R&D IN THE NATIONAL INCOME AND PRODUCT ACCOUNTS: A FIRST LOOK AT ITS EFFECT ON GDP

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Introduction

Technical change has long been considered a major source of economic growth. Since Solow s famous article identifying technical change as a source of growth, analysts have been trying to measure its contribution.[2] Technical change and innovation are usually attributed to research and development (R&D) efforts made by individuals, firms, and governments. Although the existence of a link between R&D, technical change, and economic growth is widely acknowledged, this link is difficult to quantify because the benefits from, or the output of, R&D, a critical component of the link, are not easily measured.

The spurt in GDP growth in the latter half of the 1990's, from 2.8 percent per year in 1973-95 to 4.2 percent per year in 1995-2000, has renewed interest in the sources of economic and productivity growth. Indeed, past R&D spending, particularly in information technology (IT) industries, may be considered an important contributor to this increased growth and the emergence of the new economy. According to our estimates, in 1995-2000, the annual rate of growth of real R&D accelerated to 9 percent from 4 percent in 1973-95 (see Table 1 and

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[2]Solow (1957).

Appendix Table 1). Almost all of this acceleration is the result of growth in business R&D which accounts for at least two-thirds of R&D (Chart 1), although R&D spending by nonprofit institutions and general government also contributed to the acceleration.[3] In addition, information technology industries increased their share of total R&D spending from 27 percent in 1992 to 32 percent in 1998.[4]

There are similarities between the 1995-2000 period and the 1961-66 period a period which is often viewed as a heyday of U.S. economic and productivity growth in terms of the annual rate of growth of R&D, 9 percent compared to 8 percent, respectively, and an above average annual rate of growth of GDP, 4 percent and 6 percent, respectively. There are also differences. During the 1995-2000 period, R&D expenditures by business grew faster than expenditures by nonprofit institutions and general government, and represented the bulk of R&D performance (75 percent for business compared to 8 percent for general government and 17 percent for nonprofits). During the 1961-66 period, R&D expenditures by nonprofit institutions and general government grew faster than that of business, and accounted for almost 30 percent of R&D performance (compared to over 70 percent for business).[5] The nature of R&D performed by businesses, nonprofit institutions and general government has also changed over the two

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[3]The rate of growth of real R&D has been higher over the period covered by the National Science Foundation s (NSF s) series on R&D (National Science Board, 2000). In our estimates the rate of growth of real R&D is 11 percent per year from 1953-61.

[4]See U.S. Department of Commerce (February 2002, Appendix, p. 13). This level of industry data is not publicly available from the National Science Foundation on a consistent time series basis (industry detail is on a 2- to 3-digit SIC basis, with many cells unavailable because of disclosure problems). Thus, earlier estimates of the share of detailed IT producing industries could not be provided.

[5]National Science Foundation (2001).

periods. In the past, according to NSF data, general government performed the bulk of basic research (that is, work undertaken to acquire new knowledge without any particular application in mind),[6] accounting for about 75 percent of basic research in 1961-66. The share of general government performance of basic R&D has declined over time from 15 percent 1961 to 7 percent of total basic R&D by 2000, while that of business performance rose from 26 percent in 1961 to 34 percent of total basic R&D in 2000 and that of nonprofit institutions has stayed relatively constant (around 60 percent).[7] In addition, 1961-66 was preceded by a period of high growth in R&D. In the1960's and early 1970's, general government (own account and others, net of others funding of general government) funded the bulk of total R&D, especially for defense and the space race. Its share has declined steadily from 66 percent of the total in 1961-66, to 32 percent in 1966-2000. Moreover, while general government funding of nonprofit institutions R&D has been relatively stable at 7 percent of total R&D, its support of R&D performed by business has fallen from over 40 percent of total R&D in the 1961-66 period to 10 percent in 1996-2000. This decline in general government financing of R&D performed by business reflects, in part, the de-

[6]The other two categories of R&D are applied research, aimed at gaining the knowledge to meet a specific recognized need, and development, which is the systematic use of the knowledge gained from research directed toward the production of useful materials, devices, systems, or methods. See National Science Board (1998), p. 4-9.

[7]National Science Board (1998, Chapter 4); National Science Foundation (2001).

emphasis in government programs in defense R&D.[8] Another difference is the rise in the importance of information technology (IT) R&D.[9]

Although economic growth in the second half of the 1990's and in the 1960's are both above trend, these differences between the two periods need to be taken into account, in terms of who is performing the R&D and the beneficiaries of the R&D, the character of the R&D, and the life to the R&D capital. Broader conclusions about the effect of R&D on the new economy depend on factors about which little is known, such as the obsolescence rate of knowledge. Moreover, because economic growth depends on accumulated knowledge stock, the full effect of the recent spurt in R&D on the economy may not be realized for a number of years.

This paper presents a preliminary and exploratory examination of the role of R&D in the U.S. economy in terms of a partial R&D Satellite Account (R&DSA).[10] It extends the National Income and Product Accounts (NIPA s) framework, treating R&D as an investment. It uses the growth accounting model to identify R&D as a separate factor contributing to economic growth and estimate the returns to R&D investment. Rates of return to R&D are drawn from past analyses of rates of return, and estimates of the R&D investment and capital stock balance sheet

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[8]National Income and Product Account (NIPA) Table 3.11 shows little growth (1 percent between 1982-2000) in government expenditures for defense R&D. Defense R&D peaked in 1987 (National Science Foundation, 1998).

[9]The increase in the importance of IT R&D relative to R&D in industries other than IT is reflected in patent data. These data indicate that the shares of total patent applications for computers and communications has risen steeply from 5 percent in the 1960s to 20 percent in the late 1990s, and applications for electrical and electronics had a steady share at 16-18 percent. Shares of the three traditional fields (Chemical, Mechanical, and Others) declined from 76 percent in 1965 to 54 percent in 1997. See Hall, Jaffe, and Trajtenberg (September 2001), p. 13 and Figure 5.

[10]For a description of a full R&DSA, see Fraumeni and Okubo, 1999 and 2001.

presented in a previously published R&D satellite accounts by the Bureau of Economic Analysis are updated.[11] An additional extension is an imputation of a net return to general government capital which is not included in the current national accounts. This approach provides a more comprehensive measure of investment than currently available, and shows the importance of R&D in economic growth.

Capitalizing R&D changes the estimates of GDP, the components of the accounts, and the growth of GDP. It has a very small effect on the rate of growth of real GDP, but a significant effect on the composition of GDP and on our understanding of the sources of economic growth. Capitalizing R&D raises investment and therefore savings and GDP. Over the 1961-2000 period:

--- R&D is a significant contributor to economic and productivity growth, with the contribution of R&D investment accounting for 3 of overall GDP growth and the contribution of returns to R&D capital accounting for 10 percent of GDP growth. Capitalizing R&D increases the rate of growth of GDP by 0.1 percentage point.

--- The treatment of R&D as investment and the imputation of a net return to general government capital changes the distribution of consumption and investment in the economy and raises the national savings rate by 2 percentage points, from 19 to 21 percent.

--- R&D investment is on average 13 percent of current fixed investment; R&D fixed capital stock adds 6 percent of current fixed capital stock.

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[11]Carson, Grimm, and Moylan, 1994. For a description of how the estimates from that project were updated, see the technical appendix.

--- The share of property-type income in Gross Domestic Income (GDI) rises by 2 percentage points, of which R&D property-type income is 1 percentage point and the addition to property-type income from imputing a net return to general government capital is 1 percentage point.

--- Returns to R&D capital represent 19 percent of property-type income.

--- Regardless of the alternative assumptions made about R&D service lives, depreciation, lag in benefits, or deflators, R&D appears to be a significant contributor to economic and productivity growth, with the contribution of R&D investment ranging from 2 to 7 percent of GDP growth and the contribution of returns to R&D capital ranging from 6 to 14 percent of GDP growth.

Background

Neither the national income and product accounts (NIPA s) nor the standard growth accounting model has adequately taken into account R&D s contribution to the country s stock of knowledge and to the economy in general. R&D is not capitalized in the NIPA s and growth accounting models have typically not separated out R&D.

A country s national accounts ideally provide measures of the composition and growth of its economic activity. However, to the extent that they do not include all economic activities or classify some expenditures as intermediate when they actually represent a final use, the accounts are an incomplete basis for measuring a country s potential for growth including productivity growth. In particular, not taking into account R&D investment, like education and other types of intangible capital, understates investment, net wealth, and national savings.[12] This understatement is larger if intangible capital has risen in importance in the U.S. economy over the past decade, as some have argued.[13]

NIPA measures of investment include plant, equipment, and inventories acquired by private businesses, nonprofit institutions, and government, and net foreign investment, and exclude household consumer durables, as well as most intangible capital, such as R&D and, until 1999, software. R&D expenditures are treated as an intermediate input for businesses and current consumption for nonprofit institutions and general government. Yet, R&D uses resources to create products or output for future, rather than current, consumption, and in many cases, provides output and benefits long into the future, especially with 17-year, or more recently 20-year, patent protections. In this way, R&D more closely resembles investment than intermediate inputs or current consumption. R&D adds to the stock of knowledge or productive capital and wealth, and provides a flow of services from this stock over time, rather than in one period, depreciating over time like plant and equipment. Accordingly, R&D expenditures should be capitalized and depreciated and treated the same as other NIPA investment.

Treating R&D expenditures as investment in the NIPA s would make these expenditures fully comparable to other expenditures on intangibles, such as software that are already considered investments.[14] This treatment represents a step toward producing a comprehensive

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[12]See Eisner (1989, Chapters 1 and 2); Kendrick (1976, pp. 9-11).

[13]See for example, Nakamura (2001).

[14]Software was capitalized beginning with the 1999 comprehensive NIPA revision. For a description of the methodology and quantitative impacts, see Bureau of Economic Analysis (2000).

and more accurate measure of investment and savings in the U.S. NIPA s, as well as capital stock and depreciation, the value of services from R&D and other fixed capital and net domestic product, and as a result, improved measures of economic output and growth.[15] It provides a basis for addressing important macroeconomic, technology, and tax policy concerns and better informs policy makers about the true size of national saving, and the nature of choices being made between current and future consumption.

Although this treatment provides conceptually improved estimates of output and growth, R&D is not be treated as investment in the NIPA s for several reasons. First, R&D expenditures do not have an easily identifiable set of assets that can be measured or valued in a balance sheet.[16] Unlike plant and equipment and software, R&D capital is not generally sold for a market price. Thus, estimating services from R&D capital cannot be easily imputed from a representative set of market values as can be done, for example, with imputed rents from owner-occupied housing. It is usually measured on an investment cost basis, and does not represent a final demand value. Second, the rate of return to business R&D is included in the returns to all fixed capital -- plant, equipment, and R&D; separating out the returns to R&D is as thorny problem as estimating services of R&D capital. A third and related problem is one of appropriability; other private producers may also benefit from the R&D, either as imitators or as buyers of the new product incorporating the new technology. Also difficult to determine are spillover benefits from nonprofits and government R&D investments, and those spillovers, such

[15]Eisner (1989), pp. 14-17.

[16]See System of National Accounts 1993, for discussion of treatment of R&D in the national accounts, pp. 9-10, para. 1.51.

as pollution reduction R&D, from which society as a whole benefits and for which no market exists. Other problems in measuring R&D capital and R&D services include the choice of deflators, service lives, depreciation, the rates of return, and the lag structure, or the length of time before the benefits from R&D are realized.

These problems create uncertainty with estimates of R&D capital and its rate of return, but can be addressed by using a supplemental or satellite account. Satellite accounts provide a means of experimenting with methods of estimating R&D capital and alternative scenarios of R&D returns to get a picture of the order of magnitude of the size and impact of R&D capital on GDP, without reducing the usefulness of the main accounts. In this paper, the R&D satellite accounts: (1) capitalize R&D expenditures; (2) impute a return to R&D capital, both private and social; (3) estimate the impact of R&D investment on GDP growth; (4) provide adjusted estimates of investment, capital stock and wealth, saving, and returns to fixed capital, other than R&D. It tests the sensitivity of the estimates using alternative assumptions about the R&D deflator, depreciation rates, and the lag structure.[17] It uses a growth accounting model to estimate the returns to R&D capital.

Growth accounting models have been used to analyze the relationship between output and inputs in production and to determine the contribution of inputs, including R&D.[18] They are part of a rich tradition examining the sources of economic growth, including productivity growth, as epitomized by the work of Edward F. Denison, John W. Kendrick, Dale W. Jorgenson and his

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[17] These issues are addressed in the technical appendix.

[18] See op. cit., Solow (1957); and OECD (2001), Annex 3.

co-authors, and others such as Stephen D. Oliner and Daniel E. Sichel.[19] R&D expenditures have been listed as a possible cause of productivity growth in the attempts to identify the factors behind the so-called Solow residual.[20]

The basic growth accounting model starts with a production function which specifies output as a function of inputs and productivity change.[21] The model may be implemented at an aggregate or disaggregated level, e.g., specifying GDP as a function of capital and labor inputs or specifying industry gross output as a function of intermediate, capital and labor inputs. Productivity measures may be single of multi-factor productivity measures. The level of implementation and whether single or multi-factor productivity measures are used, as well as other factors, impact on the specific form of the growth accounting model.[22]

R&D input in sources of economic growth models, parametric or non-parametric, frequently is measured by an index of R&D expenditures or R&D stock. It is also sometimes measured by the number of employees involved in R&D, the average age of tangible capital under the assumption that technology is embodied in capital, or by the return to R&D capital. Direct measures of R&D input are used less frequently than direct measures of intermediate,

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[19]See Denison (1985); Kendrick (1973); Jorgenson, Gollop, and Fraumeni (1987); Jorgenson and Stiroh (2000); Oliner and Sichel (2000); and Jorgenson (2001).

[20]See Denison (1979), pp. 122-127; and Kendrick and Grossman (1980), pp. 10, 16-18, and Chapter 6, pp. 100-111.

[21]See Bureau of Labor Statistics (1989); and National Science Board (1996), Chapter 8.

[22]These other factors include whether it is assumed productivity change is factor augmenting, neutral or biased, and whether technical change is embodied in factors or disembodied. OECD (2001) includes a discussion of all these factors and their implications for the model.

capital, or labor input, in part because of the difficulties in estimating a rate of return to R&D stock and depreciation required to measure R&D input. Inputs to the R&D effort are typically used -- R&D expenditures and R&D employment -- as a way of gauging the new knowledge created by R&D. Of the two, R&D expenditures is more often used since it includes expenditures on other inputs besides labor. With R&D, the existence of both direct and indirect (spillover) effects from R&D increase the measurement challenge.

In this paper, R&D input refers to R&D performance (as opposed to funding) by business, government, and nonprofit institutions, and is measured by the return to R&D capital. A sources of economic growth approach is used, and the contribution of R&D capital to growth in GDP is measured by the current dollar share of returns to R&D capital (R&D property-type income) in GDP times the rate of growth of R&D capital. This methodology assumes constant returns to scale, and that factors, including R&D capital, are chosen to minimize costs and are hired until the marginal revenue products of these factors are equal to their purchase price.[23]

Private and Social Returns to R&D Capital and Their Inclusion in the Accounts

In its simplest formulation, ignoring taxes, the service value of an asset, including R&D, should equal the reduction in the value of the asset due to its use during the current period (depreciation) plus a net return equal to the current value the asset could earn if invested elsewhere (opportunity cost).[24] According to the theory of the firm, investments will be made only if the expected gross return from those investments over the long-run at a minimum covers

[23]See equation 2 of this paper and Annex 3 of OECD (2001), particularly pp.124-6.

[24]See Parker, Dobbs, Pitzer, Triplett, and Herman (September 1995), p. 34.

depreciation, plus a net return equal to the opportunity cost of the funds. The actual gross return may be more or less than the expected. However, if in the long-run actual gross returns are less than depreciation plus a net return equal to opportunity cost of the funds, these investments will no longer be made. Normally this minimum gross return condition is met, which implies that the net return is positive. Estimates of the gross return to capital must separate returns to R&D from returns to other types of capital. Returns to R&D include returns to R&D performed by the entity (private returns to in-house R&D) and spillover returns from R&D performed by others.[25] Frequently these two types of returns are called direct effect and indirect effects, respectively. Indirect effects (spillovers) include the benefits from the use of higher quality or new inputs developed through R&D undertaken by others and benefits from technology transfers.[26] [27] Indirect effects can also include the unpaid-for benefits from new and improved consumer goods and services. Together, these two effects, equaling the total returns to R&D capital, could be very large.

The following graph is used to identify what is included and excluded in current measures of GDP and GDI.[28]

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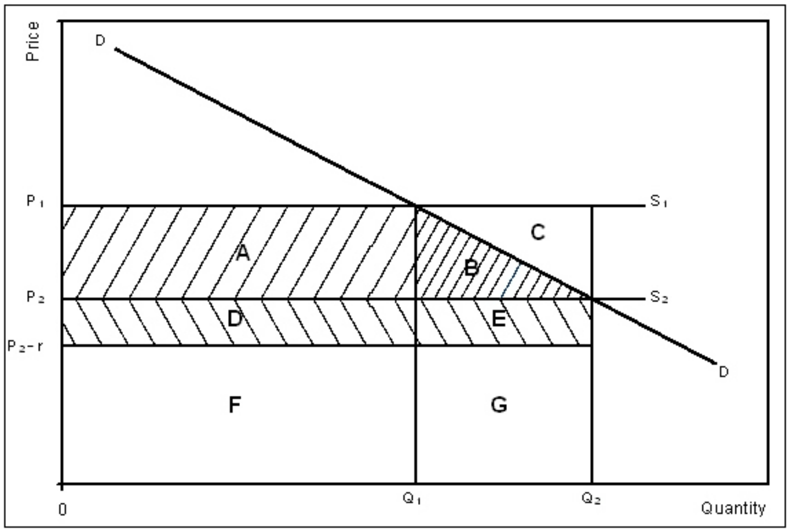
[25]Using a performer basis begs the question of whether it is the performer or the funder, if different from the performer, who receives the private return.

[26]See Bureau of Labor Statistics (1989), op. cit., p. 5.

[27]Griliches distinguishes between two types of spillovers. One is the spillover from purchasing the results of R&D inputs at less than their full quality price. This spillover reflects a problem of measuring improvements in the quality of capital and materials and their prices correctly. The second type are knowledge spillovers, and refers to ideas borrowed by research teams in one industry from the research results from another industry. See Griliches (1995, pp. 65-66).

[28]See Mansfield, et. al. (1977).



The graph shows the benefits from a product innovation that reduces the cost of an industry using the innovation. The product innovation reduces the price or cost per unit of output of the industry using the innovation from P_1 to P_2 and increases the output of that industry from Q_1 to Q_2.[29] The sum of all hatched areas: A, B, D, and E, show the economic benefits from the innovation. Area A plus area B show benefits derived by buyers of the product innovation. Area A is the difference between what they had paid for Q_1 (P_1*Q_1) and what they now pay for Q_1 after the innovation (P_1*Q_2). Area B is the difference between the maximum amount consumers would have been willing to pay as determined by the demand curve -- for each marginal unit of the product greater than Q_1 up to Q_2 and what they actually paid $P_2*(Q_2-Q_1)$. Area D plus area E

[29]A similar graph could be used to illustrate the case of product innovation used by households.

shows the gross profit,[30] equal to r dollars per unit, received by the innovator, which is assumed to be transferred from the firm using the innovation to the innovator; thus potential spillover benefits to the innovation-using firm are appropriated by the innovating firm.[31] The graph assumes that the market structure of the industry using the innovation is competitive and that the supply curve is perfectly horizontal in the relevant range.[32]

Because GDP measures what is actually paid for a product in any given time period, rather than what consumers would have been willing to pay, GDP in any given time period does not measure the consumer surplus gain associated with the innovation, but only measures the resource saving, area D plus area E, which is indistinguishably included in the gross profits of the innovator and in the expenditures of the consumer.

However, when one looks at changes in nominal GDP from one period to next, the resource savings to consumers on the old quantity, area A, will likely be included in the change

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[30]The term gross profits is used as profits include depreciation on the investment in the innovation.

[31]P_2-r is the innovators per unit cost of production and P_1 is the price for the innovation received by the innovator under the assumption that the gross profit is transferred to the innovator.

[32]If other firms in the supplying industry imitate the innovator and the market structure of the industry supplying the innovation is competitive, although in the short-run economic profits may be earned, in the long-run economic profits will be zero. Alternatively, if the market structure of the supplying industry is not competitive, then economic profits may be earned even in the long-run.

in GDP as spending on other goods and services.[33] Thus, what will not be measured in nominal GDP will be the triangle area B, the Harberger triangle.[34]

What is included in changes in real GDP is a bit more complicated. A Laspeyres index of changes in real GDP will overestimate the change in real GDP in period two because it will include not only the entire consumer surplus gain – areas A and B but also the area C. This overestimate occurs because the Laspeyres index values the entire output in period two in at period one prices $(P_1*Q_2)/(P_1*Q_1)$. A Pasche index will underestimate the change because it includes none of the consumer surplus gain. The Pasche index values the period one output at period two prices and thus includes only the areas D and F for period one in valuing the increase in real GDP in period two $(P_2*Q_2)/(P_2*Q_1)$. However, the Fisher, a chain index, which is a geometric mean of a Laspeyres and Pasche index approximately includes the value of the consumer surplus gain area B excluded from the nominal GDP calculation and the change in real GDP will be an average of the changes produced by the Pasche and Laspeyres indexes.

This paper assumes that market benefits to business R&D direct and spillover are included in somewhere in current national accounts measures. That is, in contrast to the simple example presented, the innovator is often not paid for the spillover benefits to firms using the innovation, but in the following estimates it is assumed that they appear in the aggregate property

[33]Unless labor and or capital supply is reduced.

[34]The Harberger triangle is defined as the consumer surplus gain with a decrease in price from P_1 to P_2 excluding the consumer surplus gain that is part of the total amount P_1*Q_1 paid for the product at the higher price.

income estimates. (Extension of this aggregate analysis to the industry level would have to address this issue.[35])

A number of researchers have estimated the private and social rates of return to private R&D capital. In general, these returns are gross returns, including both the net return to capital and depreciation (U.S. Department of Labor, 1989, p. 39). Table 3 provides a summary of estimated rates of return to private R&D,[36] arranged by lowest to the highest private rate of return estimates. Private rates of return average from 20 to 30 percent. These private rates of return reflect the returns received by the innovator. Social rates of return, which include the splliover benefits, are much higher, ranging from an average lower bound of about 30 percent to an average upper bound of 80 percent. Although, researchers have in various ways attempted to include nonmarket benefits, for the most part they reflect spillovers that we assume are already included in GDP.

The private rates of return to R&D based on these studies are considerably higher than the average returns to other types of investments. It can be argued that R&D investments would require a higher rate of return than other investments because of the risk and uncertainty attached to R&D. There are more failures than successes associated with R&D investments the rule of thumb often used is that for every successful project, there are ten failures. In addition, businesses investing in the R&D must take into account the likelihood of imitation by competitors, and also the uncertainty in the timing of commercialization of the R&D project,

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[35]In order to undertake an industry analysis including spillovers, interindustry technology flow estimates similar to those developed by Scherer (1984) would have to be constructed.

[36]See Council of Economic Advisors (CEA) (1995), p. 5. The CEA table is adapted from Griliches (1992) and Nadiri (1993).

especially for basic and applied research. Because of the wide range of estimated rates of return, the assumption made is that the average private rate of return is 25 percent, and the average social rate of return, which includes spillovers, is 50 percent.[37]

In contrast to the returns to private R&D, the returns to nonprofit institutions and general government R&D is less likely to be included in the existing measure of GDP. This is partly due to the way in which nonprofit institutions and general government are counted in GDP and partly due to the different nature of nonprofit institutions and general government R&D. Because the output of nonprofit institutions and general government is for the most part not sold in markets, their output is assumed to be equal to their input costs. Since there is no input cost associated with R&D beyond the original investment period and the R&D output is not sold in markets there is no direct value put on the returns to R&D and the value of nonprofit institutions and general government is understated. Secondly, because much of the output of nonprofit institutions and general government R&D is likely to be in nonmarket goods and services, such as reduced morbidity and mortality, they are less likely to be included in GDP which is a measure of market .

Because the focus of nonprofit institutions and general government R&D is less likely to be focused on nonmarket benefits and does not have to pass the market test that private firms do,

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[37]A recent Joint Economic Committee Staff Report (U.S. Congress, 1999, p. 12) concluded that it is reasonable to assume that the private rate of return is about 25 percent and that the social rate of return is about twice as high as the private rate. The Economic Report of the President concludes that the social return to R&D averages about 50 percent (Economic Report of the President, 1995, Box 3-5, p. 122). A recent study of patenting by R&D laboratories of a manufacturing firm conducting R&D estimated the average private rate of return to product R&D to be about 21 percent (Arora, Ceccagnoli, and Cohen, 2002).

their rate of return on R&D is arbitrarily assumed to be two-thirds of the rates of return to private R&D: 16.7 percent for the private rate of return and 33.4 percent for the social rate of return.

Table 2 lists the assumptions made regarding what type of benefits are included in the current NIPA tables and what benefits are included in the estimates in this paper. It also lists the gross rate of return on R&D capital assumptions for all performing sectors, and other assumptions regarding the R&D deflator, the depreciation rate, and the lag structure.

Property-type Income, Gross Returns to Capital, and Contributions

The growth accounting model provides the basis for estimating the returns to R&D capital. By typically excluding R&D capital, past analyses of sources of economic growth have attributed property-type income to fixed assets other than R&D capital. Accordingly, the rate of return to fixed assets has been overstated. Recognizing returns to R&D capital, as distinguished from returns to other types of capital, provides a means of determining its size relative to other types of traditionally measured returns to capital, and therefore, R&D s relative contribution to economic growth.

The basic constant dollar equation in the growth accounting model is:

(1) ROG of Q = ${}_K$* ROG of K + ${}_L$* ROG of L + , where

${}_K$ = current dollar property-type income share = rS/p_QQ,

${}_L$ = current dollar labor income share = wL/p_QQ,

p_Q is the price of output, Q is real output, K is real capital input, r is the rate of return on capital, S is real capital stock, w is the wage rate, L is real labor input, is the rate of productivity change, and ROG is the abbreviation for rate of growth.

Equation (1) is revised to include R&D capital as follows:

(2) $\text{ROG of } Q = {}_{R\&D} * \text{ ROG of } K_{R\&D} + {}_{O} * \text{ ROG of } K_{O} + {}_{L} * \text{ ROG of } L +$,

where the subscript R&D refers to R&D capital and O refers to all other capital. Equation (2) separates out R&D and allows the computation of asset specific rates of return for R&D capital and all other capital. It expands on past analyses in explaining sources of GDP growth, and its estimation affects estimates of productivity change.

The basic identity in current dollars is that output is equal to the sum of property-type income and labor income. Gross return to capital is defined as property-type income divided by fixed capital stock. Distinguishing R&D fixed capital stock and property-type income from fixed capital stock, other than R&D, and the related property-type income allows for the estimation of gross rates of return for R&D capital, as distinct from all other capital. Property-type income is the same as what would be used in the construction of the alphas, the income shares, in equation (1) and (2).

The gross rates of return and two types of R&D contributions to economic growth are calculated in this paper. The first contribution, from the product- (demand) side, looks at the contribution of R&D investment to GDP growth. The second contribution, from the income- (supply) side, looks at the contribution of returns to R&D to GDP growth. The income-side calculation estimates the R&D component of equation (2) above.

Changes to the National Accounts

Capitalizing R&D produces several changes in the national accounts, in terms of the composition and level of GDP. First, capitalizing business R&D raises investment on the product side, raising GDP. Income increases by an equal amount because R&D is no longer expensed, and R&D capital is depreciated, raising profits (property-type income). Second, property-type income from all R&D capital is estimated separately from other fixed capital (and as a share of total property-type income). Third, capitalizing R&D expenditures by nonprofit institutions and general government [38] increases investment, but lowers their consumption by the same amount, and as a result, does not change GDP. Nonprofit institutions consumption is part of personal consumption expenditures (PCE) in the accounts, and general government consumption is part of government consumption. However, GDP rises by the value of imputed services or returns to R&D capital (measured by depreciation plus the return on capital) from nonprofit R&D capital. On the product side, the imputed services from nonprofit institutions and general government R&D capital consumed in the current period adds to total consumption. On the income side, unlike business R&D capital where the return is already included in property-type income, depreciation and return to nonprofits R&D capital must be added. Fourth, to improve comparability of government and other types of capital including R&D capital, a net return to general government capital is also imputed in the adjusted accounts. These returns are a net addition to GDP and GDI as the return to general government capital in the current national account measures is set equal to depreciation which implicitly assumes that the net rate of return

[38] The expenditures include those by Federally Funded Research and Development Corporations (FFRDCs). Government entities which perform R&D, such as public colleges and universities, are all classified as being part of general government.

to general government capital is zero.[39] [40] This adjustment is an extension of current methodology for government investment in the NIPA s.[41] Finally, these reclassifications of R&D expenditures and imputations of returns to R&D capital change the composition of GDP. Investment rises and consumption falls, while the level and rate of savings increase. Similarly, capital stock expands.

Adjusted National Account Tables

Treating R&D as investment and computing rates of return to R&D change the estimates of GDP and the components of the accounts. These changes, showing expanded detail for R&D, are presented in three sets of NIPA tables Tables 4, 5, and 6. Appendix Tables 1, 2, and 3 are abbreviated versions of these tables listing data in 1996 dollars for selected years: 1961, 1966, 1973, 1995, and 2000.

Table 4 shows the adjusted GDP table, when R&D components are added and reclassifications made within GDP.[42] Two changes to GDP are made: the first is related to R&D investment; and the second to returns to R&D stock. Under all investment categories,

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[39]The net return to nonprofit institutions and general government software capital in the national accounts is also set to zero.

[40]Government enterprises are treated like businesses in the national accounts as they sell a substantial part of their costs by selling goods ans services to the public. The current surplus of government enterprises is the profit-like income of government enterprises, which implicitly includes a return to other than R&D capital. See BEA (November 1988) pp. 6-8 and Parker, et. al. for a discussion of the treatment of government enterprises.

[41]While using depreciation as a measure of the value of services of general government fixed assets represents only a partial measure of the total value, it was a first step in recognizing government investment to be consistent with the SNA93. See Parker, et. al. (September 1995).

[42]This table is based NIPA Tables 1.1 and 1.2.

Completed Research and Development and Change in R&D-in-Progress are added. The sum of these two categories is equal to R&D expenditures. Estimates of the return to R&D capital, broken out by net return and depreciation, are also added under consumption for nonprofit institutions and general government. Estimates are made of the return to general government capital, other than R&D capital, with the net return component of this being a new imputation.

The largest R&D cross-funding category is general government funding of R&D performed by business.[43] As this cross-funding is in government consumption in our current measure of GDP, when R&D is capitalized GDP rises by R&D performed by business less that part funded by general government. Government funding of R&D performed by others as well as self-funded (own) R&D is subtracted from government consumption; nonprofit institutions funding of R&D performed by others as well as own R&D is subtracted from PCE. Investment of the performing sector is increased by the amount of R&D performed.[44]

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[43]General government funds R&D performed by business and nonprofit institutions R&D, business funds R&D performed by nonprofit institutions and general government, and nonprofit institutions fund R&D performed by general government. Of these five cross-funding categories, only general government funding represents more than 1 percent of total R&D expenditures. According to our estimates, from 1961-2000 general government funding of business represented on average 34 percent of total R&D expenditures, while general government funding of nonprofit institutions represented 7 percent. The treatment of all cross-funding, except in the case of general government funding business, depends on whether the funding is a transfer or a contract.

[44]Some government R&D investment is already capitalized in the current national accounts measures. Adjustments are made to deduct what can be specifically identified: R&D software defense expenditures, from the estimates of other than R&D investment, capital stock, and depreciation.

Table 5 shows an adjusted Relation of Gross Domestic Product, Gross National Product, Net National Product, National Income, and Personal Income table.[45] Including R&D in the accounts requires estimates of Consumption of R&D Capital for all performing sectors. Also needed are Subsidies Less Current Surplus of Government Enterprises and Current Surplus of General Government as the surplus will change both because of the R&D and net return to other than R&D capital imputations.

A fundamental identity of national accounts is that GDP must be equal to GDI for the economy as a whole.[46] Accordingly, when there is an addition to GDP, GDI must change as well. Table 6 shows changes needed in the Components of GDP by Industry Group table[47] to reflect returns to R&D capital for all performing sectors. As before, net return and depreciation are shown separately. For government property-type income, returns to R&D capital and a net return on fixed capital is estimated for government enterprises.

Empirical Results

The estimates presented in this paper reflect two changes in the national accounts: 1) the capitalization of R&D, and 2) the imputation of a net return to all general government capital in order to improve comparability of the measures for all types of capital, including R&D. To

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[45]Table 5 is based on NIPA Tables 1.9 and 1.10. NIPA Table 1.10, the 1996 dollar table, has significantly fewer entries than Table 1.10; Appendix Table 2 is directly comparable to NIPA Table 1.10.

[46]Of course, in practice, GDP does not equal GDI because their components are estimated using largely independent and less-than-perfect source data; the difference between the two measures is the statistical discrepancy. See Parker and Seskin (August, 1997), p. 19.

[47]Table 6 is modeled after Table 3, from Lum and Moyer (November 2001), p. 27.

isolate the effect of capitalizing R&D, the impact of capitalizing R&D is separated from that of the imputing a net return to general government capital. The terms adjusted measure without further qualification and all changes refer to the incorporation of both changes. As Table 7 shows, the largest current dollar net addition to GDP is the addition from imputing a net return to general government capital. As the shares of GDP indicate, current dollar returns to R&D capital is on average more than double the magnitude of current dollar R&D investment.

In most tables six periods are examined: 1961-66, 1966- or 1967-73, 1973- or 1974-95, and 1995- or 1996-2000.[48] The analysis begins in 1961 because it is the earliest year for which estimates of R&D capital stock can be made, given that a three-year lag structure is assumed.[49] The period 1961-66 is considered the heyday of economic and productivity growth, with an average rate of growth of almost 6 percent a year. The 1961-66 and 1995-2000 periods are often compared to each other because each were periods of not only strong economic growth but also sustained high rates of growth in R&D. 1973 is a natural ending point for the next period because it is the peak of the business cycle, the beginning of the energy crisis, and the start of the

[48]When growth rates are calculated the periods are: 1961-66, 1966-73, 1973-95, and 1995-2000; when averages or contributions are calculated the periods are: 1961-66, 1967-73, 1974-95, and 1996-2000.

[49]This paper updates earlier estimates of R&D capital stock produced in Carson, Grimm, and Moylan (1994). These earlier estimates are based on National Science Foundation data on R&D expenditures that begin in 1953; the capital stock estimates do not begin until 1959. It assumed a one-year gestation lag, or time needed to complete an R&D project. The capital stocks do not begin until 1959 because this is the first year with a one-year lag for which stock estimates were judged to be fairly insensitive to the choice of benchmark value. The alternative assumption used in this paper is a three-year gestation plus application lag structure, and thus the R&D stock estimates in this paper begin with 1961.

productivity slowdown in the United States. 1995 is a natural starting point for the next period as the term new economy is commonly associated with the second half of the nineties.[50]

Savings, Investment, and Wealth

Capitalizing R&D has a significant effect on measures of savings, investment, and wealth. In the current measures of the national accounts, R&D is treated as consumption or as an intermediate input, rather than investment. Capitalizing R&D raises the estimate of investment, and therefore, the estimate of national savings. R&D investment and R&D fixed capital stock, an important component of wealth, are large relative to current measures of investment and stock. Business performers account for more than two-thirds of R&D investment and capital stock. Notable period-by-period differences in the growth rate of R&D investment by performing sector may have had, and continue to have, an impact on economic growth.

Table 8 shows that capitalizing R&D raises the national savings rate by around 2 percentage points. As defined in NIPA Table 5.1, the national savings rate is equal to gross investment (the sum of gross private domestic, gross government, and net foreign investment) less the statistical discrepancy, divided by Gross National Product (GNP). Imputing a net return to general government capital lowers the national savings rate by 0.4 percentage point as the numerator of the savings rate expression (savings) stays constant but the denominator (GNP) goes up. Government gross investment is already recorded in the national accounts. Net return to general government capital is not recorded in the national accounts. Accordingly, imputing a

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[50]See Appendix Table 1 for a listing of the levels and growth rates of real R&D expenditures for 1953-2000.

return to general government capital increases GDP (see Table 7) and GNP, and lowers the national savings rate. However, on net, after both adjustments the national savings rate is higher.

Although the 1961-66 and the 1995-2000 period appear to be quite similar, there are some notable differences as mentioned earlier.[51] Overall rates of growth of real R&D investment are about the same (see Table 1).[52] However, in the most recent period, 1995-2000, acceleration in business R&D is the major catalyst for the high overall rate of growth, yet in the earlier period, it is nonprofit institutions and general government.[53] In addition, the earlier period was preceded by a period, 1953-61, of high rates of growth in real R&D investment.[54] There was a significant shift in the composition of R&D investment between 1953-60 and 1961-66, with business decreasing its share of investment in 1961-66 and nonprofits institutions increasing its share. The composition of R&D investment by performers in 1961-66 and 1995-2000 are quite similar (Chart 1).

With the runup in R&D investment in 1953-61 and the slow rate of growth in R&D investment in the years preceding 1995, it is not surprising that real R&D fixed capital stock grew at a record rate in 1961-66, but not in 1995-2000 (see Table 9). As the benefits from R&D

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[51]Investment and stocks are estimated on a performer basis. Investment is equal to expenditures, split between change in R&D in progress and completed R&D. Details of the methodology are in the technical appendix.

[52]Rates of growth are computed throughout this paper from endpoint to endpoint. Fox example, the 1953-2000 rate of growth of total R&D investment is calculated as [(1996 dollar investment_{2000}/1996 dollar investment_{1953}) raised to the power (1/(2000-1953))-1] all times 100.

[53]All R&D activities are allocated to the general government sector in the national accounts.

[54]1953 is the first year of R&D expenditures data from the NSF R&D data base; see the NSF (2001) or Web site at http://www.nsf.gov/sbe/srs/indus/start.htm.

investment occur over a number of years, it is highly likely that we will be enjoying the fruits of the R&D mainly undertaken by business in the second half of the nineties through the first decade of the new millennium. An important consideration in this story is whether the service life of R&D has shortened since the sixties or equivalently the obsolescence rate of R&D has increased. The sensitivity of our results to our service life assumptions is discussed later under Alternative Scenarios. R&D investment represents 13 percent of current fixed investment; R&D fixed capital stock is less than half that in percentage terms at 6 percent of current fixed capital stock, reflecting the shorter service life of R&D compared to the average service life of all fixed assets currently included in the national accounts (see Table 10).

Although the 1961-2000 rates of growth for real R&D investment and fixed capital stock are very similar across all performing categories, those for investment show much more fluctuation by sub-periods than those for fixed capital stocks (see Tables 1 and 10). Other things held equal, stocks will change much more slowly than investment as current stocks are large relative to investment. Accordingly, it is not surprising that there is less variation in the composition of R&D fixed capital stocks than for R&D investment (Charts 1 and 2). For the last three periods: 1967-73, 1974-95, and 1996-2000, the average share of R&D fixed capital stocks for business, nonprofit institutions, and general government are almost constant. In all but the first period shown (1953-60), the sum of the shares for business and nonprofits is very close to 80 percent. Only the 1953-60 period shows any significant difference from the typical pattern and even in that period the business share is about 70 percent, the share for the last three periods. The share of the total for business is close to or above 70 percent for both the R&D investment share and the R&D fixed capital stocks share.

Returns to R&D and Property-type Income

Capitalizing R&D affects both the product (GDP) and income (GDI) side of the national accounts in a double-entry system. In the previous section, the focus was on an asset flow (investment) and balance sheet (stock) account. This section describes the effect of capitalizing R&D on the income side of the accounts. Capitalizing R&D increases property-type income from nonprofit institutions and general government R&D capital (depreciation plus the imputed rate of return from this capital). Also, property-type income rises by the imputed net return to all general government capital, including R&D capital. This increase in property-type income raises GDI by the same amount.[55] In addition, by capitalizing R&D, the returns to R&D capital can be separated out from other types of capital, and its share of property-type income can be identified.

The share of property-type income in GDI is higher on average by 2 percentage points per year (see Table 11), with 1 percentage point coming from the general government capital imputation and 1 percentage point coming from capitalizing R&D. The addition to GDI from the imputation of a net return to general government capital as previously shown in Table 7 is roughly double the addition from imputing returns to nonprofit institutions. The share of returns to R&D in property-type income is significant, averaging 19 percent (see Table 12). Except for1961-66, when the share of property-type income in GDI is relatively high, there is little variation in the share of R&D returns in property-type income. Charts 3, 4 and 5 show the impact of the changes on shares for the period as a whole, 1961-2000.

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[55]Property-type income is defined as the sum of corporate profits, proprietors income, net interest, capital consumption allowances, inventory valuation adjustments, rental income of persons, business transfer payments, and surplus of government industries, less subsidies. Alternatively, it is GDI less compensation of employees, indirect business tax and nontax liabilities, and the statistical discrepancy.

Gross Rates of Return to Fixed Capital Stock

Rates of return on capital that do not separate out the return to R&D capital tend to overstate its returns. Equation 2 of this paper shows the revisions needed in the basic growth accounting to allow for incorporation of R&D capital. Tables 7 and 10, discussed previously, show that R&D fixed capital stock averages 6 percent of current measures of fixed capital stock, and that net additions to GDP average 4 percent of GDP. Accordingly, the effect on the gross return to total fixed capital stock is small (see Table 13).[56] Most of the difference between the current measure of the gross rate of return and the adjusted measure of the gross rate of return, incorporating all changes, is due to the imputation of a net return to general government capital. This imputation increases property-type income without changing fixed capital stock as all non-R&D government fixed capital stocks are already included in the BEA measure of capital stocks. The difference between the gross rate of return to total fixed capital stock and other than R&D fixed capital stock varies by one to two percentage points for the periods shown.

Contributions of R&D to Growth

Contributions of R&D to growth can be estimated on the product- (demand) side and on the income- (supply) side. The contribution of R&D investment to growth in GDP is the product-side number, and the contribution of return on R&D capital to GDP growth is the income-side number.[57] National account estimates using the product-side approach are reported in NIPA

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[56]Gross rates of return are computed as the ratio of property-type income to fixed capital stock. If inventories and land (including subsoil minerals) were included in the estimate of capital stock, both the current and adjusted measure of the gross rate of return would be lower.

[57]Annual approximate contributions are calculated in this paper as a weighted growth rate, where the weights are the average share in the preceding period and the current period. For example, the contribution of R&D investment to growth in GDP is calculated as .5*(current

Tables S.2 and 8.2. Income-side estimates follow the sources of economic growth approach discussed earlier. The contributions are presented in two formats (see Table 14). The first corresponds to the presentation in the NIPA tables, where the sum of all contributions sum to the rate of growth of GDP. The second takes these same contribution estimates and presents them as a percentage of the rate of growth of GDP, where the sum of all contributions so calculated is 100 percent.

The contribution of R&D to economic growth is significant, regardless of whether the product-side or the income-side perspective is taken, and should be recognized. For 1961-2000, the contribution of R&D investment to growth in GDP averages 3 percent, while the contribution of return on R&D capital to growth in GDP averages 10 percent.[58] The period-to-period fluctuation in the contribution of R&D investment mainly reflects the variation in the growth rate of R&D investment (see Table 1), rather than variation in the rate of growth of GDP. The lesser period-to-period fluctuation in the contribution of returns to R&D capital reflects the smaller variation in the rate of growth of R&D fixed capital stock (compare estimates in Table 1 to those in Table 9).[59]

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dollar R&D investment$_{t-1}$/current dollar GDP$_{t-1}$ + current dollar R&D investment$_t$/current dollar GDP$_t$)* ((real R&D investment$_t$/real R&D investment$_{t-1}$)-1)*100. An average of the annual contributions is then calculated and reported in Table 14.

[58]Griliches (1973, p. 78) estimates the product-side contribution of R&D to GDP growth to be .34 percent as of 1966, probably considerably less. Our estimate of this contribution is .21 for the 1961-66 period (see Table 14).

[59]Only contribution estimates for all changes are shown as the impact on contributions of imputing a net return to general government capital is rarely significant at the level of detail shown in Table 13.

Alternative Scenarios

Since much is unknown about R&D, such as the appropriate deflators, depreciation rates, and the lengths of gestation and application lags, several alternative scenarios are analyzed using different assumptions about the deflators, the depreciation rates, and lag structure. The estimates under these alternative scenarios are compared to the results given above to gauge the significance of the contribution of R&D. These estimates highlight their preliminary nature because of the uncertainty about many facets of R&D.

In the tables and discussion that follow, two alternative deflators are employed. The deflator used above and in the appendix tables is the private fixed nonresidential investment chain-type price index from NIPA Table 7.6. The alternative deflators are the overall R&D deflator used in the previous BEA R&D study (Carson, Grimm, and Moylan,1994) extended beyond 1992 with a GDP deflator and the information processing equipment and software chain-type price index from NIPA Table 7.6.[60]

Two alternative depreciation rates are employed for business R&D. The geometric depreciation rate used above and in the appendix tables for all R&D from the 1994 BEA study is 11 percent. The alternative geometric depreciation rates for business R&D are 20 percent in all years and a rate that increases gradually from 10 percent in 1961 to 20 percent in 2000.[61] The latter rates take into account the rise in the R&D in information technology (IT) relative to other

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[60]The BEA 1994 study R&D deflator is very similar to the GDP deflator, particularly in the later eighties and nineties.

[61]The alternative R&D depreciation rate assumptions in BLS Bulletin 2331 (BLS, 1989) are 10 percent and 20 percent.

industries[62] and the increased pace of technological change in information technologies that has reduced the life of R&D capital, especially semiconductor technology, which is an important component of IT and many other products and has experienced increasingly rapid rates of obsolescence, as reflected in the steeply falling prices of semiconductor devices.

The declining balance rate that is assumed determines the service life of R&D capital. In the 1994 BEA study, the depreciation rate was picked as opposed to a service life. With a double declining balance rate, an 11 percent rate corresponds to an 18-year service life; with a 1.65 declining balance rate (the current BEA default for equipment), the service life is 15 years; and with a .91 declining balance rate (the current BEA default for structures), the service life is 8 years.[63] For a 20-percent depreciation rate, the corresponding service lives are 10 years, 8 years and 4.5 years. Only the business R&D depreciation rate is varied for two reasons: 1) the level of the assumed gross rate of return; and 2) the composition of R&D undertaken by business compared to that undertaken by nonprofit institutions and general government. Since the gross rate of return to nonprofit institutions and general government performers is set at two-thirds of the business rate, or 16.7 percent, a depreciation rate of 20 percent implies a long-term negative 3.3 percent net return to R&D capital. Unless nonprofit institutions and general government are undertaking R&D because the social rate of return is positive, even though the net return to themselves is negative, this is not a reasonable assumption. Business R&D is heavily

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[62]See Hall, Jaffe, and Trajtenberg (September 2001), p. 13 and Figure 5.

[63]The default rates are given in Fraumeni, 1997. The formula for a geometric rate of depreciation is the declining balance rate divided by the service life. Accordingly, the service life can be derived as the declining balance rate divided by the geometric rate of depreciation. (Fraumeni, 1997, p. 11).

concentrated in development; the same is not true for nonprofits or general government. Because development investment is generally believed to have a shorter service life than either basic or applied research, there is a rationale for lowering the average service life for all business R&D without doing the same for nonprofit institutions and general government.

For both types of contributions, the private fixed nonresidential investment deflator used in this study produces contribution estimates that lie between those of the alternative deflators, with the BEA 1994 study/GDP deflator producing the lowest estimates and the information processing equipment and software deflator producing the highest estimates in all time periods. For 1961-2000, the contributions of R&D investment to growth in GDP estimates are 2 percent, 3 percent, and 7 percent (see Table 15), using the three alternative deflators. For 1961-2000, the contribution of returns to R&D capital to growth in GDP estimates are 9 percent, 10 percent, and 14 percent (see Table 16).

As changing the R&D depreciation rate has no effect on investment, only estimates of the contribution of return on R&D capital to GDP growth are presented for the alternative depreciation rate assumptions. To see the full range of possible estimates and to compare the results in Table 17 which use an 11 percent depreciation rate, Table 17 shows the results of assuming the two alternative depreciation rates and the three possible deflators. In this case the depreciation rate assumption of 11 percent used in this paper consistently produces contribution estimates that are higher than either of the two alternatives, with the varying depreciation rate being the middle estimate, and the 20-percent depreciation rate alternative being the lowest estimate. For 1961-2000, under the assumption of fixed 11-percent depreciation rate, the estimated contributions of return to R&D capital to GDP growth are 9 percent, 10 percent, and

14 percent for the BEA 1994/GDP deflator, private fixed nonresidential investment deflator, and the information processing equipment and software deflator, respectively (refer back to Table 16). The corresponding estimates using the varying depreciation rate assumption are 6 percent, 8 percent, and 12 percent. Finally, the corresponding estimates using the fixed 20 percent depreciation rate are 5 percent, 7 percent, and 11 percent. These results are not surprising, as raising the depreciation rate lowers the 1996 dollar value of R&D fixed capital stock. The total return on those stocks falls by the same percentage as the decrease in the stocks.

One alternative lag structure is tested. The lag used above and in the appendix tables is a one-year lag which reflects an average lag applied to all categories of R&D expenditures, and follows the assumption used in the earlier BEA estimates of R&D capital. Past studies have identified two types of lags: Gestation lags and application lags. Gestation lags refer to the time needed to complete an R&D project, and application lags, to the time between completion of the R&D and its initial commercialization. Research has found that the gestation lags range between 1 to 2 years and that application lags range from less than 1 year to 2 years.[64] A one-year lag assumption takes into account only the gestation period. The alternative assumption is a three-year long lag. Because the data used in this paper do not distinguish the categories of R&D basic, applied, and development assuming a three-year average lag would take into account the other types of R&D, and the longer time taken before R&D produces results.

The 1961-2000 average contribution of return to R&D capital to growth in GDP is at most 1 to 2 percentage points lower than in the one-year lag scenario (compare Table 16 and

[64]Carson, Grimm, and Moylan, (1994), p. 44. See also Bureau of Labor Statistics (1989), pp. 6-7, 19-21, for a discussion of studies that look at the lag between research and profits and productivity growth.

Table 18). The contribution estimates vary by period, reflecting the impact of a longer lag. Not surprisingly, the contribution in the three-year lag scenario for the 1994 BEA/GDP deflator and the private fixed nonresidential investment deflator is higher in 1967-73 than in the one-year lag scenario, reflecting the delayed impact of the high rates of growth of R&D expenditures in 1953-1961 and 1961-1973 (see Table 1).

The results of assuming alternative scenarios indicates that regardless of the assumptions used, the contribution of R&D to economic growth is very significant. For 1961-2000, the contribution of R&D investment to growth in GDP ranges from 2 to 7 percent. For 1961-2000, the contribution of return on R&D capital to growth in GDP ranges from 6 to 14 percent. There is only one sub period, 1967-73, for which either contribution is less than 3 percent.

Future Research

There is substantial additional work needed to determine the effect of R&D on GDP. Estimates provided in this paper depend on assumptions made about the rates of return, depreciation rates, service lives, deflators, gestation and application lags. The reasonableness of these assumptions needs to be assessed. Each of these factors may have varied over time as the composition of R&D expenditures by performers has changed and the nature of technical change itself has changed. Also, further work is needed to determine whether or not the pattern of returns to R&D has varied over time, or has remained constant over the life of a particular investment. Without a means of gauging these kinds of changes, it is difficult to assess the effect of R&D on GDP. In addition, rates of return that may be appropriate for private R&D may not be appropriate for government R&D.

Despite these remaining questions, this exploratory paper is a significant and valuable step forward towards understanding the contribution of R&D to growth. It shows how a national income accounting methodology can be used to examine the role of R&D and how capitalization of R&D expenditures might affect GDP. When the System of National Accounts (1993) was revised, one of the last decisions made was not to capitalize R&D expenditures. This decision is being revisited by a number of national income accountants, and is an area in which BEA could again demonstrate that it is a world leader in statistical innovations. One only needs to look as far as the adoption of a quality adjusted computer price index and chain indices, and most recently, the capitalization of software to understand the important role that BEA has played.

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Technical Appendix

This technical appendix provides additional information about the construction of the estimates of R&D investment, R&D capital stock, returns to R&D capital, and net returns to other than R&D general government capital, as well as the deflation and aggregation methodologies employed. Table 2 lists the base scenario assumptions. The alternative scenarios are described in the body of the paper. This technical appendix provides additional details of the base scenario, and describes how alternative scenarios are constructed.

R&D Investment and Capital Stock

The original BEA investment and capital stock estimates were updated through 2000 for this paper based on NSF expenditure data.[65] The NSF expenditure data from 1992 are adjusted for differences in the levels and composition of BEA and NSF R&D expenditures using a regression approach. This is a simplified approach; in the earlier project a number of specific adjustments were made to the NSF data. One basic difference between the BEA and NSF R&D data is the allocation of R&D expenditures by public colleges and universities. BEA allocates these expenditures to government while NSF allocates these expenditure to nonprofit institutions. The NSF data only identify R&D expenditures by the Federal government, not by State and Local governments.

NSF R&D expenditures prior to 1992 are not directly comparable to those from 1992-2000 because of a change in sample design and survey methodology.[66] Surveys after 1992 provide more accurate and better quality data because they reflect the current year distribution of companies by size and industry, changes in industry classification systems, and changes in the way industry classifications are assigned. There is no way of knowing how large the differences might be or an expectation that this can be accurately determined judging from the attempt by, but failure of, NSF staff to create a consistent time series. However, the potential problem is

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[65]See National Science Foundation (2001).

[66] See National Science Foundation (2001B), p. 10.

reduced by using aggregate data instead of industry data or data by separated out by type of R&D: basic, applied, and development.

Very little information is available to estimate imports or exports of R&D services. NSF data on business performance of R&D includes R&D funded by foreign entities. What little data exists to break out foreign funding of R&D performed in the United States or U.S. funding of R&D performed abroad is for unaffiliated services and comes from BEA. Estimates based on these data indicate that these imports and exports each represent well under 0.5 percent of total R&D expenditures in the U.S. during the 1986-2000 period.[67] Accordingly, no attempt was made to estimate the magnitude of these R&D services, the spillover from R&D performed abroad, or to gauge whether the spillover rates of return reflect only spillovers to U.S. businesses, excluding spillovers to foreign entities.

There is an assumed one-year lag before R&D expenditure enters the capital stock. With this convention, expenditure in one year becomes investment of the following year and there is an entry for change in R&D-in-progress.

The investment equation is as follows:

(1) GDP total $\text{investment}_t = \text{expenditures}_{t-1} + \text{change in R\&D-in-progress}_t = \text{expenditures}_t$,

where by definition:

(2) change in $\text{R\&D-in-progress}_t = \text{expenditures}_t - \text{expenditures}_{t-1}$, and

(3) completed $\text{R\&D}_t = \text{expenditures}_{t-1}$

[67]Data are available for research, development, and testing services for unaffiliated services. See Bureau of Economic Analysis (2001), Table 1, pp. 64-65. R&D services data is now being collected for affiliated services, but this data will not be available until later in 2002.

As previously noted, the base scenario uses a geometric depreciation rate of 11 percent to update the capital stock. In the earlier BEA project, straight-line depreciation was combined with a Winfrey (bell-shaped) retirement distribution to construct the BEA R&D capital stocks because this methodology was used at the time to construct BEA estimates of fixed tangible capital stocks. The R&D service life was adjusted to mimic a target 11-percent geometric rate of depreciation since this rate was approximately the midpoint of then available estimates of R&D depreciation rates. The previous project compared estimates using the straight-line/Winfrey methodology and an 11-percent geometric rate, and found that the differences were modest .[68]

Two alternative depreciation rate scenarios were developed as R&D service lives may have shortened over time given the general overall increase in the rate of technical advance as well as a compositional shift in R&D expenditures over the decade of the 1990s.[69] The latter effect is reflected by the increasing share of GDP expenditures devoted to products, such as personal computers, with relatively short life spans, and away from products such as pharmaceuticals with a 17-year patent life. In addition, obsolescence-related depreciation rates

[68]See Carson, Grimm, and Moylan (1994), p. 45 and box, p. 48, for a comparison for selected years.

[69]NSF R&D expenditure data by industry are extremely limited. Data for office, computing, and accounting machines (OCAM - the computer category) are only available from 1972-80, 1993-94, and 1997-98. Data for drugs and medicine, and machinery (the latter being the category which includes OCAM) are available for most years from 1953 forward. Analysis of these data shows that the share of R&D devoted to drugs and medicine rose from 1961-98, while that for machinery may have fallen since the mid-eighties. No data are available for non-manufacturing industries, including service industries, until 1995. See National Science Foundation (2001), Total (company, Federal, and other) funds for industrial R&D performance, by industry and by size of company: 1953-98."

may increase as the level of R&D expenditures rise and the pace of technical change quickens.[70] However, the magnitude and timing of a possible shortening of service lives are difficult to measure.

The capital stock equation is:

(4) capital stock_t = $\text{expenditures}_{t-1}$ + (1- depreciation rate) * capital stock_{t-1}.

<u>Returns to R&D Capital</u>

A simplified capital service flow equation is used in this paper to estimate returns to R&D capital; all tax terms are ignored:

(5) return = net return + depreciation, or

(6) return_t = net rate of return * capital stock_{t-1} + depreciation rate * capital stock_{t-1},

where the rate of return is held constant for each scenario over all years, but varies depending upon whether a private, spillover, or social rate of return is employed. Ignoring the tax terms (such as those which would reflect the expensing of many R&D costs and the taxation of profits from R&D) on average tends to underestimate business returns to R&D. Tax terms are not an issue for nonprofit institutions and general government performers. Thus, since only nonprofit institutions and general government returns to R&D capital and net returns to other fixed general government capital are a return net addition to GDP (see Table 7), appendix equation (6) provides a good approximation of additions to GDP due to R&D capitalization. Ideally, the equation should be revised to include taxes to adjust the estimates of the return to business R&D capital and the contribution of that capital to GDP growth.

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[70] This was suggested by Adam Jaffe in his comments at the January 7, 2001 presentation of Fraumeni and Okubo, 2001.

The prior BEA project concluded that gestation lags range from one year to two years and that application lags range from something less than one year to somewhat more than two years; in addition that lags between the investment and its peak effect on profits may be long, particularly for basic research.[71] The application lags may have shortened over the 1959-2000 time period because of the quickening pace of technical change in the past decade and shifts in composition of industry R&D expenditures. However, we lack empirical evidence to support a specific lag form. No attempt is made to adjust for variation in the return to R&D or the time pattern of industry returns to R&D capital. The issue of the peak impact on profits would be moot if the age distribution and composition of R&D capital stock were constant over time -- an unlikely case. In this paper, the alternative scenario lengthens the overall lag expenditure to capital stock lag from one to three years.

Net Return to Other Than R&D General Government Capital

The real net return rate on other than R&D general government capital is assumed to be constant at 3.5 percent. The Office of Management and Budget lists real interest rates on Treasury notes and bonds as 3.5 percent for ten-years and 3.6 percent for thirty years.[72] Accordingly with R&D service lives at most 18 years in our estimates, we chose 3.5 percent as the relevant rate.

Deflation and Aggregation

The base case deflator and one alternative deflator, the information processing equipment and software deflator, are NIPA deflators. The other alternative deflator is the BEA 1994 study

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[71]Carson, Grimm, and Moylan (1994), p. 44.

[72]See Office of Management and Budget (1997), Appendix C.

deflator until 1992, then a slightly modified GDP (NIPA table 7.1, chain-type price index) deflator for all subsequent years. From 1987 to 1992 the BEA 1994 study deflator and the GDP deflator are almost identical; from 1974 to 1992, the deflators are very similar except for a couple of years around 1980. The BEA 1994 deflator was extended through 2000 using the GDP deflator growth rate. From 1959 to 1988, except for a few years around 1980, the Griliches/Hall/Jaffe deflator[73] and the BEA 1994 study deflator are almost identical. The information processing equipment and software deflator is chosen as an alternative deflator to check the sensitivity of our results to use of a deflator which behaves very differently from either of the other two scenario deflators.

The same scenario specific deflator is used to deflate R&D investment, stock, and returns to R&D. Additive aggregation is used when creating R&D totals as there are no differences in the underlying deflator.

A chain index number formula is used to aggregate across estimates, say consumption and investment, with different underlying deflators, unless a component is negative. For example, if GDP is equal to the sum of investment (I) and consumption (C), the rate of growth of aggregate real GDP is calculated as

[73]The deflator is from Table 3.1 of Hall (1990) and is described on p. 20 of that source. It is constructed using methodology similar to Jaffe (1972). In BLS (1989) p. 45 the deflator based on the 1972 methodology is called the Jaffe-Griliches deflator.

(7) .5*(current dollar R&D I_{t-1}/current dollar GDP_{t-1}

+ current dollar R&D I_t/current dollar GDP_t) * (real R&D I_t/real R&D I_{t-1}-1)

+ .5*(current dollar R&D C_{t-1}/current dollar GDP_{t-1}

+ current dollar R&D C_t/current dollar GDP_t) * (real R&D C_t/real R&D C_{t-1}-1),

a methodology parallel to that used for contributions as described in footnote 59. The growth rates are then used to extend the real GDP series backwards and forwards from 1996, the base year.

Additive aggregation is used when a component is negative.

Tables and Charts, followed by Appendix Tables

Table 1
Rates of Growth of Real R&D Investment and Real Gross Domestic Product (GDP)
(percent)

Periods	Real R&D Investment				Real GDP
	Total	Business	Nonprofit Institutions	General Government	
1953-61	11	12	16	6	3
1961-66	8	7	14	12	6
1966-73	1	1	1	3	4
1973-95	4	5	4	4	3
1995-2000	9	10	7	6	4
1961-2000	5	5	5	5	3
1953-2000	6	6	7	5	3

<table>
<tr><th colspan="4">Table 2
Assumptions</th></tr>
<tr><th colspan="4">Benefits</th></tr>
<tr><td></td><td>Current Measures</td><td colspan="2">Adjusted Measures
(percent)</td></tr>
<tr><td>Return to business R&D capital</td><td>Social benefits included</td><td colspan="2">No change: Social benefits included</td></tr>
<tr><td>Return to nonprofit institutions and general government R&D capital</td><td>Spillover benefits included</td><td colspan="2">Private and spillover benefits included</td></tr>
<tr><td>Net return to other than R&D general government capital</td><td>n.a.</td><td colspan="2">3.5</td></tr>
<tr><th colspan="4">Gross Rates of Return</th></tr>
<tr><td>Rates of Return on:</td><td>Private Return
(percent)</td><td>Spillover Return
(percent)</td><td>Social Return
(percent)</td></tr>
<tr><td>Private R&D</td><td>25</td><td>25</td><td>50</td></tr>
<tr><td>Nonprofit institutions and general government R&D
(2/3rds of the above rates)</td><td>16.7</td><td>16.7</td><td>33.4</td></tr>
<tr><th colspan="4">Other</th></tr>
<tr><td colspan="2">Deflator</td><td>Depreciation Rate</td><td>Lag</td></tr>
<tr><td colspan="2">Private fixed nonresidential investment</td><td>11%</td><td>One year</td></tr>
</table>

Table 3 Estimated Rates of Return to Private R&D		
Author (year)	**Private (%)**	**Social (%)**
Sveikauskas (1981)	7 - 25	50
Bernstein-Nadiri (1988)	10 - 27	11-111
Bernstein-Nadiri (1991)	15 - 28	20 -110
Nadiri (1993)	20 - 30	50
Mansfield (1977)	25*	56*
Goto-Suzuki (1989)	26	80
Terleckyj (1974)	29	48-78
Scherer (1982, 1984)	29 - 43	64 - 147

* These rates are median rates.

Table 4
Adjusted Gross Domestic Product

(Bolded italics show R&D components.)
(Bolded only show net return to general government other than net return to R&D capital components.)

Gross domestic product
Personal consumption expenditures
Households
Durable goods
Nondurable goods
Services
Nonprofit institutions
Durable goods
Nondurable goods
Services
Returns to R&D capital
Net return
Depreciation
Other services
Gross private domestic investment
Business Fixed investment
Nonresidential
Structures
Equipment and software
Residential
Completed R&D
Change in R&D-in-progress
Change in business inventories
Nonprofit institutions fixed investment
Nonresidential
Structures
Equipment and software
Residential
Completed R&D
Change in R&D-in-progress
Net exports of goods and services
Exports
Goods
Services
R&D expenditures
Other services
Imports
Goods
Services
R&D expenditures
Other services

(Continued)

Table 4 Concluded

Government consumption expenditures and gross investment
Consumption expenditures
Federal
Goods
Services
Returns to R&D capital
Net return
Depreciation
Returns to other than R&D capital
Net return
Depreciation
Other services
State and local
Goods
Services
Returns to R&D capital
Net return
Depreciation
Returns to other than R&D capital
Net return
Depreciation
Other services
Fixed investment
Federal
Nonresidential
Structures
Equipment and software
Residential
Completed R&D
Change in R&D-in-progress
State and local
Nonresidential
Structures
Equipment and software
Residential
Completed R&D
Change in R&D-in-progress

Table 5
Adjusted Relation of Gross Domestic Product, Gross National Product, Net National Product, National Income, and Personal Income
(Bolded italics show R&D components.)
(Bolded only show net return to general government other than net return to R&D capital components.)

Gross domestic product

Plus: Income receipts from the rest of the world
Less: Income payments to the rest of the world

Equals: Gross national product

Less: Consumption of fixed capital
Business
Consumption of R&D capital
R&D capital consumption allowances
Less: R&D capital consumption adjustment
Consumption of other fixed capital
Capital consumption allowances for other fixed capital
Less: Capital consumption adjustment for other fixed capital
Nonprofit Institutions
Consumption of R&D capital
R&D capital consumption allowances
Less: R&D capital consumption adjustment
Consumption of other fixed capital
Capital consumption allowances for other fixed capital
Less: Capital consumption adjustment for other fixed capital
Government
General government
Consumption of R&D capital
Consumption of other fixed capital
Government enterprises
Equals: Net national product

Less: Indirect business tax and nontax liability
Business transfer payments
Statistical discrepancy
Plus: Subsidies less current surplus of government enterprises
Current surplus of general government

Equals: National income

Addenda:
Gross domestic income
Gross national income
Net domestic product

Table 6
Adjusted Components of Gross Domestic Product by Industry Group
(Bolded italics show R&D components.)
(Bolded only show net return to general government other than net return to R&D capital components.)

Gross domestic product

Private industries

Compensation of employees

Indirect business tax and nontax liability

Property-type Income

Returns to business capital
Returns to R&D capital
Net return
Depreciation
Returns to other than R&D capital
Net return
Depreciation
Returns to nonprofit institutions capital
Returns to R&D capital
Net return
Depreciation
Returns to other than R&D capital
Net return
Depreciation

Statistical Discrepancy

Government

Compensation of employees

Indirect business tax and nontax liability

Property-type income

Returns to general government capital
Returns to R&D capital
Net return
Depreciation
Returns to other than R&D capital
Net return
Depreciation
Returns to government enterprises capital
Returns to other than R&D capital
Net return
Depreciation

Table 7 **Net Additions to GDP and R&D Totals** (as a percent of current dollar GDP)						
Periods	Net Additions to GDP				R&D Totals	
	Total	R&D Funded and Performed by Business	Returns to NP&GG from R&D Performed by NP&GG*	Net Return to General Government Capital other than R&D Capital	R&D Investment	Returns to R&D
1961-66	4	1	1	2	3	6
1967-73	4	1	1	2	3	7
1974-95	4	1	1	2	2	7
1996-2000	4	2	1	2	3	7
1961-2000	4	1	1	2	3	7

* NP&GG is an abbreviation for nonprofit institutions and general government.
Note: Totals may be off by +/- 1 because of rounding.

Table 8 **National Savings Rate** (percent)					
Periods	Current Measure	Impact of Imputing a Net Return to General Government Capital	Impact of Capitalizing R&D	Adjusted Measure	Difference Adjusted Measure and Current Measure
1961-66	21.3	-.5	2.4	23.2	1.9
1967-73	19.7	-.4	2.2	21.4	1.7
1974-95	18.1	-.4	2.0	19.8	1.7
1996-2000	18.1	-.3	2.1	20.0	1.8
1961-2000	18.9	-.4	2.1	20.6	1.7

Note: Totals may be off by +/- .1 because of rounding.

Table 9
Rates of Growth of Real R&D Fixed Capital Stock and Real Gross Domestic Product (GDP)
(percent)

Periods	R&D Fixed Capital Stock				GDP
	Total	Business	Nonprofit Institutions	General Government	
1961-66	10	10	17	9	6
1966-73	6	5	8	7	4
1973-95	4	4	4	4	3
1995-2000	6	6	5	5	4
1961-2000	5	5	7	5	3

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Table 10
R&D Investment and Wealth Share of Existing Measures
(percent)

Periods	Share R&D Fixed Investment is of Current Measure Investment*	Share R&D Fixed Capital Stock is of Current Measure Fixed Capital Stock*
1961-66	14	5
1967-73	13	6
1974-95	13	6
1996-2000	13	6
1961-2000	13	6

* Shares are average current dollar shares.

Table 11
Share of Property-type Income in Gross Domestic Income (GDI)
(percent)

Periods	In Adjusted GDI			In Current Measure GDI	Difference Adjusted and Current Measure GDI
	All Changes	R&D Change Only	Impact of Imputing a Net Return to General Government Capital		
1961-66	38	36	1	35	2
1967-73	35	34	1	32	3
1974-95	36	35	1	34	3
1996-2000	38	37	1	36	2
1961-2000	36	35	1	34	2

* Shares are average current dollar shares.
Note: Totals may be off by +/- 1 because of rounding.

Table 12
Share of Returns to R&D in Property-type Income
(percent)

Periods	Returns to R&D as a % of Adjusted Measure Property-type Income		Impact of Imputing a Net Return to General Government Capital
	All Changes	R&D Change Only	
1961-66	15	16	-1
1967-73	20	21	-1
1974-95	19	20	-1
1996-2000	18	19	-1
1961-2000	19	20	-1

* Shares are average current dollar shares.
Note: Totals may be off by +/- 1 because of rounding.

Table 13 **Gross Rates of Return to Total Fixed Capital Stock** (percent)					
Periods	Adjusted Measures			Current Measure	Difference Adjusted and Current Measure
	All Changes	R&D Change Only	Impact of Imputing a Net Return to Government Capital		
1961-66	14	13	1	14	1
1967-73	14	13	1	13	1
1974-95	13	12	1	12	1
1996-2000	15	14	1	14	1
1961-2000	13	13	1	13	1

Note: Totals may be off by +/- 1 because of rounding.

Table 14 **Contribution of R&D Investment and Return to R&D Capital to Growth in GDP** **All Changes** (percent)				
Periods	R&D Investment		Return on R&D Capital	
	Summing to GDP Growth Rate	As a % of GDP Growth Rate	Summing to GDP Growth Rate	As a % of GDP GrowthRate
1961-66	.21	4	.61	10
1967-73	.03	1	.42	12
1974-95	.11	4	.29	10
1996-2000	.22	5	.36	9
1961-2000	.12	3	.37	10

Table 15
Contribution of R&D Investment to Growth in GDP
All Changes
Alternative Deflators
(as a percent of GDP growth rate)

Periods	1994 BEA/GDP Deflator	Gross Private Fixed Nonresidential Investment Deflator	Information Processing Equipment and Software Deflator
1961-66	3	4	5
1967-73	0	1	4
1974-95	3	4	8
1996-2000	3	5	9
1961-2000	2	3	7

Table 16
Contribution of Return to R&D Capital to Growth in GDP
All Changes
Alternative Deflators
(as a percent of GDP growth rate)

Periods	1994 BEA/GDP Deflator	Gross Private Fixed Nonresidential Investment Deflator	Information Processing Equipment and Software Deflator
1961-66	10	10	12
1967-73	9	12	14
1974-95	8	10	17
1996-2000	6	9	12
1961-2000	9	10	14

Table 17
Contribution of Return to R&D Capital to Growth in GDP
All Changes
Alternative Rates of Depreciation
Alternative Deflators
(as a percent of GDP growth rate)

Periods	Varying Depreciation Rate from 10% to 20%			Constant 20% Depreciation Rate		
	1994 BEA/GDP Deflator	Gross Private Fixed Nonresidential Investment Deflator	Information Processing Equipment and Software Deflator	1994 BEA/GDP Deflator	Gross Private Fixed Nonresidential Investment Deflator	Information Processing Equipment and Software Deflator
1961-66	9	10	11	6	7	8
1967-73	7	9	12	5	7	9
1974-95	4	7	13	5	7	12
1996-2000	3	5	9	4	6	9
1961-2000	6	8	12	5	7	11

Table 18 **Contribution of Return to R&D Capital to Growth in GDP** **All Changes** **Alternative Deflators and Alternative Three-Year Lag** (as a percent of GDP growth rate)			
Periods	1994 BEA/GDP Deflator	Gross Private Fixed Nonresidential Investment Deflator	Information Processing Equipment and Software Deflator
1961-66	9	9	10
1967-73	11	13	13
1974-95	8	9	14
1996-2000	5	7	9
1961-2000	8	10	12

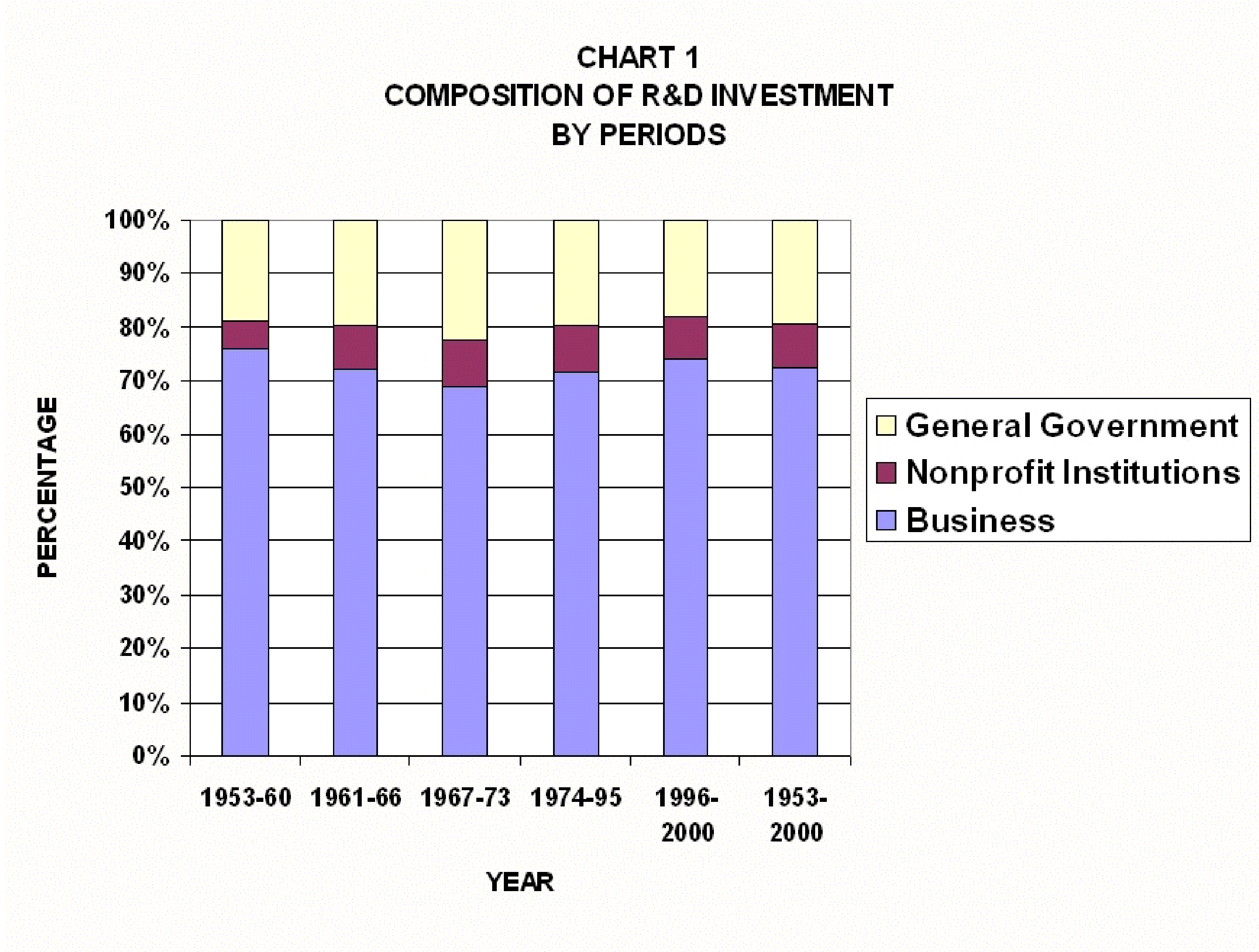
CHART 1
COMPOSITION OF R&D INVESTMENT
BY PERIODS
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
PERCENTAGE
1953-60
1961-66
1967-73
1974-95
1996-2000
1953-2000
YEAR
General Government
Nonprofit Institutions
Business

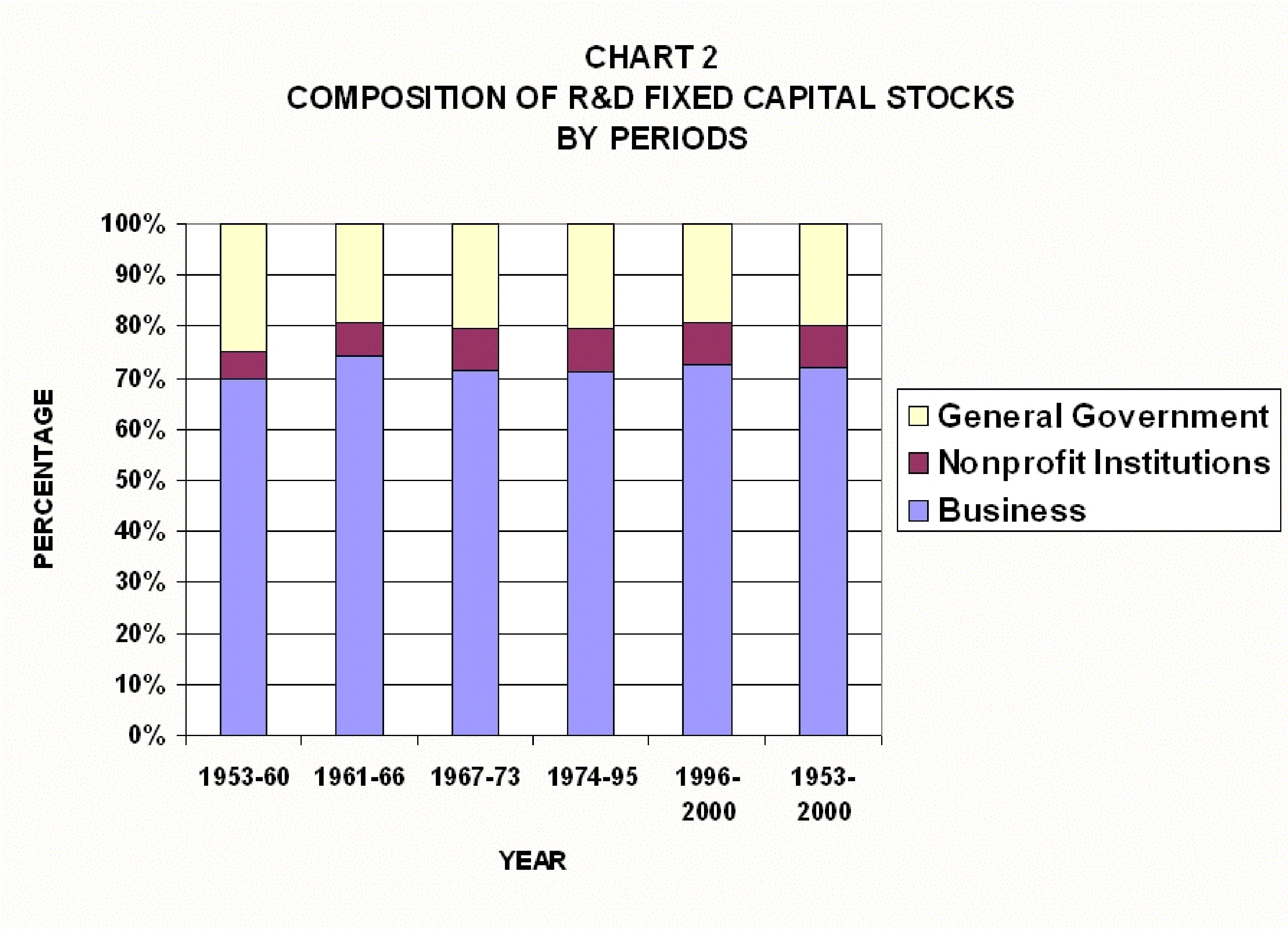
CHART 2
COMPOSITION OF R&D FIXED CAPITAL STOCKS
BY PERIODS
PERCENTAGE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1953-60
1961-66
1967-73
1974-95
1996-2000
1953-2000
YEAR
General Government
Nonprofit Institutions
Business

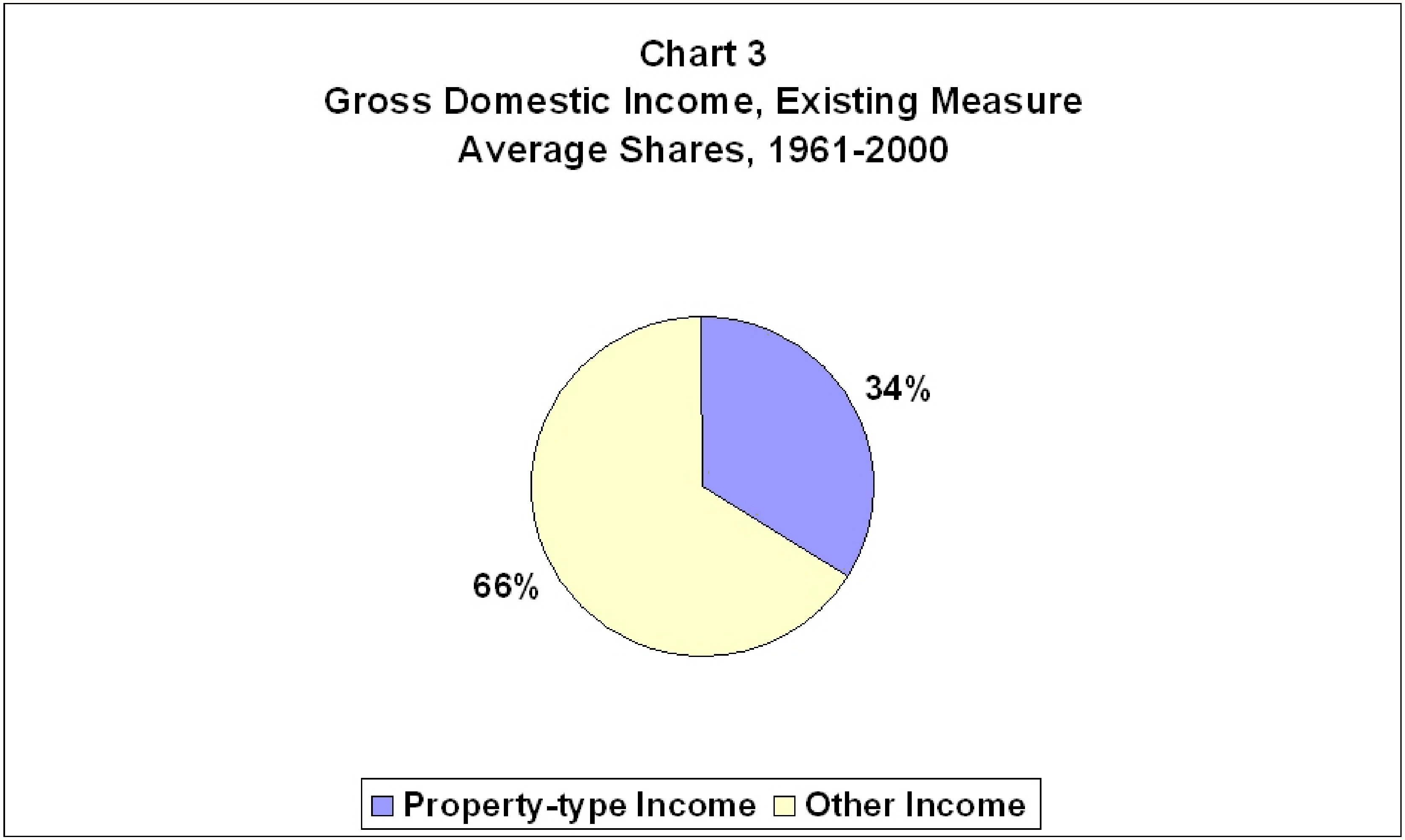
Chart 3
Gross Domestic Income, Existing Measure
Average Shares, 1961-2000
34%
66%
Property-type Income
Other Income

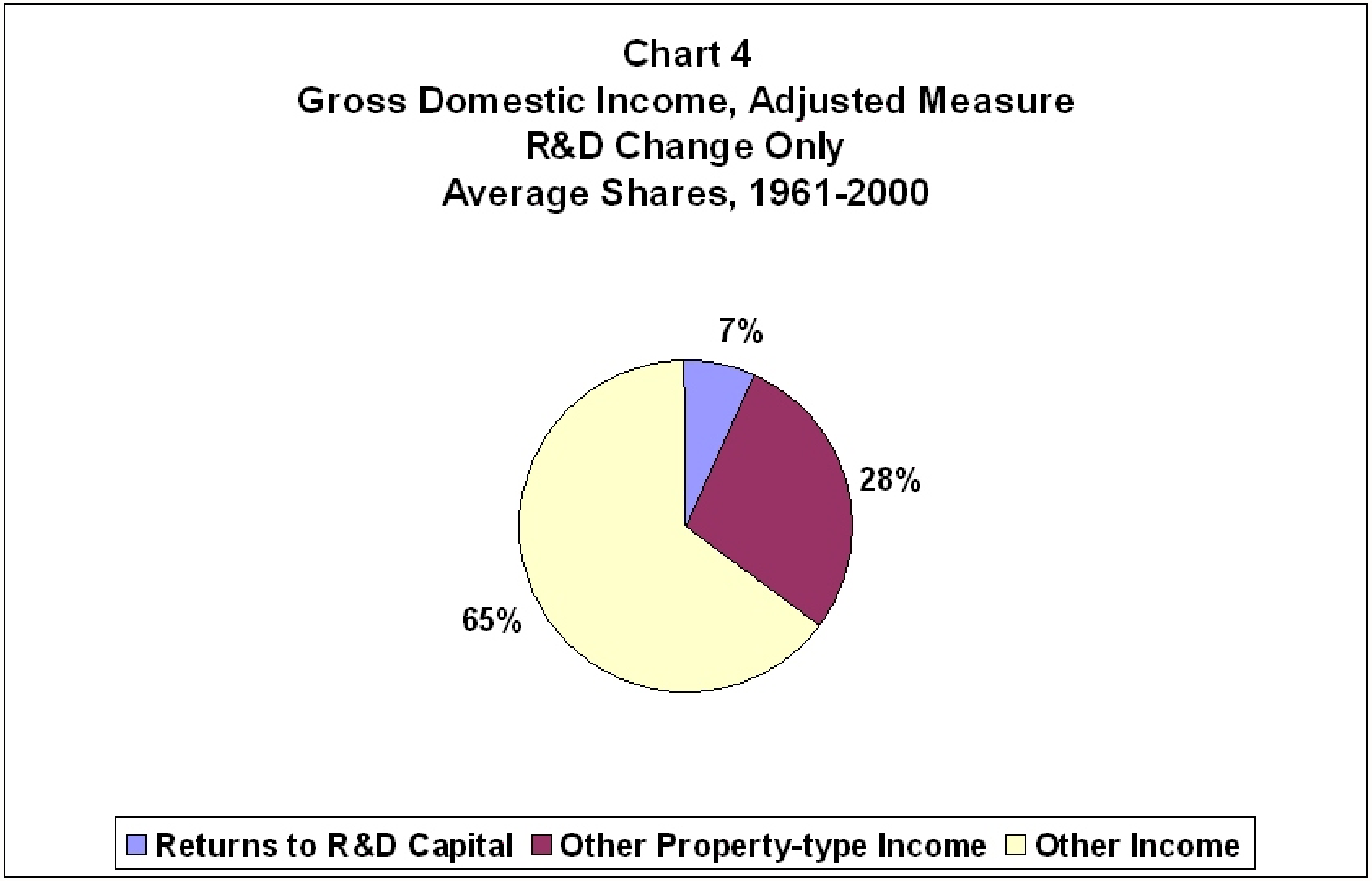
Chart 4
Gross Domestic Income, Adjusted Measure
R&D Change Only
Average Shares, 1961-2000
7%
28%
65%
Returns to R&D Capital
Other Property-type Income
Other Income

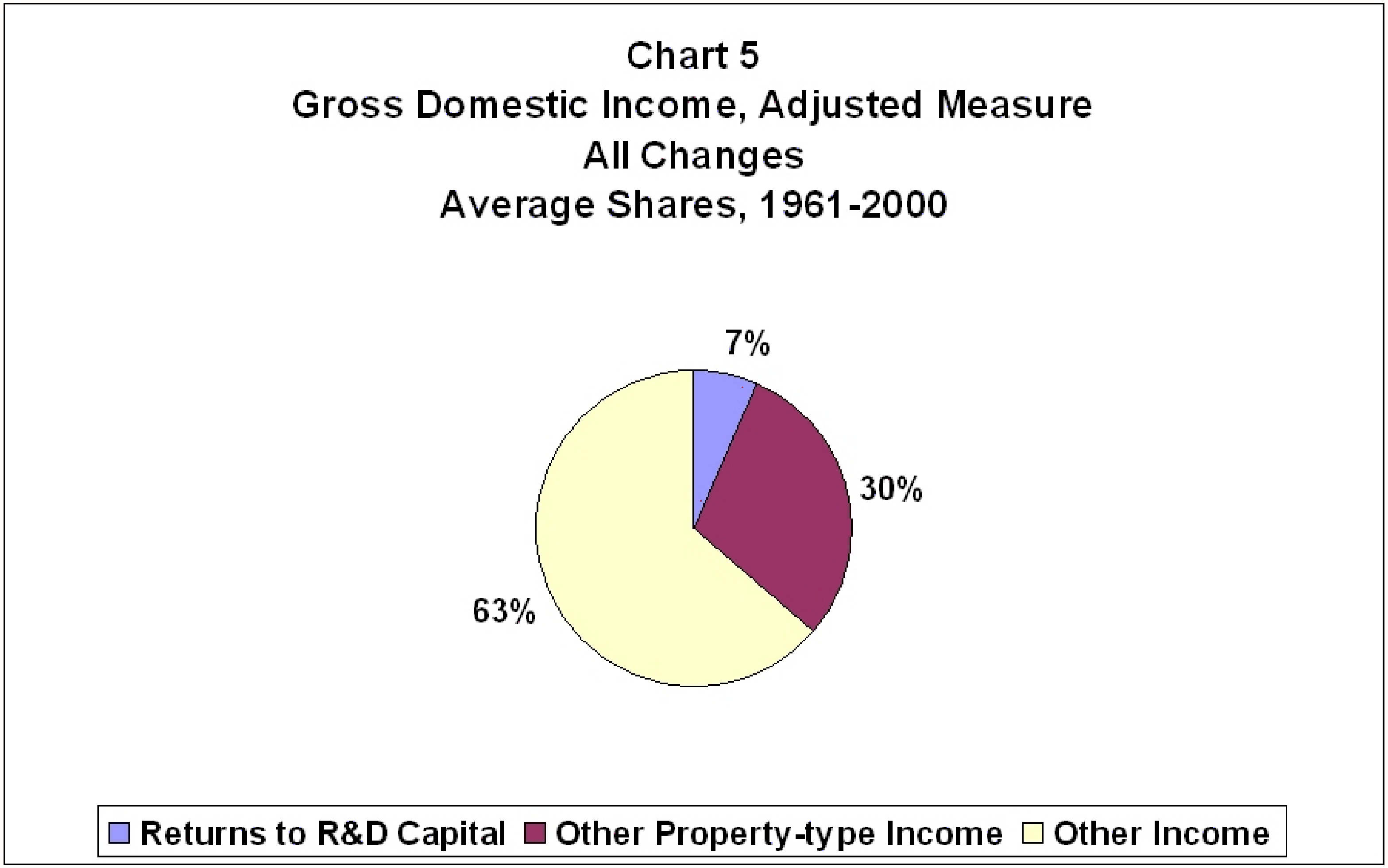
Chart 5
Gross Domestic Income, Adjusted Measure
All Changes
Average Shares, 1961-2000
7%
30%
63%
Returns to R&D Capital
Other Property-type Income
Other Income

AppendixAppendix Table 1
Real R&D Investment, Levels and Growth Rates
(in billions of 1996 dollars)

Year	Level	Rates of Growth	Year	Level	Rates of Growth	Year	Level	Rates of Growth
1953	19,285		**1974**	71,466	-2			
1954	20,878	8	**1975**	67,450	-6			
1955	22,814	9	**1976**	70,528	5			
1956	28,201	24	**1977**	72,330	3			
1957	31,536	12	**1978**	75,935	5			
1958	34,213	8	**1979**	80,500	6			
1959	38,585	13	**1980**	84,229	5			
1960	42,145	9	**1981**	87,703	4			
			1982	92,378	5			
1961	44,820	6	**1983**	102,978	11	**1996**	202,743	9
1962	48,081	7	**1984**	116,624	13	**1997**	220,762	9
1963	53,805	12	**1985**	128,877	11	**1998**	241,145	9
1964	58,521	9	**1986**	132,965	3	**1999**	263,195	9
1965	61,664	5	**1987**	138,452	4	**2000**	285,010	8
1966	66,584	8	**1988**	143,230	3			
			1989	148,425	4		**Period Rates of Growth**	
1967	68,839	3	**1990**	156,213	5		**1953-61**	11
1968	70,638	3	**1991**	163,144	4		**1961-66**	8
1969	71,459	1	**1992**	170,519	5		**1966-73**	1
1970	68,946	-4	**1993**	169,694	0		**1973-95**	4
1971	67,558	-2	**1994**	172,122	1		**1995-2000**	9
1972	69,641	3	**1995**	186,735	8		**1961-2000**	5
1973	72,594	4					**1953-2000**	6

AppendixAppendix Table 2
Estimated Components for Adjusted Gross Domestic Product
(in(in billions of 1996 dollars)

(***Bolded italics*** show R&D components.)
(**Bolded only** show net return to general government other than net return to R&D capital components.)

Year	**1961**	**1966**	**1973**	**1995**	**2000**
Gross domestic product	2,495	3,317	4,243	7,828	9,622
Personal consumption expenditures	1,541	2,008	2,681	5,087	6,271
Nonprofit institutions					
Services					
Returns to R&D capital*	2	4	7	17	22
Net return*	1	1	2	6	7
Depreciation	1	2	5	11	14
Gross private domestic investment	304	483	652	1,286	2,001
Business Fixed investment					
Completed R&D	33	43	47	121	195
Change in R&D-in-progress	1	4	2	12	18
Nonprofit institutions fixed investment					
Completed R&D	3	5	6	16	21
Change in R&D-in-progress	1	0	0	1	1
Net exports of goods and services	(18)	(40)	(62)	(78)	(399)
Government consumption expenditures and gross investment	720	891	976	1,534	1,731
Consumption expenditures					
Services					
Returns to R&D capital*	7	10	17	39	49
Net return*	2	4	6	13	17
Depreciation	5	7	11	26	32
Returns to other than R&D capital					
Net return	49	59	75	123	147
Fixed investment					
Completed R&D	7	13	16	35	47
Change in R&D-in-progress	1	1	1	2	3

*Net return to NP&GG R&D capital in this table includes only private returns. In Appendix Table 3, net return to NP&GG R&D capital includes social returns.

AppendixAppendix Table 3
Estimated Components for Adjusted Relation of Gross Domestic Product,
Gross National Product, Net National Product, National Income, and Personal Income
(in(in billions of 1996 dollars)
(***Bolded italics*** show R&D components.)

Year	1961	1966	1973	1995	2000
Gross domestic product	2,495	3,317	4,243	7,828	9,622
Plus income receipts from the rest of the world and less income payments to the rest of the world					
Equals: Gross national product	2,512	3,338	4,281	7,848	9,614
Less: Consumption of fixed capital					
Business					
Consumption of R&D capital	16	26	39	96	125
Nonprofit Institutions					
Consumption of R&D capital	1	2	5	11	14
Government					
General government					
Consumption of R&D capital	5	7	11	26	32
Equals: Net national product	2,288	3,057	3,881	6,798	8,205
Addenda:					
Gross domestic income*	2,496	3,291	4,220	7,801	9,744
Gross national income**	2,513	3,312	4,257	7,821	9,737
Net domestic product	1,905	2,600	3,415	6,746	8,485

*Gross domestic income deflated by the implicit price deflator for adjusted GDP.
**Gross national income deflated by the implicit deflator for adjusted GNP.

AppendixAppendix TableAppendix Table 4
Estimated Adjusted Components for Components of Gross Domestic Product by Industry Group
(in(in billions of 1996 dollars)
(***Bolded*** italics show R&D components.)
(**Bolded** only show net return to general government other than net return to R&D capital components.)

Year	1961	1966	1973	1995	2000
Gross domestic product	2,495	3,317	4,243	7,828	9,622
Private industries					
Property-type Income					
Returns to business capital					
Returns to R&D capital	73	120	178	438	567
Net return	57	94	139	341	442
Depreciation	16	26	39	96	125
Returns to nonprofit institutions capital					
Returns to R&D capital*	3	7	14	34	44
Net return*	2	5	9	23	29
Depreciation	1	2	5	11	14
Government					
Property-type income					
Returns to general government capital					
Returns to R&D capital*	14	21	35	78	98
Net return*	9	14	23	52	66
Depreciation	5	7	11	26	32
Returns to other than R&D capital					
Net return	49	59	75	123	147

*Net return to NP&GG R&D capital in this table includes social returns. In Appendix Table 1, net return to NP&GG R&D capital includes only private returns.