The Contribution of Intangible Investments to U.S. Economic Growth: A Sources-of-Growth Analysis

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(very preliminary, not for quotation)

Contents:

Key Points/Results

- The results presented in the accompanying tables represent a follow-on study to our first paper on intangibles/knowledge capital, which was presented at the April 2002 CRIW conference on the New Economy (http://www.nber.org/books/CRIW02/index.html). That paper applied basic intertemporal optimization theory to establish the principle that any expenditure intended to increase future consumption at the expense of current consumption should be regarded as saving/investment.

- An immediate implication is that many expenditures on intangibles, e.g., R&D spending, should be treated symmetrically with tangible investment and added to GDP. Intangibles are traditionally treated as current inputs in both macro and firm-level financial practice, although this is beginning to change with the capitalization of software expenditures in the NIPAs and the possible move to a satellite account for R&D.

- Our first paper used our theoretical framework to obtain estimates of the value of business fixed investment in intangibles. We identified three major categories (comprised of nine asset types), developed annual data series starting in the late 1980s, and found that investment in intangibles was approximately one trillion dollars by the late 1990s – roughly the same size as business investment in traditional, tangible capital.

- We view our estimates as a rough cut at the right answer, but as Keynes observed, it is better to be approximately right than to be precisely wrong. Under our expanded view, compared with the current published estimates, nominal output is nearly 10 percent higher during first half of the 1990s and 12 percent higher during 1998-2000. The saving rate also is higher.

- Our first paper provided some provisional estimates of real output in the nonfarm business (NFB) sector, but only from 1988 on. No estimates of the real stock of intangibles (or knowledge capital) were made; nor did we estimate the capital share of income under the expanded definition of capital. We therefore did not present a sources-of-growth (SOG) table that included our intangible capital. This is the goal of the current paper.

- As a first step, we extend our estimates of intangible investment back to the 1950s (using the same general methods as in our earlier paper) and apply the NFB output price deflator to convert the estimates to constant dollars. We then estimate the corresponding stock of intangible capital using plausible assumptions about the service lives of the different types of intangibles. We also estimate intangible capital's share of the expanded value of nonfarm business output.

- The recognition of intangibles has an impact the empirical accounting of factors determining economic growth. We show three tables of results: Table 1 reports growth accounting without intangibles; table 2 includes one major type of intangible, software, and corresponds to the view in published data; table 3 portrays the economy with intangible capital formation treated on a similar footing as that of tangible capital.

- The main result is that the full inclusion of intangibles has a large effect on the average annual growth rate (AAGR) of output per worker in each of the three periods studied: a 0.43 percentage point increase for the 1973 to 1990 period between the no-intangible case of table 1 to our full-intangible treatment in table 3; a 0.26 percentage point increase for the 1990 to 1995 period; and a 0.43 percentage point increase for the period from 1995 to 2002. These increases are very large percentage point changes relative to the no-intangible baseline – and possibly imply that the historical neglect of intangibles (and the current neglect in firm financial accounting) leads to a potentially significant understatement of the true dynamism of the U.S. economy.

- Our second main result is that inclusion of intangibles significantly increases the role of capital as a SOG. The contribution of capital deepening to the AAGR of output per worker in each of the three periods studied is: a 0.46 percentage point increase in the average rate of change from 1973 to 1990 in the no-intangible case (table 1) to the full-intangible case (table 3); a 0.45 percentage point increase for 1990 to 1995; and a 0.68 percentage point increase for 1995 to 2002. The percentage contribution of capital deepening to the AAGR of output per worker is:

	1973–1990	1990–1995	1996–2002
Conventional SOG, w/o any intangibles (T.1)	54%	23%	38%
Conventional SOG, with software (T.2)	57%	34%	46%
SOG with full intangibles (T.3)	67%	47%	56%

- The move to incorporate intangibles into the growth accounting framework leads to a reallocation of the SOG in favor of capital formation, with a reduction in the relative importance of total factor productivity (shades of Jorgenson and Griliches!).

- The move to incorporate intangibles into the growth accounting framework has only a small effect of the acceleration of the growth rate of output per worker occurring after 1995. All methods show a significant increase; 1.12 percentage points in the baseline case of table 1; 1.17 percentage points in table 1; and 1.29 percentage points with full intangibles in table 3.

- Our results also call attention to a generally neglected aspect of intangible investment: the importance of firm specific human capital and training. R&D, software, and brand equity/advertising have all been accepted as potential candidates for inclusion in the list of intangible assets, but our results suggest that firm-specific human capital is also a major part of the intangible investment story.

Algebra

This is a follow on to Section II.D in our paper for the CRIW "New Economy" conference volume.

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The effect of moving to the expanded view has an ambiguous effect on growth rates. The source-of-growth decomposition for the standard view is an variant of original formulation

$$(1) \qquad g_Q = s_K g_K + s_L g_L + g_A.$$

(the g-terms are growth rates, the s-terms are factor shares, and $_Q$ denotes real output, $_K$ and $_L$ are capital and labor, and $_A$ is an index of the level of total factor productivity, or TFP) in which the outputs of consumption (C) and tangible investment (I) are shown separately:

$$(2) \qquad s_C g_C + s_I g_I = s_K g_K + s_L g_L + g_A .$$

This becomes

$$(3) \qquad s^*_C g_C + s^*_I g_I + s^*_N g_N = s^*_K g_K + s^*_R g_R + s^*_L g_L + g_{A^*}$$

when intangible capital is introduced ($_N$ denotes investment in intangibles, $_R$ the accumulated stock of intangibles, adjusted for depreciation, and the asterisk on the efficiency term distinguishes it from the term in 1). This obviously leads to an expanded list of items in the source-of-growth decomposition table, but the effect on Solow residual measure of the change in TFP is potentially ambiguous. The two residuals are linked by the expression

$$(4) \qquad g_{A^*} = \lambda g_A + (s^*_N g_N - s^*_R g_R).$$

(where λ is a factor of proportionality between output in the original formulation and output in the new formultion – see equation 10 in CHS 2004).

The result obtained by Jorgenson (1966) can be applied here to show that the term in parentheses vanishes when an economy has reached its optimal balanced growth path. In this case, the rate of saving, s_N, equals capital's income share, s_R, and the growth rates of investment and capital stock are also equal, $g_N = g_R$. Thus, it really doesn't matter whether intangibles are included or excluded from the growth account along a balanced growth path, except that the

Solow residual is smaller by the factor λ when intangibles are included (for exactly the same reason that a Solow residual computed using gross output tends to be smaller than one computed using a real value added measure of output).

However, it is also true that Solow residual is invariant to the omission of *tangible* capital in the optimal steady state growth. In fact, no form of capital "matters" in this situation, because the source-of-growth decomposition reduces to

(5) $$g_C - g_L = (g_{A*}/s^*_L g_L) = (g_A/s_L g_L).$$

The last two terms are equivalent to the Harrodian rate of productivity change, a familiar result in steady-state growth theory. The standard (Hicksian) Solow residual, g_{A*}, is not invariant to the omission of intangible capital from the analysis, but the Harrodian rate clearly is.

This line of analysis may support the practice of excluding the growth rate of *all* capital from the analysis of TFP (as in Hulten (1979)), but it does not support the current practice of including (or excluding) one type of capital but not the other. In other words, the symmetry principle of the intertemporal analysis is not invalid in optimal balanced growth.

However, there is no reason to assume that the economy is in balanced growth at any point in time, much less at every point in time. This is particularly true when a technological revolution of unexpectedly large magnitude occurs, such as the surge knowledge investment seen during the 1990s in the U.S (CHS 2004; many other possible citations). The capital terms in parentheses in equation (4) would not disappear in this situation, and the weighted growth rate of new investment, $s^*_N g_N$, might well exceed that of the stock, $s^*_R g_R$. In this case, the true growth rate of TFP, g_{A*}, may even exceed that of the conventional g_A. But even if it does not, the change in g_{A*} from one period to the next may exceed that of g_A. This is an issue that is best resolved by empirical work, and, in any event, it is the acceleration in TFP growth (i.e., the comparison of the columns in tables 1, 2, and 3) that matters for the debate over the existence of the "new economy" and the issue of what factors explain the pick up in labor productivity that we have seen in recent years.

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Table 1
Annual Change in Labor Productivity,
Nonfarm Business Sector
<u>Excluding Software</u>

	1973 to 1990	1990 to 1995	1995 to 2002
Labor productivity (percent)[1]	1.27	1.36	2.48
Components (percentage points)			
Capital deepening	.68	.31	.95
IT equipment	.32	.26	.65
Other equipment and structures	.36	.05	.30
Labor composition	.22	.46	.32
Multifactor productivity	.36	.59	1.20

NOTE—Components may not sum to totals because of rounding.
SOURCES—Corrado, Hulten, and Sichel (2004) based on Bureau of Labor Statistics, *Multifactor Productivity Trends, 2001* (2003) and an unpublished update to Oliner and Sichel (2000, 2002).
1. Output per hour of all persons.

Table 2
Annual Change in Labor Productivity,
Nonfarm Business Sector
<u>Published Measures</u>

	1973 to 1990	1990 to 1995	1995 to 2002
Labor productivity (percent)[1]	1.37	1.54	2.71
Components (percentage points)			
Capital deepening	.78	.52	1.26
IT equipment and software	.41	.57	.97
Other equipment and structures	.36	.05	.29
Labor composition	.22	.45	.32
Multifactor productivity	.37	.58	1.13

NOTE—Components may not sum to totals because of rounding.
SOURCES—Corrado, Hulten, and Sichel (2004) based on data from Bureau of Labor Statistics, *Multifactor Productivity Trends, 2001* (2003) and an unpublished update to Oliner and Sichel (2000, 2002).
1. Output per hour of all persons.

Table 3
Annual Change in Labor Productivity,
Nonfarm Business Sector,
Including Unrecognized Investments in Intangibles

	1973 to 1990	1990 to 1995	1995 to 2002
Labor productivity (percent)[1]	1.70	1.62	2.91
Components (percentage points)			
Capital deepening	1.14	.76	1.63
IT equipment and software	.38	.42	.87
Other equip. and structures	.34	.05	.26
Unrecognized intangibles	.41	.29	.50
Computerized information	.00	.00	.00
R&D, scientific	.05	.04	.07
R&D, nonscientific	.08	.08	.14
Brand equity	.05	.03	.07
Firm-specific human and structural resources	.24	.14	.22
Labor composition	.20	.41	.28
Multifactor productivity	.36	.46	.99

NOTE—Components may not sum to totals because of rounding.
SOURCES—Authors calculations based on data in Corrado, Hulten, and Sichel (2004), Bureau of Labor Statistics, *Multifactor Productivity Trends, 2001* (2003); and an unpublished update to Oliner and Sichel (2000, 2002).
1. Output per hour of all persons.

Assumptions:

1. The table that includes intangibles is based on the following assumptions:

-- uses the CHS (2004) investment series based on a 1-year cutoff
-- uses the business output deflator to deflate intangibles
-- uses the following service life assumptions:

computerized info other than software	5 years
R&D, scientific	15 years
R&D, non-scientific	10 years
Brand equity	2 years
Firm organization and training	10 years.

2. The investment series developed in Corrado, Hulten, and Sichel (2004) from 1988 on have been taken back to the early 1950s using generally the same methods. However, in some cases, we could not use the same data sources, and figures were extrapolated using related series. This occurred most prominently for the data series from SAS, which are not available prior to 1985 and were extrapolated using a related aggregate in BEA's gross product by industry system. (Tables of the investment data are available upon request).

3. The calculations reported in the tables use the same methods as Oliner-Sichel (2000, 2002).