of economic growth.

Several options are available in this regard: the neoclassical growth model, the endogenous growth model, and optimal-growth theory. The latter is the most suitable because it deals directly with consumer saving behavior. We will therefore work with the variant of this model used in Hulten (1979) to endogenize capital in an expanded growth-accounting framework. Following standard intertemporal capital theory, we assume that optimal consumption in each period is determined by the maximization of an intertemporal utility function $U(C_1, \ldots, C_T)$ subject to (a) the constraints of the technology represented by the production function in equation (1); (b) the capital accumulation equation expressed in its "perpetual inventory" form as

$$K_t = I_t + (1 - \delta) K_{t-1}, \tag{3}$$

where δ is the rate of depreciation; (c) the constraint that the production of consumption and investment goods cannot exceed total output in any period

$$p_t^Q Q_t = p_t^C C_t + p_t^I I_t = p_t^L L_t + p_t^K K_t \tag{4}$$

(this expression also serves as the annual product and income account of the "economy" portrayed by this model, which for simplicity is assumed closed); (d) the exogenously given initial and terminal quantities of capital, K_0 and K_T; and (e) the initial level and paths of labor input and TFP (and thus g_L and g_A), which are all given. The resulting solution determines the path of consumption over time $\{C_t^*\}$, as well as the paths of investment and capital stock. In view of equation (4), the optimal path $\{C_t^*\}$ determines how output is divided between the production of consumption and investment goods and therefore is relevant to how intangibles ought to be treated.[7]

For purposes of exposition, we can restate the constraints on the optimization in a more compact form.[8] The production function $C_t + I_t = A_t F(K_t, L_t)$, the initial and terminal stocks of capital K_0 and K_T, the accumulation condition $K_t = I_t + (1 - \delta)K_{t-1}$, and the paths of A_t and L_t, can be expressed in equivalent form as

$$(5) \qquad \Phi(\{C_1, \ldots, C_T\}; \{L_1, \ldots, L_T\}; \{A_1, \ldots, A_T\}; K_0, K_T) = 0.$$

This is the intertemporal production possibility frontier, which indicates all combinations of the consumption vector $\{C_1, \ldots, C_T\}$, including the optimal vector, that are possible given the vector of labor input, technology levels, and the initial and terminal stocks of capital. This form of the constraint reveals the endogenous role of capital in the growth process. Capital largely disappears when the constraints are expressed in this form, and it disappears altogether if the initial and terminal stocks of capital happen to be zero.

The solution to the intertemporal optimization problem is shown graphically in figure 1.2 for the case of two time periods. The feasibility constraint Φ is represented by the curve AB, and the intertemporal utility function $U(C_1, \ldots, C_T)$ is represented by the curves UU and U′U′. The optimal consumption plan is represented by the point a, and this point defines the maximum wealth of the economy. The line WW indicates the level of this wealth and has the form

$$(6) \qquad W_{0,T} = \frac{\sum (p_t^C C_t^*)}{(1 + i)^t}, \; t = 1, \ldots T.$$

In equation (6), the nominal rate of discount, i, is assumed to be constant over time for simplicity of exposition, and the initial and terminal stocks of capital are set to zero. The optimal point, a, is an explicit function of labor input and level of technology in each period. Capital is implicit in the optimal solution, because $A - C_1$ units of consumption are forgone in period 1, and the resources freed up by this abstinence are used to make capital goods, which are then used up in production in period 2. Capital is, in effect, an intermediate intertemporal good.

The relative roles of capital formation and technical change can be explored using the following thought experiment: What would have been the

7. The Solow-Swan neoclassical growth model (Solow 1956; Swan 1956) provides an alternative description of how output is split between consumption and investment. In that model, investment is assumed to be a fixed proportion of output ($I_t = s_I Q_t$). A different growth path emerges when output is split between consumption and investment according to this rule, but the general conclusion about intangible capital obtained in this section still holds.

8. We also ignore the complication of chain weighting to keep the exposition simple.

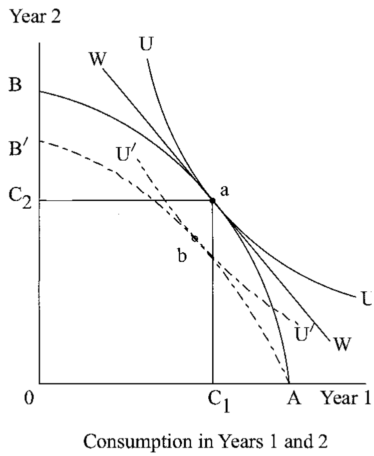

Fig. 1.2 The intertemporal framework

outcome had technology not increased from AB′ to AB, with labor held constant? The production possibility frontier in the case of zero technical change is shown as the curve AB′, and the optimal solution as b. The effect of capital formation on the optimal consumption plan (in the absence of technical change) is represented by the notional jump from A to b, and the effect of technical change (including the effect of the induced capital accumulation) as the jump from b to a. The latter is the "wealth effect" of technical change much discussed in recent years, but note that it arises only from *unexpected* increases in the level of technology. Expected increases in technology are already embedded in the long-run consumption plan of the optimizer (that is, C_t is invariant to expected technical change).

1.2.3 Implications of the Intertemporal Framework for Defining and Measuring Capital

The simple intertemporal framework of figure 1.2 has an important implication for the treatment of intangible capital in a set of economic accounts. Figure 1.2 makes clear that *any* use of resources that reduces current consumption in order to increase it in the future (for example, the movement along AB from the point A on the horizontal axis to the optimal point a) qualifies as an investment. Figure 1.2 thus argues for symmetric treatment of *all* types of capital; that is, in national accounting systems, investments in knowledge capital should be placed on the same footing as that of investments in plant and equipment. This requirement is of rather broad scope. It includes all investments in human capital (not just outlays by government and not-for-profit institutions on education), research and development expenditures, and indeed any expenditure in which a business devotes resources to projects designed to increase future rather than current output, whether it is intangible or tangible.

Financial accounting practice continues to ignore this principle, and national income and wealth accounting is only just beginning to incorporate it into practice. Of course, many practical difficulties arise in implementing the symmetry principle, and these difficulties are one reason that financial accountants prefer to expense intangibles. Much intangible capital investment occurs within the company, household, or government unit that has the intellectual property right to the capital, and no arm's-length valuation of the investment exists. Moreover, the appropriability of property rights and the spillover of externalities also present problems. However, practical difficulties do not invalidate the underlying theoretical principle of symmetry. From a conceptual standpoint, it does not matter at all whether an asset is self-constructed or not, nor does the presence of externalities or market pricing power matter in the theoretical framework of figure 1.2: the intertemporal utility function is based on the final result of the production process—consumption. The consumption possibility frontier $\Phi(\cdot)$ incorporates all externality effects, monopolistic market structures, and self-constructed assets. No theoretical basis exists for treating one type of capital differently from another simply because one type is harder to measure accurately.

Some of the practical difficulties will become apparent in section 1.3 of this paper, in which we attempt to estimate the magnitude of some of the main types of business intangible investments. However, before turning to this task, we will review some of the main implications of our theoretical analysis for national economic accounting.

1.2.4 Implications of Symmetry for Economic Accounting

The symmetry principle implies that the production function, as formulated in equation (1), is an incomplete representation of the production possibilities of an economy and must be expanded to accommodate the input and output of intangibles. Written in implicit form, the expanded production function can be expressed as

$$F(C_t, I_t, N_t; L_t, K_t, R_t, A_t^*) = 0, \tag{7}$$

where investment in intangibles is denoted by N_t; the accumulated stock of intangibles (adjusted for depreciation) is denoted by R_t; and the asterisk on the efficiency term, A_t^*; distinguishes it from the term in equation (1). The intertemporal production possibility frontier also must be reinterpreted in terms of the expanded concept of capital and correctly specified efficiency term.

The reformulation of the production possibility set has implications for the construction of national accounts and the accounting for economic growth. The GDP identity in equation (4) treats most intangibles as intermediate inputs in which the value of the spending, $p_t^N N_t$, is just matched by the value produced each period (ignoring foreign trade). As a result, the two flows cancel, and aggregate GDP is unaffected by the size and relative growth of $p_t^N N_t$. When an intangible asset is reclassified as fixed capital, the value of the spending is treated as an addition to GDP, and $p_t^N N_t$ is added to the left-hand side of the GDP identity, equation (4).

An adjustment must also be made to the input side of the GDP identity. When intangible capital is treated as a capital input, its user cost value, $p_t^R R_t$, is added to the right-hand side of equation (4). When both the user cost value and the investment value of intangibles are included in GDP, the national accounting identity becomes

$$p_t^C C_t + p_t^I I_t + p_t^N N_t = p_t^L L_t + p_t^{K*} K_t + p_t^R R_t. \tag{8}$$

For simplicity of exposition, we assume that the $p_t^I I_t$ and $p_t^{K*} K_t$ refer exclusively to tangible capital, whereas the U.S. national accounts include some intangibles in I_t. The notation p_t^{K*} denotes the user cost of tangible capital input when intangibles are recognized as in equation (8). It differs from the corresponding user cost in equation (4), which may include income from intangible capital. The two user costs are connected by the expression

$$p_t^K K_t = p_t^{K*} K_t + p_t^R R_t - p_t^N N_t. \tag{9}$$

This expression not only indicates that the conventional measure of capital income has a potential bias, but it also reveals an important feature of the expanded accounts. The symmetry principle indicates that the value of intangible production, $p_t^N N_t$, must be added to the conventional GDP identity in equation (4) to arrive at the correct expression in equation (8); this raises the issue of where this additional value of output should appear on the right-hand (income) side of equation (8).

The treatment of intangibles on the income side of the accounts is subtle because the original estimate of capital income in equation (4), $p_t^K K_t$, is measured by the sum of all property-type income (interest, dividends, retained earnings, taxes, and depreciation). This list accounts for the nonlabor payments accruing to both tangible *and* intangible capital—that is, to $p_t^{K*} \mathrm{K}_t + p_t^R R_t$. Where, then, would intangible investment, $p_t^N N_t$, appear on the income side of the accounts? The answer is that intangible investments are reflected as retained earnings that are uncounted in the conventional framework. Specifically, because intangibles are expensed in the conventional framework, they are subtracted from revenue to get earnings. Because intangibles would not be subtracted from revenue in the expanded framework, retained earnings are higher than in the conventional framework.[9] Thus, the symmetry principle is not just about uncounted output, but also about uncounted income accruing to capital.

9. Moulton, Parker, and Seskin (1999) describe this accounting for the recognition of software in the NIPAs. See also Fraumeni and Okubo (chap. 8 in this volume) and B. Hall (chap. 8 comment in this volume).

The expanded framework for growth accounting presents a somewhat different view of the economy than the approach that ignores intangibles. Comparing the GDP identities in equations (4) and (8) reveals that the latter is greater by $p_t^N N_t$. The rate of saving and investment and the relative shares of capital and labor in GDP are also affected. Labor's share in the "old" view is $s_L = (p^L L)/(p^L L + p^K K)$, which becomes $s_L^* = (p^L L)/(p^L L + p^K K + p^N N)$ when intangibles are recognized as asset. (For ease of exposition, time subscripts have been dropped, and the asterisk is used to denote the "true" income share.) The two shares are related by a factor of proportionality

$$\lambda = \frac{(p^C C + p^I I)}{(p^C C + p^I I + p^N N)}, \tag{10}$$

which is less than one. The basic result is that labor's "new" share is smaller, that is, $s_L^* = \lambda s_L$. Since both the old and new shares must sum to one, capital's income share must be larger when intangibles are recognized as being capital. Put differently, the "new" view includes the return to these forms of investment.

A similar analysis applies to the rates of saving and consumption. Consumption's true share is $s_C^* = (p^C C)/(p^C C + p^I I + p^N N)$, and the mismeasured share is $s_C = (p^C C)/(p^C C + p^I I)$; they are related by the same proportionality factor as above, that is, $s_C^* = \lambda s_C$. Consumption's share is smaller when intangibles are treated as capital, implying that the rate of saving and investment is correspondingly higher. This result is relevant in light of concerns about the low rate of saving in the U.S. economy: existing measures of saving exclude much of the investment in knowledge capital that defines the modern economy.

1.3 The Scale of Business Investment

In this section, we first identify and group the items commonly thought to represent private business spending on intangibles. We next review the available data sources and develop estimates of outlays on intangibles for three periods chosen to illustrate the growth in intangibles in the 1990s. The intertemporal model is then used to guide the determination of which (or what portion) of the items we have identified as business intangibles should be categorized as business fixed investment in national accounting systems.

1.3.1 Identifying and Estimating Business Spending on Intangibles

As illustrated in table 1.2, we group the various items that constitute the knowledge capital of the firm into three broad categories: computerized information, innovative property, and economic competencies. The table indicates, in general terms, what type of knowledge capital is included in

Table 1.2 Business intangibles, by broad group

Name of group	Type of knowledge capital	Current status in the NIPAs
Computerized information	Knowledge embedded in computer programs and computerized databases	Major component, computer software, is capitalized
Innovative property	Knowledge acquired through scientific R&D and nonscientific inventive and creative activities	Most spending for new product discovery and development is expensed[a]
Economic competencies	Knowledge embedded in firm-specific human and structural resources, including brand names	No items recognized as assets of the firm

[a]Two small components—oil and gas exploration, and architectural and engineering services embedded in structures and equipment purchases—are included in the NIPA business fixed investment.

each broad group and how each type is currently treated in the NIPAs.[10] The major component of computerized information, computer software, already is included as business fixed investment. The other components, which include the knowledge acquired by businesses in their development of new or improved products, processes, or economic competencies, are not generally recognized as assets of the firm in the U.S. NIPAs or in other national accounting systems.

Table 1.3 presents estimates of the size of outlays by businesses on these broad categories of intangibles. As indicated by the numbered rows of the table, these estimates have been built from *nine* types of intangible assets that have been identified and grouped according to our three basic categories. The table summarizes the availability of data that can be used to measure business spending on each item and then presents our spending estimates for the late 1990s, that is, from 1998 to 2000; spending rates for periods five and ten years earlier also are shown to help illustrate trends by detailed asset type during the decade.[11] In the discussion that follows, we review the data sources for each item and assess how the available information can be used to broaden measures of business investment to more fully encompass each of the categories of knowledge capital shown in table 1.2.

Computerized Information

Computerized information reflects knowledge embedded in computer programs and computerized databases. When computer software was

10. Our classification is similar, but not identical, to groupings developed in studies sponsored by the OECD (see OECD Secretariat 1998 and Khan 2001) and used by Lev 2001.

11. The spending estimates summarized in the table have been developed as consistent, annual time series from 1988 to 2002. In much of the analysis that follows, we focus on the figures for the late 1990s.

Table 1.3 **Data availability and estimated size of business spending on intangibles, by type of asset**

		Estimated size[a]		
Type of asset or spending	Comments on data availability and data sources	1988–90	1993–95	1998–2000
Computerized information		**40**	**70**	**155**
1. Computer software	Covers expenses of software developed for a firm's own use; based on NIPA data that include three components: own use, purchased, and custom software.	41	69	151
2. Computerized databases	Own use likely is captured in NIPA software measures; data from the Services Annual Survey (SAS) suggest that the purchased component is small.[b]			3
Innovative property		**205** *(165–245)*	**260** *(205–315)*	**425** *(325–525)*
3. Science and engineering R&D (costs of new products and new production processes, usually leading to a patent or license)	Mainly R&D in manufacturing, software publishing, and telecom industries. The census collects data on behalf of the National Science Foundation (NSF). Industrial R&D data are available from the early 1950s and cover work in the physical sciences, the biological sciences, and engineering and computer science (excl. geophysical, geological, artificial intelligence, and expert systems research).	103	123	184
4. Mineral exploration (spending for the acquisition of new reserves)	Mainly R&D in mining industries.			
	a. Mineral exploration, Census of Mineral Industries and NIPAs.	9	10	16
	b. Other geophysical and geological exploration R&D in mining industries, estimated from census data.[c]	2	2	2
5. Copyright and license costs (spending for the development of entertainment and artistic originals, usually leading to a copyright or license)	Mainly R&D in information-sector industries (excl. software publishing). No broad statistical information, proxied by:			
	a. Development costs in the motion picture industry[d]	9	14	25
	b. Development costs in the radio and television, sound recording, and book publishing industries are crudely estimated to be double the new product development costs for motion pictures. (No estimate for the arts is included.)	19 (9–28)	27 (14–40)	50 (25–75)
6. Other product development, design, and research expenses (not necessarily leading to a patent or copyright)	Mainly R&D in finance and other services industries. No broad statistical information, proxied by:			
	a. New product development costs in the financial services industries, crudely estimated as 20 percent of intermediate purchases.[e]	23 (12–35)	38 (19–57)	74 (37–111)
	b. New architectural and engineering designs, estimated as half of industry purchased services (revenues of the industry as reported in SAS).	36 (18–54)	42 (21–63)	68 (34–102)
	c. R&D in social sciences and humanities, estimated as twice industry purchased services (revenues as reported in SAS).	4 (2–6)	5 (2–7)	7 (4–11)

Economic competencies		**325** *(270–390)*	**425** *(350–515)*	**640** *(525–785)*
7. Brand equity (advertising expenditures and market research for the development of brands and trademarks)	a. Purchases of advertising services; advertising expenditures[f]	124	151	217
	b. Outlays on market research, estimated as twice industry purchased services (revenues of the market and consumer research industry as reported in SAS).	10 (5–15)	12 (6–19)	19 (9–28)
8. Firm-specific human capital (costs of developing workforce skills, i.e., on-the-job training and tuition payments for job-related education)	Broad surveys of employer-provided training were conducted by the Bureau of Labor Statistics (BLS) in 1994 and 1995.[g]			
	a. Direct firm expenses (in-house trainers, outside trainers, tuition reimbursement, and outside training funds)	13	17	22
	b. Wage and salary costs of employee time in formal and informal training	55	70	94
9. Organizational structure (costs of organizational change and development; company formation expenses)	No broad statistical information, and no clear consensus on scope.			
	a. Purchased "organizational" or "structural" capital, estimated using SAS data on the revenues of the management consulting industry.	27	42	81
	b. Own-account component, estimated as value of executive time using BLS data on employment and wages in executive occupations.	93 (45–155)	132 (65–220)	210 (105–345)
Grand total		**570** *(475–675)*	**755** *(625–900)*	**1,220** *(1,005–1,465)*
Percent of GDP		**10.4** *(9–12)*	**10.7** *(9–13)*	**13.1** *(11–16)*

Note: Numbers in parentheses are ranges for the point estimates shown.

[a]Billions of dollars, average annual rate. Totals and ranges for major categories are rounded to the nearest $5 billion dollars.

[b]Refers to the subscription-type revenue (i.e., total revenue, excluding advertising sales, contract printing, and other) of the database and directory publishing industry reported in the 2000 SAS.

[c]Output of the geophysical surveying and mapping services industry; Census of Mineral Industries quinquennial data were interpolated to obtain estimates for other years.

[d]Data on the cost per release for Motion Picture Association of America (MPAA) members is applied to the number of releases by independent producers. Derived from statistics reported in the MPAA U.S. Economic Reviews and available at http://www.mpaa.org.

[e]Intermediate purchases for finance industries (SICs 60–62, 67) from the Bureau of Economic Analysis's GDP-by-industry data set.

[f]The advertising data are from Bob Coen's *Insider's Report,* issued by Universal-McCann, available at http://www.mccann.com/insight/bobcoen.html.

[g]Estimates for other years were derived from (1) the industry detail on per employee costs reported in Bureau of Labor Statistics surveys, and (2) trends in aggregate educational costs, industry employment, and industry employment costs.

recognized in the NIPAs in 1999, the move captured the estimated costs of software created by firms for their own use as well as purchases of prepackaged and custom software. The own-account estimates were developed from detailed occupational data on employment and wages in private industry, in conjunction with an estimate (50 percent) of the average time spent by individuals in the relevant occupations on "software development" (Parker and Grimm 1999). This method of estimating investment, though imprecise, is consistent with the framework of figure 1.2: Some uses of employee time (development) are investments, other uses are inputs to current production. Spending in this category thus reflects the current NIPA computer software estimates (which averaged more than $150 billion during 1998–2000) plus a small figure (about $3 billion) for computerized databases, an item not capitalized in the NIPAs. Spending on computerized databases is estimated from the Census Bureau's Services Annual Survey (SAS).

The recognition in the NIPAs of computer software as investment generally has been met with acceptance and praise. During the work leading up to the introduction of software in the accounts in 1999 and in subsequent work by the BEA and others, important lessons have been learned about how to handle the possible double-counting from bundling of assets as well as issues related to own-account production.[12] Because intangibles are often bundled with fixed assets (e.g., Brynjolffson, Hitt, and Yang 2002) or constructed on own-account, the lessons learned from software should be quite valuable as efforts to measure other intangibles move forward.

Innovative Property

Although the innovative property category of intangibles includes the familiar R&D spending data as one of its components, it is broader. It reflects not only the scientific knowledge embedded in patents, licenses, and general know-how (not patented) but also the innovative and artistic content in commercial copyrights, licenses, and designs. The category thus encompasses what we term "nonscientific R&D" in addition to the familiar "scientific R&D" component. In contrast to scientific R&D, the magnitude and trajectory of the spending flow on nonscientific R&D are not very well measured. Nonetheless, we estimate that in the 1990s, nonscientific R&D spending was at least as large as scientific R&D spending. All told, our figures suggest that private businesses spent about $425 billion per year during 1998–2000 on investments in innovative property.

The industrial R&D data that have been the subject of most of the research in the United States have been collected since the early 1950s by the Census Bureau for the National Science Foundation (NSF). These data are

12. Software is an important tool in R&D, and the conceptual overlap between figures for own-account software and the data on R&D expenditures must be confronted; this point is emphasized in the OECD's work on intangibles.

defined to include expenditures "on the design and development of new products and processes and on the enhancement of existing products and processes." The included expenditures are restricted to activities carried on "by persons trained, either formally or by experience, in the physical sciences, the biological sciences, and engineering and computer science (but excluding geophysical, geological, artificial intelligence, and expert systems research)." As is consistent with this restriction, the NSF's industrial R&D data mainly capture inventive activity by industries that employ these types of workers (high-tech, pharmaceutical and other manufacturers, software publishers, telecommunications service providers, and the like), who are estimated to have spent nearly $185 billion annually on R&D in the 1998–2000 period. Adding an estimate of mining R&D (more than $15 billion) yields a point estimate for total spending on scientific R&D (items 3 and 4 on the table) of about $200 billion annually during 1998–2000.

Relatively little is known about "nonscientific" R&D spending. Information-sector industries—book publishers, motion picture producers, sound recording producers, and broadcasters—as well as financial and other services industries routinely research, develop, and introduce new products. However, we have no broad survey data on the resources they devote to these activities. In the table, we identify two types of nonscientific R&D spending (table 1.3, lines 5 and 6), noting that new product investment by information-sector industries usually leads to an identifiable asset, such as a copyright or license, whereas the fruits of nonscientific R&D spending elsewhere usually do not.

For the motion picture industry, trade association data suggest that the development costs of new movie releases averaged $25 billion per year during 1998–2000 (table 1.3, line 5a). This figure includes the *actual* costs incurred by the major motion picture producers and the *estimated* costs for independent producers, with the latter accounting for about half of the total. We have no comparable data for the production costs of new television programs, sound recordings, or books. However, the new film *and new TV program* development costs of four of the seven major U.S. film and TV producers/distributors who identify such costs on a comparable basis in their financial reports were $15 billion per year for the same period, an amount suggesting that the costs of developing new TV programs are nontrivial.[13] As a result, development costs for new products in the broadcasting, sound recording, and book publishing industries (line 5b) are crudely estimated to be twice the new product development costs for motion pictures, a relationship that is roughly the same as that between the revenue of these industries and that of motion pictures as reported in the SAS. A range of plus or minus 50 percent is placed on this point estimate to indicate the high degree of uncertainty about this guess.

Our estimates for other new product development, design, and research

13. The four companies are the Warner Bros. unit of Time-Warner, Disney, Fox, and MGM.

costs are also rudimentary guesses, again with a range of plus or minus 50 percent placed on the point estimates. Nakamura (2001) proxies new product development costs in the financial services industries as a proportion (half) of the noninterest expenses of banks and nondepository institutions. We broaden the coverage to include other financial institutions (security and commodity brokers and other financial investments and related activities), and for our proxy we use 20 percent of all intermediate purchases reported in the BEA's data on gross output and value added by industry; this spending was about $75 billion annually during 1998–2000. Elsewhere in services, we estimate that spending on *new* architectural and engineering designs was nearly $70 billion during the same period and that R&D in the social sciences and humanities was about $7 billion, twice its purchased component from SAS revenues (to include an own-account portion).

Economic Competencies

Economic competencies represents the value of brand names and other knowledge embedded in firm-specific human and structural resources; it gathers the expenditures designed to raise productivity and profits (other than the software and R&D expenses classified elsewhere) and labels them "economic competencies."

We include three basic asset types in economic competencies: brand names, firm-specific human capital, and organizational structure. As indicated on lines 7 through 9 of table 1.3, we suggest that spending on these assets can be captured by measuring the costs of brand development; the costs of workforce training and education; and the costs of organizational change and development. Our raw tally of these flows places the spending on economic competencies at about $640 billion per year in the 1998–2000 period. This large spending category, however, is imprecisely estimated, and we place a wide range around our point estimate.

Spending on brand development is represented by expenditures on advertising and market research (table 1.3, lines 7a and 7b) and encompasses the costs of launching new products, developing customer lists, and maintaining brand equity. Although advertising and market research are generally aimed at building a firm's market share at the expense of its competitors, such spending is necessary for developing new brands and maintaining the value of existing brands. Data on advertising expenditures are available from Universal-McCann, and revenues of the industry, market and consumer research services, are available in the SAS. Because we are unable to gauge the size and prevalence of own-account market and consumer research, the SAS purchases are simply doubled to obtain an estimate for this item. Our estimate for total spending on brand equity thus totals about $240 billion annually from 1998 to 2000.

The incidence and costs of employer-provided training was measured in special surveys conducted by the BLS in 1994 and 1995, and the results placed private business spending on workforce training and education in those years at a $106 billion annual rate (table 1.3, lines 8a and 8b). The BLS surveys were designed both to yield unbiased economywide estimates of the costs of employer-provided training and to capture conceptually just what the intertemporal model wants: the total spending figure includes both direct firm expenses (outlays on instructors, tuition reimbursements, and the like) and the wage and salary costs of employee time spent in formal and informal training. The figures for the early and late 1990s shown in the table are extrapolations using (a) the survey's industry detail on the mid-1990s costs per employee and (b) trends in aggregate educational costs, industry employment, and industry employment costs.

Investments in organizational change and development have both own-account and purchased components. The own-account component is represented by the value of executive time spent on improving the effectiveness of business organizations—that is, the time spent on developing business models and corporate cultures. The purchased component is represented by management consultant fees. The purchased component is estimated using the SAS annual revenues from the management consulting services industry, which rose substantially in the 1990s, from $27 billion at the start of the decade to more than $80 billion during 1998–2000 (table 1.3, line 9a).

The own-account portion is estimated as a proportion of the cost and number of persons employed in executive occupations, which rose very rapidly in the 1990s. Given that executive median pay exceeds the median pay for other employees, the fraction of total private payroll spent on executives and managers is substantial, almost 22 percent in 2000 (Nakamura 2001). Applying the executive and manager payroll share to total private business-sector compensation yields an estimate for managerial and executive costs of nearly $900 billion per year in the 1998–2000 period.

If just one-fifth of management time is spent on organizational innovation, then businesses devoted more than $200 billion per year to improving the effectiveness of their organizations during 1998–2000 (table 1.3, line 9b). This figure is highly sensitive, of course, to the admittedly arbitrary choice of one-fifth as the fraction of time managers spend on investing in organizational development and change; as a result, our estimate for this component ranges from $105 billion (based on a one-tenth fraction) to nearly $350 billion (which assumes one-third). Adding in the $80 billion annual expense for management consulting (described above), our point estimate of total spending on organizational change and development is nearly $300 billion per year from 1998 to 2000.[14]

14. Consulting expenses and the estimated value of executive time conceptually overlap by a small amount (the value of executive time in the management consulting industry). In addition, some portion of management time arguably overlaps with R&D, so that, for some industries, the line between industry-specific process innovation and organizational change more generally may not be easily drawn. But, whatever uncertainty that amount induces in

Summing Up

As indicated at the bottom of table 1.3, our best guesses suggest that business spending on intangibles was about *$1.2 trillion* annually in the late 1990s, more than 13 percent of GDP. Moreover, we estimate that nominal spending on intangibles grew relative to the total economy during the second half of the 1990s; the ratio of our estimates to GDP in the 1998–2000 period was about 2.5 percentage points more than it was at the start of the decade and during 1993–95. The picture does not change materially when software, which is already capitalized in the NIPAs, is excluded: our grand total for 1998–2000 still exceeds $1 trillion (nearly 11 percent of GDP) and still expands at a much faster rate than it did earlier in the decade.

Our estimate for business spending on intangibles in the late 1990s shown in table 1.3 is nearly 40 percent larger than the spending-based estimate issued by Nakamura (2001, 2003) and about 20 percent larger than his estimates based on other methods, such as changes in the occupational structure over time.[15] Although we use many of the same data sources, our estimates are larger because we introduce some important new sources of information on spending on intangibles. In particular, the estimates in table 1.3 incorporate official data on the revenue of selected services industries (the Census Bureau's annual SAS data) and on businesses outlays on employer-provided worker training (the BLS's special surveys). Also, our estimates include an explicit figure, based on data from a trade source, for new product investment in the motion picture industry. Last, as is consistent with the intertemporal model, our estimates regard spending on each asset type as having an own-account, as well as a purchased, component. Although our estimates of own-account spending are fairly crude, their inclusion affects the scale and trajectory of the overall aggregate results.

1.3.2 Classifying Intangible Spending as Fixed Investment

The intertemporal model and framework of section 1.2 would not necessarily classify the grand total shown at the bottom of table 1.3 as business investment in long-lasting knowledge capital. To implement the model's

our estimates, it is dwarfed by the use of an arbitrary fraction for the amount of executive time devoted to organizational change and development.

15. The Nakamura (2001, 2003) spending-based estimate adds together (a) the BEA's estimate of software spending, (b) *double* the NSF's estimate of R&D spending (to capture the nonscientific spending we estimate more explicitly), and (c) the Universal-McCann advertising data. For the 1998 to 2000 period, using figures shown in table 1.3, these items sum to $759 billion, or 8.2 percent of GDP. Nakamura also uses three other methods, or broad sources of information, to estimate intangibles: labor inputs (the relative increase in employment in "creative" occupations over time), corporate operating margins (the relative increase in "administrative" costs), and models of the ratio of consumption to GDP, a ratio that has risen since the early 1980s. All told, his estimates place business spending on intangibles at about our lower bound for the grand total shown in table 1.3.

simple rule—investment is deferred consumption—a line must be drawn to separate the expense of current production from outlays that expand future productive capacity. National economic accountants typically make this distinction on the basis of the "durability," or expected service life, of a purchase. In practice, accountants determine durability by setting a minimum time or "cutoff period" required for an asset to yield services (e.g., one year or three years).

If the cutoff period chosen is very short (long), then a larger (smaller) fraction of business expenditures are classified as fixed investments. As a result, the *scale* of business fixed investment (and thus GDP) in a particular measurement system depends on the durability cutoff period that is chosen. Put differently, although the theoretical model views *all* expenditures aimed at increasing the range of production possibilities in a future period as fixed investment (recall the discussion of symmetry in section 1.2), the model does not specify the length of time between the current and "a future" period, even though this definition is needed to determine what becomes *fixed* investment in a particular measurement system.[16]

Of course, the NIPAs and the international *System of National Accounts 1993* (SNA; Commission of the European Communities 1993) currently classify components of intangible spending, either implicitly or explicitly, and the NIPAs are guided by the SNA to some extent. For example, as they do with computer software, the NIPAs treat mineral exploration as fixed investment, and they treat scientific R&D as intermediate consumption, all of which is consistent with the SNA.[17] But no single recent statement conveys the NIPA's "choice" of a durability cutoff for determining what is business fixed investment. The BEA's practice would appear to approximate a system in which business fixed assets are inputs with a useful service life of at least three years, although a dated study defines business equipment as having an average service life of more than one year.[18]

16. But note that because what becomes fixed investment depends on the durability cutoff period chosen, what becomes inventory investment also depends on this cutoff period. Any input that is not used up in current period and is intended to be used to increase future consumption is still "capital" in the sense of figure 1.2, even if it is not classified as *fixed* capital. Such an input would simply be an *inventory* carried over for future use. An examination of the implications of the intertemporal framework for identifying and valuing intermediates as inventory investment is beyond the scope of this paper.

17. However, the SNA advises national accountants to treat the costs of developing an "artistic or entertainment original" (one of our nonscientific R&D asset types) as investment, a practice not followed in the NIPAs.

18. Moreover, different sectors in the NIPAs apply different accounting periods for capital. According to a more than twenty-year-old study, business and government equipment is defined as durable goods having an average service life of more than one year, whereas, for households, equipment (consumer durables) is defined as durable goods having an average service life at least three years (Young and Musgrave 1980). In practice, the available source data introduce additional twists in BEA practices: for example, the Census of Governments uses five years as a cutoff to determine whether a purchase is equipment. But for the business sector, in which the flows are built using data by asset type according to the commodity-flow

In the remainder of this section, we review the available evidence and confront the difficult task of determining which items in table 1.3 are fixed investment. Although we faced many hurdles in assembling the data in table 1.3, we were on a path that others (the OECD, Nakamura, Lev) have followed. At this juncture, however, we are on our own in applying the full logic of the intertemporal model to the development of measures for business fixed investment that include intangibles. Not surprisingly, the challenges we now confront exceed those we faced in the construction of table 1.3.

Table 1.4 works with five subaggregates of the detailed items reported in table 1.3 and summarizes our results. The first three columns report the table 1.3 figures for *total* spending, and the last three columns show our corresponding estimates for *capital* spending. Because the capital spending estimates were derived by considering whether some, rather than all, of total spending should be classified as investment in long-lasting knowledge capital, *the capital spending estimates for some items are lower than the total spending estimates.* Also, because we don't know whether to apply a service life cutoff of one year or three years, ranges are shown when the available evidence suggests that this choice may make a difference.

The capital spending columns of table 1.4 were developed in four steps: first, if economic research has clearly demonstrated that a given type of spending is fixed investment in the sense of our model, then we categorize 100 percent of the total spending as capital spending. For example, scientific R&D (line 2a) is unequivocally a long-lived investment; so is employer-provided training (a component of line 3b).[19] Second, if economic research suggests that only a portion of the spending on an intangible pays off in a future year (or years), we apply these findings. For example, although the marketing literature finds that the effects of advertising are generally short lived, some advertising—apparently, more than half—has a service life of at least one year; a smaller fraction—perhaps one-third—makes a cutoff of three years (Landes and Rosenfield 1994).[20] As a result, the estimates for

method (see Grimm, Moulton, and Wasshausen, chap. 10 in this volume), the NIPAs currently do not recognize any assets having a service life of less than three years. (The authors thank Brent Moulton, associate director of National Economic Accounts at the BEA, for the information in this footnote.)

19. The very high rates of return to R&D investments found in microeconomic studies are summarized in National Science Board (2000, p. 7-18); see also Griliches (1984). Studies that document the returns to employer-provided training include, among others, Bartel (1991, 1994) and Black and Lynch (1996).

20. Specifically, of the twenty two-digit Standard Industrial Classification (SIC) industries examined by Landes and Rosenfield, the implied annual geometric rate of decay of advertising was about 55 percent or less for seven industries (furniture; paper; chemicals; fabricated metals; transportation equipment; instruments; and building materials, hardware, and garden supplies) and about 65 percent to 70 percent for seven more (food, rubber and plastics, industrial machinery, electrical machinery, miscellaneous manufacturing, apparel retailers, and business services). For the remaining six industries (wholesale distributors of durable goods, general merchandisers, eating and drinking places, miscellaneous retailing, investment offices, and hotels), the effects of advertising dissipated within one year.

Table 1.4 Business intangibles: Total spending and capital spending

	Total spending				Estimated capital spending[a]		
Type of asset or spending	1988–90	1993–95	1998–2000	Comments on evidence as capital spending	1988–90	1993–95	1998–2000
1. Computerized information (mainly computer software)	41	69	154	Firms capitalize only a fraction of purchased software in financial accounts. Relatively little is known about service life of software assets.	35–40 (41)	55–70 (69)	125–155 (151)
2. Innovative property							
a. Scientific R&D	114	135	201	Yields relatively long-lasting returns and is fixed investment.	114 (9)	135 (10)	201 (16)
b. Nonscientific R&D	91	126	223	A portion of new product development costs in the entertainment industry apparently is short lived.	75–90 (21)	100–125 (25)	180–225 (40)
3. Economic competencies							
a. Brand equity	134	164	235	The effects of some advertising dissipate within one year, but more than half has effects that last more than one year; a smaller fraction, perhaps one-third, makes a three-year cutoff.[b]	40–75	50–95	70–140
b. Firm-specific human and structural resources	188	261	407	Firm-specific training is fixed investment. Spending for organizational change also is likely long lived, but a portion of management fees probably is not capital spending.	170	235	365
4. Total (1 + 2a + 2b + 3a + 3b)					**425–490 (70)**	**570–660 (105)**	**940–1,085 (205)**
a. Percent of GDP					8 to 9	8 to 9	10 to 12
b. Ratio to tangible capital spending					.8 to .9	.9 to 1.0	1.0 to 1.2

Notes: Components may not sum to totals because of rounding. All results are rounded to the nearest $5 billion. Numbers in parentheses are the amounts already included in the NIPAs.

[a]Ranges correspond to estimates using a service life cutoff of one (upper) to three (lower) years.

[b]See text note 20. Because the relatively longer-lived ads are those aimed at selling specific products, rather than promoting sales at specific stores, the "national" portion of the Universal-McCann data (nearly 60 percent of the total) plus two-thirds of purchased marketing and consumer research is used as a measure of the spending that makes a one-year cutoff. This figure is reduced by 50 percent to obtain the estimate corresponding to a three-year cutoff, and the result is rounded to the nearest $5 billion.

capital spending on brand equity (line 3a) are noticeably smaller than the corresponding total spending figures.

Our third and fourth steps are less precise: when we have a strong suspicion that the lifetime of a type of intangible may not be at least three years, we discount the item by 20 percent (an arbitrary amount) and show a range for our estimate for capital spending for the item. The lower bound of this "lifetime ignorance" range is the discounted figure and the upper bound is the total spending figure. For example, BEA's assumptions of a three-year service life for all prepackaged software and a five-year service life for custom and own-account software are based on indirect and anecdotal evidence (Parker and Grimm 1999). Because many businesses expense recurring software fees and routine purchases of upgrades,[21] and because very little is known about the age-efficiency and retirement patterns of software assets, we apply the discount; the software capital spending estimate (line 1) thus shows a range to capture the uncertainty about software lifetimes. Also, the spending for some new products in the entertainment industry—a new television series or a new copyright film—are investments that generate, on average, relatively long-lasting revenue streams; but other spending on new product development pays off very quickly, while still other costs are "paid for" by advertising (Caves 2000). All told, to indicate our ignorance about the service lives of assets in this category, we apply the discount and show a lower bound for nonscientific R&D spending (line 2b) as well.

Fourth, when we have a strong suspicion that a portion of the spending in table 1.3 may be for routine tasks or represent current consumption, we discount the point estimate 20 percent. For example, we know very little about the composition of purchased management expertise; but we guess that a portion of these costs are current expenses, so we deduct the arbitrary discount before carrying this item over to the capital spending column. The total on line 3b includes our point estimate for the costs of organizational development and change on own-account that, although highly imprecise, was developed by explicitly considering what was investment.

Putting the pieces together, our table 1.4 estimates place business fixed investment in intangibles at nearly $1 trillion in the 1998–2000 period, or about 10–11 percent of existing GDP. Moreover, as indicated on the table, only a portion of this spending (about 2 percent of existing GDP) is currently included in the NIPAs. Indeed, when this is viewed in relation to NIPA business spending on tangible capital—that is, spending on durable equipment and structures—we find that businesses invested in intangibles at roughly the same rate at which they invested in tangibles.

21. Businesses reported to the Census Bureau that they spent about $12 billion on separately purchased, capitalized software in 1998, compared with the BEA's estimates for business purchases of prepackaged and custom software that were *each* three and one-half times larger that year. The census figure is from table 8 in the 1998 issue of *Annual Capital Expenditures.*

We recognize, of course, that the figures in tables 1.3 and 1.4 are imprecise and that, in putting them together, we raised many issues that we were unable to resolve: for example, software is a major tool in R&D (and thus the own-account software estimates and the scientific R&D figures likely overlap); remarkably little is known about innovative activity outside of the industries that employ scientists and engineers; and quantifying the scale and service lives of business outlays geared to the acquisition of economic competency is very difficult. All in all, though, one cannot escape the conclusion that business capital spending on intangibles was a very substantial and growing component of the economy in the 1990s—and that a serious attempt to fully account for these intangibles significantly alters one's view of the scale and composition of business fixed investment.

1.4 Real Output and Productivity Including Business Knowledge Capital: A First Step

Given the magnitude and trajectory of our estimates of business investment in knowledge capital, the full recognition of intangible assets in national economic accounting would be expected to have implications for measured changes in real output, output per hour, and TFP. As a first step in answering how much of an effect those changes might be, we adjusted the value of nonfarm business output (the nominal output metric used in most productivity calculations) to include unrecognized intangible investments, and we experimented with how to express the resulting adjusted output series in real terms.

Alternative values of nonfarm business output adjusted to include unrecognized investment in intangibles are shown in table 1.5. The alternatives use the table 1.4 capital spending estimates corresponding to a one-year versus a three-year service life cutoff; as may be seen in table 1.5, the value of output including the unrecognized investment corresponding to a one-year service life cutoff exceeds that using the investment series corresponding to a three-year cutoff. The ratio of the published value of nonfarm business output to our alternative adjusted values (the λ defined in equation [10]) also is shown in table 1.5. The ratio of published to adjusted is lower for the output figures that incorporate the unrecognized investment corresponding to a one-year cutoff. This implies that economic accounts that include intangibles and adopt a one-year cutoff would show a higher saving rate and a lower labor share than would accounts that adopt a three-year cutoff. However, because the published-adjusted ratio for *each* alternative is noticeably below one, the inclusion of unrecognized investment in intangibles would imply an economy with a higher saving rate and a lower labor share than implied by the existing published figures, whatever choice is made about the service life cutoff.

The conversion of our estimates to real terms is especially difficult

Table 1.5 **The value of nonfarm business output adjusted to include unrecognized investment in intangibles, by service life cutoff (annual average for period shown)**

Service life cutoff	1988–1990	1993–1995	1998–2000	2000–2002
		In billions of dollars		
One-year	4,569	5,897	8,049	8,851
Three-year	4,504	5,809	7,903	8,688
		Ratio, published to adjusted (λ)		
One-year	.908	.906	.891	.889
Three-year	.921	.919	.908	.906

because intangibles often are owner constructed, or are "difficult-to-measure" services (Griliches 1994), with no available (or reliable) price deflator. As a result, we use two surrogates, one based on the price of output for the overall nonfarm business sector, the other based on employment costs in the sector. The rationale for using the overall output price as a surrogate is that intangible investments are firm specific and occur broadly across industries; the rationale for using employment costs is that the construction of intangibles is a labor-intensive process, perhaps with little growth in productivity.[22]

Our estimates of real output using the two deflators are applied to the adjusted output series corresponding to the one-year service life cutoff and shown in table 1.6. In this table we present annualized results for periods that correspond to the final two columns in table 1.1. When the nonfarm business output price is used to deflate the unrecognized business investment, the rates of change in the adjusted real output measure exceed the existing measures of change, suggesting that a move to fully recognize intangibles *could* raise the growth rate of real output, on average, by a noticeable amount. However, if employment costs are used to deflate the unrecognized investment flows, the resulting rates of change in real output are little different from the published measures of change.

The figures shown in table 1.6 thus frame the answer to the question posed at the outset of this paper: how much difference does the theoretically appropriate treatment of knowledge capital make to the productivity estimates shown in table 1.1? The adjustments to real output shown in table 1.6 imply corresponding percentage point adjustments to the rate of change in measured output per hour shown in line 1. All told, therefore, the

22. Under constant returns to scale, the rate of change in the intangible output price is connected via the factor price frontier to the rate of change in the prices of inputs used in the production of the output, less the rate of change in the efficiency, or productivity, of the process. If the rate of productivity change is close to zero, and labor's share is close to one, employment costs are a good proxy for the output price.

Table 1.6 **Real nonfarm business output adjusted to include unrecognized investment in intangibles, by type of deflator**

Type of deflator[a]	1990 to 1995	1995 to 2002
Average annual percent change		
Nonfarm business output price	2.98	3.96
Private business employment costs	2.85	3.72
Adjusted, less published[b]		
Nonfarm business output price	0.12	0.25
Private business employment costs	–0.01	0.01
Memo:		
Published real nonfarm business output[c]	2.86	3.71

[a]Uses the investment series that corresponds to a one-year service life cutoff.

[b]Percentage points per year.

[c]Average annual percentage change.

change to measured productivity that would result from the *full* recognition of intangibles *could* be as large as that which occurred with the move to include software in business investment—about .25 percentage points per year in recent years.

The potentially striking nature of these results underscores both the importance of further work on measuring business investment in intangibles in real terms and the need to obtain additional information on historical investment flows and service lives for the many and varied types of intangibles assets described in the previous section. We have made no estimate of the aggregate real stock of knowledge capital, nor of its impact on TFP, but our results and our framework suggest that intangible investments need to be included in the empirical accounting of factors determining economic growth.

1.5 Conclusion

The remarkable performance of the U.S. economy in the second half of the 1990s has refocused attention on identifying the underlying sources of economic growth. In the introduction to this paper, we discussed some of the strands of literature that have, in different ways, started to stir the pot of growth analysis and measurement. Because we, too, share the general sense that the conventional framework and current data are not telling us all that we need to know about the role of knowledge capital in economic growth, we set out in this paper a broader framework for the economic measurement of capital.

On the theory side, we described a growth framework that adds an explicitly intertemporal dimension to the standard Solow growth-accounting framework. One important way in which the extended framework is useful is that it provides guidance on the "boundary" question of what should be included in investment and therefore what measure of capital should be entered into the production function. The conventional framework provides little guidance on this point, while the extended framework yields the concept necessary to define investment: any use of resources that reduces current consumption in order to increase consumption in the future qualifies as investment. Thus, spending on a host of intangibles—including R&D, copyrights, films, computerized databases, improved organizational structures, brand equity, and so on—should, in principle, be counted as investment.

In terms of practice, we assembled data on spending on intangibles (using the types of definitions that national economic accountants might use) to gauge their possible magnitude via the application of our model. The estimates suggested that business fixed investment in intangibles may have been large as the spending on tangible capital—as much as $1 trillion in recent years—and that a significant portion of this amount is excluded from the existing investment figures in the NIPAs. Although we regard our numbers on intangible investment as illustrative, not definitive, the inclusion of heretofore unrecognized business intangible capital in the NIPAs implies that the move could alter the average rate of growth of real output and labor productivity in the late 1990s.

We believe that the statistical agencies and the broader research community should construct satellite accounts for as many of the categories of intangible investment as possible. Satellite accounts would illuminate the data hurdles and information needs and position researchers to suggest improved techniques and data sources. At the same time, the use of satellite accounts would insulate the headline accounts from the spotty data that invariably would be used in the satellites. One noteworthy effort in the development of satellite accounts is the work of Fraumeni and Okubo (chap. 8 in this volume), who take a first look at an accounting of GDP that includes scientific R&D.

As indicated, we regard this paper, along with other papers in this volume, as one step in a long process. Despite the challenges ahead, we believe that useful progress is being made on measuring and understanding the role of business intangibles in the economy and that substantial further progress is both possible and necessary.

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Comment Edward C. Prescott

My comments are organized as follows. First I state why I think this paper is of great value to macroeconomic researchers: intangible capital investment is large and cannot be ignored when we are addressing many important macroeconomic questions. Then I argue that the intangible capital investment numbers are not sufficiently manipulation-proof by politicians to be included in any official national accounting system.

Why Currently Unmeasured Intangible Capital Investment Is Important in Macroeconomic Analyses

What I found most interesting in this very interesting paper is table 1.3. Table 1.3 summarizes the authors' best guess or estimate for the values of intangible investments. They divide intangibles into three categories: computerized information, scientific and creative property, and economic competencies. For the 1998–2000 period the estimated size of business spending on intangible investments is 0.13 times greater than the GDP, which is a large number. I will now discuss the individual components and

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will argue that this large number may greatly understate the size of these intangible investments.

Computerized information is primarily software, which is included now in the national income and product accounts (NIPA). For the period considered, 1998–2000, Corrado, Hulten, and Sichel estimate computer software investment at around 0.015 times GDP. If they include estimates of development costs, their total for computerized information is around 0.017 times GDP.

These numbers may be conservative. I say this because I know a little about what goes on at the Federal Reserve Bank of Minneapolis. The information technology (IT) department employs 10 percent of this organization's workforce. Most of these people are not involved in the direct production of services that are supplied by the Minneapolis Fed—check clearing, cash provision, banking supervision, policy advice, protection, and handling Treasury Direct. About half of the time of the IT people is devoted to providing services to these production units within the Minneapolis Fed and therefore is an intermediate good. The other half, however, is allocated to investment activities, which implies a big number for computerized information investment. This suggests that 0.017 times GDP for computerized information is too small a number.

The second category is scientific and creative property investments. The largest component here is R&D expenditures that are expensed and therefore not included in the NIPA. R&D expenditures, as estimated by the National Science Foundation (NSF), are around 0.019 times GDP. The smaller categories of technology and innovative property are mineral exploration, copyright and license costs, and other R&D expenditures not counted by the NSF, such as R&D in finance and other service industries. Corrado and her coauthors estimate the total of mineral exploration, copyright and license costs, and R&D expenditures to be about 0.042 times GDP.

Again, I think their estimates are conservative. Some R&D activity is mixed with production activities. For example, an engineer in the production sector may be supervising activities or may be studying how to make the production process more efficient. The part of the engineer's time allocated to making the production process more efficient is R&D investment. The returns to this investment are often captured in what is called *learning by doing.* Actually, engineers are not the only ones making investments. Production workers try different things and learn from seeing what happens. This is an investment because the knowledge gained enhances future production possibilities.

The final category is economic competencies. This category is the most difficult to measure but quite possibly the largest. Corrado and her coauthors include firm-specific human capital, organizational capital, and brand equity. The total for these categories is a large number, 0.064 times GDP during the 1998–2000 period.

Let me start with brand equity because better measures are available for this category. Investments for brand equity include expenditures on advertising and market research. Corrado and her coauthors estimate that this investment for advertising is 0.023 times GDP and that market research is 0.002 times GDP.

For firm-specific human capital, Corrado and her coauthors use BLS surveys to estimate the costs of developing workforce skills such as on-the-job training and payments for job-related education. They estimate these expenditures to be 0.012 times GDP.

On-the-job training is an important investment. Indeed, Heckman, Lochner, and Taber (1998) and Parente and Prescott (2000) estimate it to be 0.075 times GDP. They estimate the worker-financed, on-the-job skill investment using experience wage profiles. There is also some skill-capital investment that is firm specific and is financed by the firm. Given that this skill-capital investment is produced in the business sector, it is part of the output of the business sector. The part financed by the worker is part of labor compensation. On-the-job skill investment is probably closer to 0.075 times GDP than the 0.012 times GDP estimate of Corrado and coauthors.

For organization capital, Corrado and her coauthors use information on executives' wages and management consulting fees. The idea is that executive time spent on investment decisions is a proxy for organizational change and development investment. I think that this number is too small. Many years ago, Prescott and Visscher (1980) wrote a paper on organization capital. We found that efficiencies of organizations improve over time as the workers learn who in the organization knows what. Knowing whom to ask for the answer to a question is almost as good as knowing the answer to that question. People spend a lot of time interacting within organizations, and this interaction has an investment component because it results in knowing how to get things done within the organization. The Corrado, Hulten, and Sichel upper-bound estimate for organizational capital investment is 0.030 times GDP. These estimates for investments, while interesting, are not the end of the story.

For some purposes, what we need to know is how large the *stock* of intangible capital is. This stock has to be important in accounting for differences in output across countries and across time. It is also important in judging whether the stock market is overvalued, undervalued, or correctly valued. We can use the investment numbers from Corrado and coauthors if we have some measure of depreciation to estimate this stock. While there has been some work on determining depreciation rates of intangible capital, it has been limited to depreciation of R&D capital.

McGrattan and Prescott (2002) needed an estimate of the corporate intangible capital stock in an analysis of the U.S. stock market. We developed an indirect route to the measurement of the corporate intangible net capital stock that does not require knowledge of depreciation. Our approach uses BEA measures of corporate profits, corporate tax liabilities, tangible investment, tangible depreciation, and growth in GDP. Under the assumption that the after-tax returns on tangible and intangible capital are equal, growth theory gives us a formula for intangible capital as a function of these data and the BEA measures of corporate tangible capital stocks.

We find that the corporate intangible capital stock is large now and was large in the past. If the NSF's 11 percent R&D depreciation rate is used for all intangible investment, the upper-end investment numbers for Corrado and coauthors imply intangible capital stock close to our indirect estimate. This consistency is comforting.

Parente and Prescott (2000) found additional evidence that investment in intangible capital is a very large number, much bigger than the estimate of Corrado and coauthors. The evidence is provided by the behavior of the Japanese economy during its postwar growth miracle. Parente and I use the growth model with intangible capital and find that only if the intangible investment is very large is the Japanese growth miracle consistent with the theory. If it were not large, convergence to the steady-state growth path would have been too rapid.

Should the national accounts be changed to better incorporate intangible investment?

I turn now to the question of whether the national income accounts should be modified to include intangible investments. My view is that they should be included if there are market prices and not otherwise.

One category of intangible capital investment that it may make sense to include is R&D investment. This investment is monitored by the tax authorities, and the United States gives tax credits for some R&D investments. Those R&D investments for which there are credits could be included as part of output. However, even here, there is the danger that the definition of expenditures that fall into this class will be broadened for political reasons in order to make it appear that the economy is doing better than it is, in fact, doing. Consequently, what should be done in this case is not clear. Perhaps it is better to categorize expenditures as investment only if firms are required to capitalize these expenditures for tax purposes.

As my comments indicate, the numbers that Corrado and coauthors have come up with are conservative, and I think that intangible capital investment is larger than their estimate. However, in being conservative in their estimates, I think that they showed good judgment. Only hard numbers should be reported in even a supplementary accounting system. To conclude, this is an important paper that I am sure will spur further research on this very important topic.

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