Estimating Prices for R&D Investment in the 2007 R&D Satellite Account

Bureau of Economic Analysis/National Science Foundation 2007 R&D Satellite Account Background Paper

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November 2007 www.bea.gov

Abstract

This paper is part of a series that provides the details behind the Bureau of Economic Analysis's (BEA) satellite account on research and development (R&D) activity. In the current work, the focus is on the theoretical underpinnings and empirical implementation of the R&D price index used to construct real R&D output. We examine four alternative price indexes. For each, we lay out the theoretical assumptions needed for the approach to be valid and examine how well the approach works in practice. We then compare these four alternative price indexes and explain the choice of our preferred price index.

Acknowledgements

Dennis J. Fixler, Chief Statistician of the Bureau of Economic Analysis, oversaw the development of the research presented in this paper. **Rosemary Marcuss,** Deputy Director, and **Sumiye Okubo,** Associate Director for Industry Accounts provided valuable comments.

Introduction

The Bureau of Economic Analysis and the National Science Foundation are jointly working to produce estimates of the impact of treating R&D as investment in a satellite account for the U.S. economy. This paper is one in a set of background papers detailing the concepts and methodology underlying the 2007 satellite account estimates. This paper describes and explains the price index used in the 2007 R&D satellite account to transform current dollar expenditures into real, or inflation-adjusted, gross domestic product (GDP).

The ongoing methodological work for the R&D satellite account has two goals: 1) In the near term to produce reasonable and internally consistent estimates of the impact on GDP and other macroeconomic variables of the impact of treating R&D as investment in a satellite account format, and 2) to develop the conceptual framework, methodology, and data sources necessary to incorporate R&D expenditures as investment into BEA's core accounts beginning in 2012.

R&D investment expenditures in the satellite account have two components, the internal production of R&D output for the firm's own use, and the purchase of R&D output from other firms. The estimation goal of the R&D satellite account is to measure the direct effects of this R&D investment, that is to say, excluding any separate measure of spillovers or externalities which are captured in the core GDP but not separately distinguished. For this reason, the magnitude of the impact that R&D investment would have on real GDP depends, in large part, on the price indexes used to deflate current dollar investment. Ideally, such deflation would be conducted with a price index in which the components are R&D output prices that reflect market transactions. Unfortunately such price data are unavailable to construct these R&D output price indexes directly. Consequently, four alternative methods which infer the change in price of R&D output are evaluated to produce measures of real R&D investment. These are 1) a set of industry-specific residual intangible asset price indexes, essentially profit-based price indexes, 2) a set of thirteen detailed industry output price indexes from R&D intensive industries, 3) an aggregate R&D output price index that combines the thirteen detailed output price indexes, and 4) an aggregated input price index based on the price indexes of the inputs to the R&D production process. After describing the each of the price indexes, a comparison of index levels is presented.

For the 2007 R&D satellite account, the aggregate R&D output price index is used for the featured estimates of the NIPA-based component of the satellite account as well as for the detailed estimates shown in the GDP-by-Industry component of the satellite account. Even though we preferred the residual intangible asset price index on theoretical grounds, the aggregate input price index is used because the residual intangible asset price index yielded results that were implausible for some industries. By aggregating the detailed output prices, the measurement errors for individual industries offset. Thus, the choice of the aggregate output price index is a second-best solution that reflects implementation challenges and data limitations.

The use of the aggregate R&D output price index for the satellite account reflects the experimental nature of the current work on the concepts and methodologies for treating R&D expenditures as investment. Its use is a departure from the standard method of forming a price index when market prices are unavailable; this standard method is the input price index approach. Indeed, if R&D expenditures were to be treated as investment in the national accounts today, the input price index approach would be used because it is a consistent, repeatable, and internationally comparable standard. Despite its practicality, the input price index suffers from the disadvantage of not allowing for productivity changes in the production of R&D output. Instead, the input price index only reflects the impact of inflation on the cost of performing R&D activity. Consequently, using the input price index produces the unintuitive result that capitalizing R&D has little-to-no effect on real GDP. By contrast, the aggregate R&D output price index allows us to obtain good approximation of how capitalizing R&D would impact the national accounts, even though we currently do not have R&D output price data.

The paper is organized as follows: Section 1 describes the theoretical approach underlying the construction of the alternative R&D price measures. Section 2 provides an explanation of the construction of each alternative and the challenges involved in implementation. Section 3 compares the price indexes and explains the rational for the selection of the featured index, and Section 4 concludes. An appendix section provides tables of the price indexes and provides a diagram and explanation of the components of R&D output, investment, and assets that will need prices in the R&D satellite account work.

1. Approaches to Price Indexes for R&D output and investment

1.1 Residual intangible asset price index

This index focuses on the price that an innovator would charge for his output, which is taken to be an idea. Except for the input-price index, all the price indexes are based on a framework that defines R&D output as an idea. Innovators produce ideas which are then sold to firms who incorporate these ideas into their products. A main premise of this approach is the comparability of R&D ideas from one period to the next. This approach works best when considering "evolutionary" ideas that are marginal improvements to the existing state of knowledge. These evolutionary ideas stand in contrast to "revolutionary" innovations which present dramatic improvements to the current technology.[1] As detailed below, under our approach the innovator sets the price of an idea equal to the increase in the downstream firm's profits attributable to the R&D output. From the downstream firm's perspective, the acquisition of R&D output can be interpreted as a fixed or sunk cost.[2]

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[1] The distinction between evolutionary and revolutionary innovations is frequently made in studies of R&D. For a thorough review of revolutionary innovations (a.k.a. general purpose technology innovations), see the chapter written by Boyan Jovanovic and Peter Rousseau in the forthcoming Handbook of Economic Growth v.1B. Kenneth Arrow also distinguishes between drastic and non-drastic innovations in "Economic Welfare and the Allocation of Resources for Invention" (Rand Working Paper P-1856-RC, 1959).

[2] Our approach has the same flavor of the endogenous growth model developed by Philippe Aghion and Peter Howitt (for a review of some of their work, see chapter 2 of the Handbook of Economic Growth, v1A). Because our focus is on the transaction between the innovator and the downstream firm, we also explicitly model both agents' profit maximizing problems. In this respect, our work is also related to Arrow's work cited above, because we model how R&D innovation can affect the marginal revenue and marginal cost curves of the downstream firm and investigate the resulting effects of equilibrium profits and prices.

We model the production of R&D output as a stochastic process that can require a long period of time. We describe the innovator's problem as a research program that aims to either improve the quality, or reduce the cost, of a good produced by a downstream firm. Research within the pharmaceutical industry, for example, typically aims to improve the quality of treatment for diseases. We assume that downstream firms have some market power, and so model the quality improvement gain as an outward shift in the marginal revenue curve for the downstream firm. Similarly, we model the reduction in costs as a downward shift in the marginal cost curve for the downstream firm. In the downstream market, suppose the current demand curve and production technology implies a marginal revenue curve $MR(q;\theta,\boldsymbol{\gamma})$ and a marginal cost curve $MC(q;\alpha,\boldsymbol{\beta})$, where q denotes the quantity produced. The parameter θ shifts the marginal revenue curve while $\boldsymbol{\gamma}$ is a vector of all other parameters that characterize this function. Similarly, α is a shift parameter for the marginal cost curve, while $\boldsymbol{\beta}$ is vector of all other parameters.

We model the influence of R&D output on the downstream market through the shift parameters of the marginal revenue and cost curves. R&D output can be product-innovative, we which interpret as in increase in θ. Given $\theta_1 > \theta_0$, we assume that $MR(q;\theta_1,\boldsymbol{\gamma}) > MR(q;\theta_0,\boldsymbol{\gamma})$ for all $q>0$. Alternatively, R&D output can be process-innovative, which we interpret as in increase in α. Given $\alpha_1>\alpha_0$, we assume that $MC(q;\alpha_1,\boldsymbol{\beta}) < MC(q;\alpha_0,\boldsymbol{\beta})$ for all $q>0$. Note that in both cases, the downstream firm will generate higher profits with the R&D innovation, either through stronger demand or lower costs of production.

We assume the R&D process uses a sequence of labor, *l*, and capital, *k*, inputs is over *T1* periods. Let

$$L = \sum_{t=1}^{T1} \omega(t) l(t),$$
$$K = \sum_{t=1}^{T1} \omega(t) k(t),$$

so that *L* represents the weighted sum of labor inputs over *T1* periods. *K* is similarly defined. Following the literature on R&D productivity, the weights account for the possibility that inputs at various stages in the R&D process may have different effects on R&D outcomes.[3] This specification highlights the difficulties associated with measuring the rate of return for R&D, given the potentially long periods of time necessary to generate R&D output.

Producing R&D output is uncertain. We denote the probability of producing an R&D innovation that produces a θ_1 greater than the current θ_0 by

$$G(\theta_1 \mid \theta_0, L, K),$$

where *G* has the expected properties of being a non-decreasing function of *L* and *K*. Similarly, we denote the probability of generating an R&D idea that generates an α_1 greater than the existing α_0 by

$$H(\alpha_1 \mid \alpha_0, L, K),$$

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[3] For background on various weighting schemes used in the literature, see Chapter 2 in R&D and Productivity: The Econometric Evidence (1998) by Zvi Griliches.

where H has the expected properties of being a non-decreasing function of *L* and *K*.

We assume that the innovator has all the bargaining power when negotiating with the downstream firm over the sale of R&D output. Let $\Pi(\theta,\alpha,\boldsymbol{\gamma},\boldsymbol{\beta})$ be the net present value of profits of the downstream firm given the current product and technology (i.e. conditioning on the current marginal cost and marginal revenue curves). The price of R&D output depends upon the change in the net present value of profits resulting from the incorporation of the R&D idea. For an R&D idea that generates a $\theta_1 > \theta_0$ and so improves product quality, the price of R&D is

$$P_{R\&D} = \Pi(\theta_1, \alpha_0, \gamma, \beta) - \Pi(\theta_0, \alpha_0, \gamma, \beta). \qquad (1)$$

Because the innovator has monopoly power, we assume the innovator captures all the gains resulting from the R&D idea. Similarly, for an R&D idea that generates an $\alpha_1 > \alpha_0$ and so improves the production process, the price of R&D is

$$P_{R\&D} = \Pi(\theta_0, \alpha_1, \gamma, \beta) - \Pi(\theta_0, \alpha_0, \gamma, \beta). \qquad (2)$$

Equation 1 demonstrates that the price of R&D output can be written as $P_{R\&D} = P(\theta_1,\theta_0,\alpha,\boldsymbol{\gamma},\boldsymbol{\beta})$. This specification emphasizes how the price of an R&D idea depends both on how it compares to existing technology, θ_1 versus θ_0, and how the current new idea will compare with future innovations. The parameter vectors $\boldsymbol{\gamma}$ and $\boldsymbol{\beta}$ incorporate information on the expected depreciation of θ_1, or how long θ_1 will last before becoming obsolete.[4]

Using the notation developed above, we can formally write down the innovator's optimization problem. Below, we write down the case where the R&D output is aimed at improving quality, but the case where R&D output is process-oriented is analogous. The innovator's profit maximizing problem is

$$Z = \max_{\{l(t),k(t)\}_{t=1}^{T1}} \left\{ \begin{aligned} &\sum_{t=1}^{T1} \left(\frac{1}{1+\delta}\right)^{t-1} \left(-wl(t) - rk(t)\right) + \\ &\left(\frac{1}{1+\delta}\right)^{T1} \int_{\theta_0}^{\infty} \left[\Pi(x,\alpha,\gamma,\beta) - \Pi(\theta_0,\alpha,\gamma,\beta)\right] G(x \mid \theta_0, L, K)\, dx \end{aligned} \right\}, \qquad (3)$$

$$s.t. Z \geq 0,$$

where *(w,r)* are the rental rates of labor and capital, respectively and δ is the real interest rate. The innovator also faces a participation constraint, which implies that only R&D projects that have positive expected profits are undertaken. This participation constraint ensures that, in expectation, R&D projects leads to higher profits for the downstream firm.

While we assume that innovators capture all the gains in the downstream firm's profits, this assumption can be relaxed. Innovators can be modeled as capturing any fraction of the increase in profits from the downstream firm. Further, we have described

[4] For more details on R&D depreciation, see "Measuring the Returns to R&D: The Depreciation Problem" by Bronwyn Hall, NBER working paper 13473 (October 2007) and references therein.

the case where the R&D innovator sells the innovation to the downstream firm. An alternative case, which provides the same result, occurs when the R&D innovator rents or licenses the idea to the downstream firm. To fully describe the innovator's problem in this case, we would need to decompose the downstream firm's net present value of profits, Π, into per period profits and define both the length of time the innovation will be in use, and the licensing agreement between the R&D innovator and the downstream firm.

Further, we consider R&D innovations as incremental improvements to existing technology. Alternatively, R&D innovations could result in new products that create markets where none had existed before. For these cases, the same framework can be applied. Rather than pricing the R&D output as a change in profits, the innovator extracts the discounted value of profits from the sale of the new product (or some fraction thereof).

Lastly, the above framework considers the innovator and the downstream firm as two separate entities. There is no reason, however, that the innovator could not be part of the downstream firm. In this case, the above framework could be used to properly allocate an internal return to investing in R&D.

As discussed above, solving the innovator's problem implies that the price of R&D, the price of one idea, is characterized by $P_{R\&D} = P(\theta_1,\theta_0,\alpha,\boldsymbol{\gamma},\boldsymbol{\beta})$. We use this relationship in taking the model to the data to construct R&D price indexes for each industry. The residual intangible asset price index approximates the change in the price of R&D output by measuring the change in profits attributable to R&D over time. We measure the downstream firm's gain to using R&D through a two-step process. First, in every period we compute the gain attributable to R&D as gross output minus intermediate inputs minus labor costs minus the return to physical capital. Physical capital costs are calculated using an average rate of return to existing fixed capital, where the average rate of return is the interest rate on Moody's BAA corporate bonds. Second, we take a five year moving average of these R&D gains, which we denote as $\Pi_{5yr}(t)$. We take this second step for two reasons. First, there is often an implementation lag for firms acquiring R&D innovations. Second, the price of R&D depends upon the future discounted value of revenue attributable to the R&D innovation (see equation 1). Taking a five-year moving average addresses these timing concerns, and also ensures that we consider only longer term trends in the return to R&D.

Because the five-year moving average serves as an approximation to the downstream firm's gains from purchasing R&D, it allows us to construct a price index for R&D output. Under this approach, the change in R&D output price between 2 adjacent years is the 1 year change in the 5 year moving average. Formally,

$$\frac{P_{R\&D}(t)}{P_{R\&D}(t-1)} = \lambda \frac{\Pi_{5yr}(t)}{\Pi_{5yr}(t-1)}, \qquad (4)$$

where the price relatives on the left hand side are elements of the R&D output price index. We assume that λ is equal to 1 in our calculations, but acknowledge that this scaling factor could also be set to a positive number smaller, or larger than 1.

There are a couple of limitations to this approach. First, our measure of profits attributable to R&D, being a residual measure, likely contains the effects of non-R&D factors. Second, this approach assumes that R&D ideas are comparable from period to period. Considering that most innovations are marginal improvements and our approach is at an industry level, the assumption that R&D innovations are evolutionary does not seem severe. But the arrival of a revolutionary innovation would introduce substantial measurement error. Third, our specification in equation 4 assumes that λ is constant over time and that there is a linear relationship between the two ratios. Although these assumptions may be incorrect for particular industries or episodes of major technological change, it would require additional analysis at the micro-data level to ascertain the validity of these assumptions.

The residual intangible asset price index is based on a data-intensive approach that requires the computation of firm's profits attributable to gains from R&D. This approach depends on detailed data, which can be too demanding. As described later (see section 2.1), for several R&D intensive industries, the resulting residual intangible asset price index was extraordinarily volatile and hence unbelievable. These results lead us to consider an alternative, second-best approach.

1.2 Detailed industry price index

The detailed industry price index is this second-best approach, and it infers the change in the price of R&D output from the change in price of the downstream product. To establish the link between R&D output and downstream product prices, we build upon the framework described above. In particular, we use the fact that the purchase price of R&D derives from the innovator's optimization problem. Recall, this purchase price reflects the intricacies of the R&D production function as well as expectations about the depreciation of the R&D idea and its rate of return to the downstream firm. Establishing the connection between movements in the downstream market product's price and the price of R&D, naturally, requires additional assumptions on the nature of R&D output.

We define R&D output as product-innovation when it shifts the marginal revenue curve of the downstream firm. In contrast, R&D output is labeled as process-innovation when it shifts the marginal cost curve of the downstream firm. While R&D innovations raise the downstream firm's profits, they have different effects on the downstream market-clearing price. We continue to denote the downstream firm's marginal revenue curve as $MR(q;\theta,\gamma)$ and assume that $dMR/d\theta > 0$, where successful R&D ideas increase the value of θ. Holding all else constant, this increase in demand due to the R&D innovation leads to a rise in the equilibrium price of the downstream firm's product.[5] Because innovators capture a fixed proportion of the rents to implementing a R&D

[5] See Chapter 1 in The Theory of Industrial Organization by Jean Tirole (1998) for details on this general property of monopoly pricing.

innovation, within this framework there is a positive relationship between the price of R&D product innovation and the price of the downstream industry's product, or

$$P_{R\&D}(t) - P_{R\&D}(t-1) \propto P_{industry}(t) - P_{industry}(t-1), \qquad (5)$$

where the *industry* subscript refers to the downstream market.

Conversely, those process-innovations that shift the marginal-cost curve to the right result in a fall of the market-clearing price. Recall that the downstream firm's marginal cost curve is MC(q;α,**β**), where as before we assume that dMC/dα <0 and that R&D innovations increase the value of α. Holding all else constant, increases in α, by shifting the downstream firm's marginal cost curve outward, lower the equilibrium price. This result holds in very general settings where the firm's marginal revenue curve is decreasing and the marginal cost curve is increasing. Importantly, this relationship implies a negative relationship between the price of R&D output and the price of the downstream industry's product; where

$$P_{R\&D}(t) - P_{R\&D)}(t-1) \propto -\lfloor P_{industry}(t) - P_{industry}(t-1)\rfloor \qquad (6)$$

Consequently, process-oriented R&D innovations may have the opposite effect on downstream product prices relative to product-oriented innovations. As such, it is important to identify which type of R&D innovation prevails in an industry.

It is likely that in most industries, R&D innovations are a mix of process and product-oriented ideas. We assume the majority of R&D innovations are product-oriented, and so use equation 5 as the basis for our empirical work to derive a R&D output price index. Mansfield, "Industrial R&D in Japan and the United States: A Comparative Study" (AEA Papers and Proceedings, 78, 2, 1988, p.224-228) supports our approach, because it also characterizes the majority of U.S. industrial R&D activity as product innovation. A 2006 IBM Global Business Services study of the chief executive officers also found that the emphasis of corporate innovation was a third more likely to be directed toward new products, services, or markets compared with operational innovation that improved effectiveness and efficiency (Expanding the Innovation Horizon, The Global CEO Study 2006, page 12).

Rewriting equation 5, we arrive at the equation used to construct the detailed industry price index,

$$\frac{P_{R\&D}(t)}{P_{R\&D}(t-1)} = \lambda \frac{P_{industry}(t)}{P_{industry}(t-1)}, \qquad (7)$$

where the price relatives on the left hand side are elements of the R&D output price index. As with the residual intangible asset price index, we assume that the scaling factor λ is equal to 1.

The main limitation to this approach is the assumption that changes in the output price of the downstream industry largely reflect changes in the price of R&D, as opposed to changes in other factors. Using the notation introduced above, we are assuming that the changes in the downstream industry's price are largely coming from changes in θ, as opposed to changes in $\boldsymbol{\gamma}$. In addition, we assume the R&D output in product-innovative and so affects the downstream firm's marginal revenue curve. If, on the other hand, the majority of R&D innovation is process-oriented, then our approach makes incorrect inferences about the price of R&D output from changes in the price of industry output. Lastly, as with the residual intangible asset price approach, we assume that R&D ideas are comparable from period to period, a reflection that most innovations are marginal improvements upon existing technology.

Empirically, this detailed industry approach yielded credible price indexes for most R&D-intensive sectors. For several industries, however, the resulting price indexes were implausible (see section 2), an outcome that is likely due to measurement error. To reduce the effect of industry-idiosyncratic measurement error, we considered a third, aggregate approach.

1.3 Aggregate R&D output price index

This approach averages the individual industry price indexes constructed from the detailed industry approach. This single index is then used as the R&D price index for each industry. By averaging across industries, the measurement errors associated with industry detailed price indexes likely offset. There are at least two sources of measurement error that may be diminished by averaging. First, individual industry price relatives contain measurement error as a result of our approximations. For example, we assume there is a constant, linear relationship between the price relatives of R&D output and the downstream product. Averaging price relative reduces some of this random noise. Second, there is measurement error at the industry level. Certain industries, for example, may have a substantial amount of process-innovation which would likely bias the estimated price relatives downwards. Once again, averaging across industries would dampen the impact of this source of measurement error. The resulting aggregate price index then presents us with a measure of the long-run change in the price of R&D, smoothing through idiosyncratic industry effects.

Not surprisingly, an additional assumption is necessary to validate the averaging of the industry detailed price indexes. This approach assumes there are common drivers in R&D productivity across industries. As such, we assume there are strong correlations among R&D output prices across industries.

Mechanically, this approach constructs a single price index by using a Fisher-weighted average of the output prices of the thirteen R&D-intensive industries, where the weights are the industry's share of annual business investment in R&D. For years prior to 1987, detailed industry investment measures are not available, and so this index uses a weighted average of the top five industry R&D performers in each year. Here the weights are not based on investment, but rather expenditures for R&D performance.

As with the detailed industry approach outlined above, a major limitation of the aggregate price index is the assumption that economy-wide, most R&D innovation is product-oriented. Further, an important underlying assumption of the aggregate price index approach is that the underlying R&D production process is similar across the R&D intensive industries. Under this premise, averaging across industries is advantageous because it potentially reduces the influence of measurement error. If it is the case, however, that the R&D production process across industries is distinctly different, then averaging across these industries does not result in an accurate price index for R&D output.

1.4 Cost of R&D Approach

When transaction data are hard to obtain, a standard approach in the national accounts to measuring an output's price change is to rely on input cost data. The underlying assumption is that the price of R&D is a constant markup over marginal cost. Thus, changes in R&D prices reflect changes in input costs. This approach is consistent with the way that prices for government and other hard to measure services are often estimated in the national accounts. It is also the approach recommended by Mansfield[6] and others for R&D price indexes, and has been widely used in recent efforts to produce R&D satellite accounts in other countries. In the U.S. R&D satellite account, these price indexes are based on Fisher aggregation of detailed price indexes for the inputs used to

[6] Mansfield, Edwin, Anthony Romeo and Lorne Switzer, 1983. "R&D price indexes and real R&D expenditures in the United States." Research Policy 12: 105 -112.

create R&D. A well-known disadvantage of the input-cost approach, however, is its inability to account for productivity increases within the R&D production process.

An important use of input price indexes for R&D activity is to track changes over time in the cost of performing R&D. For example, the Biomedical Research and Development Price Index (BRDPI), estimated by the Government Division of the Bureau of Economic Analysis (BEA), is used by the National Institutes of Health (NIH) to assess the impact of changes in input prices for R&D on the funding for biomedical research by NIH and its contractors/grantees. Similarly, the Small Business Innovation Research program (SBIR) funds high-tech R&D projects, and also uses R&D input price indexes to assets the impact of inflation on their funding recipients.

2. Details of the construction of various price indexes.

This section describes the calculation of the price indexes tested for the R&D satellite account. In each case the price relatives (P_t/P_{t-1}) are chained together to create price indexes, which have been normalized to 100 in the base year, 2000, set to 100.

2.1 Residual intangible asset price index

The residual intangible asset price index uses the change in industry gains or residual profits that are attributable to intangible expenditures as an estimate of the unobserved price index for R&D. Using equation (4) we estimate:

$$\frac{P_{R\&D}(t)}{P_{R\&D}(t-1)} = \lambda \frac{\prod_{5yr}(t)}{\prod_{5yr}(t-1)} = \frac{\sum_{t}^{t-4} TR_y - VC_y - Cost_{R\&Dy} - u^K K}{\sum_{t-1}^{t-5} TR_y - VC_y - Cost_{R\&Dy} - u^K K}, \qquad (8)$$

It is calculated as the change in the 5-year moving average of the industry's gains from its intangibles. Each year's gain is calculated as total revenue less variable costs, R&D expenditures, and the user cost of the currently recognized capital stock, where the user cost is calculated with an average rate of return.

Industry total revenue data are measured as gross output (the market value of an industry's production); these data are drawn from BEA's GDP-by-industry series.[7] Variable costs and the cost of R&D are measured as the sum of labor compensation and intermediate inputs; these variables are also drawn from BEA's GDP-by-Industry series. Assuming that there are no holding gains for the capital assets, the user cost, u, times the quantity of the industry's existing capital stock, K, simplifies to:

$$u * K \approx [P^t (r^{*t} + \delta)] * K$$

This cost is calculated in two parts, current cost depreciation ($P^t \delta K$) and current cost capital stock ($P^t K$) times an average rate of return, where $P^t r^t K$ is replaced with:

$$\bar{r} P^t K$$

Current cost depreciation and current cost net capital stock data are drawn from BEA's Private Fixed Assets by Industry data.[8] The average rate of return is estimated with a BAA corporate bond rate from Moody's Investors Service.[9]

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[7] Source: GDP-by-Industry data: 1987-1997 data are from GDPbyInd_VA_NAICS_47to97R.xls, 1997-2004 data are from GDPbyInd_VA_NAICS.XLS, both worksheets are accessed at: http://www.bea.gov/industry/gdpbyind_data.htm

[8] Source: Private Fixed Assets by Industry data, tables 3.4ES and 3.1ES: http://www.bea.gov/national/FA2004/SelectTable.asp#S3

These residual intangible asset price indexes are estimated at the most detailed level possible based on existing BEA data. Because this level of aggregation is less detailed than the level of the current dollar R&D investment estimates for the R&D satellite account, only seven intangible residual asset price indexes are estimated. These seven indexes are applied to the thirteen detailed industries. For example, a price index calculated for all chemical manufacturing is applied to both pharmaceutical and medicine manufacturing and to all other chemical manufacturing. An eighth index is created for all other industry R&D investment. Table A shows the aggregation level of the residual intangible asset price indexes.

The estimated residual intangible asset price is a component of gross operating surplus, a broad profit-like measure that includes corporate profits, proprietors' income, net current business transfer payments, and consumption of fixed capital. For computer and electronic products manufacturing, motor vehicle-related manufacturing, and other transportation equipment manufacturing the volatility of gross operating surplus during the estimation period 1987-2004 resulted in negative values for the five-year moving average of intangible asset residual. Chart A shows gross operating surplus and the five-year moving average of the intangible asset residual for the computer and electronic products manufacturing industry, where annual gross operating surplus itself becomes negative. This pattern is also consistent with NIPA-reported measures of corporate

[9] Source: 2007 Economic Report of the President, Table B-73, accessed at: http://www.gpoaccess.gov/eop/2007/B73.xls

profits for the industry these industries, for example, profits are negative for the computer and electronic products industry between 2001 and 2004.[10]

While taking the five-year moving average of the intangible asset residual smoothed out transitory negative values for some industries, for three of the seven detailed indexes, negative values persisted and complicated the price index calculation. Although negative profits or a negative residual due to intangible assets have a sensible economic interpretation, negative prices do not, necessitating special handling of these values. The industries affected are computer and electrical manufacturing, motor vehicle and parts manufacturing, and other transportation equipment manufacturing.

The following steps were used to create the price relatives for the index:

a) P_t , $P_{t-1} > 0$
The price relative is P_t / P_{t-1}.
For example, if P_t =16,000 and P_{t-1} = 8,000.
The residual gain has doubled, and the price relative is 2 .

b) P_t , $P_{t-1} < 0$, and $|P_t| < |P_{t-1}|$
The price relative = $2 - P_t / P_{t-1}$
For example, P_t =-8,000 and P_{t-1} = -16,000
The residual gain has risen from -16,000 to -8000, and the price relative increases proportionately to = 1.5

c) P_t , $P_{t-1} < 0$, and $|P_t| > |P_{t-1}|$
The price relative = $(1/(P_t / P_{t-1}))$
For example, P_t =-16,000 and P_{t-1} = -8,000
The residual gain has fallen from -8,000 to -16,000, and the price relative falls proportionately to 0.5.

[10] BEA corporate profit measures are based on IRS data, and industries are reported on a company basis. These data are reported in NIPA table 6.16D: Corporate Profits by Industry, which can be accessed at: http://www.bea.gov/national/nipaweb/Index.asp

d) $P_t \times P_{t-1} < 0$
The price relative is undefined.
Use linear interpolation for the undefined price relative and the two adjacent price relatives.

Appendix table A details these prices indexes for the years 1987-2004. Values that are shown in bold were originally estimated as undefined (for example year 2000 for computer and electronic product manufacturing) and imputed using the procedure above. Values that are shown in italics were also imputed because they neighbored an undefined value and therefore produced an implausibly volatile price relative.

2.2 Detailed industry price index

The detailed industry R&D output indexes are individual chain-type Fisher indexes of industry output prices. The change in the price of R&D investment is approximated with changes in the downstream or R&D using industry's output price. Using equation (7) we estimate:

$$\frac{P_{R\&D(t)}}{P_{R\&D(t-1)}} = \lambda \frac{P_{industry(t)}}{P_{industry(t-1)}} = \sqrt{\left(\frac{\sum P_g(t)Q_g(t)}{\sum P_g(t-1)Q_g(t)} \times \frac{\sum P_g(t)Q_g(t-1)}{\sum P_g(t-1)Q_g(t-1)} \right)}, \quad (9)$$

Here commodity price indexes are combined to create industry-specific R&D output prices indexes. P_g refers to the price for each commodity that an industry produces, and Q_g refers to quantities of each commodity, and summation index g refers to the separate components being aggregated. These commodity prices and quantities are drawn from BEA's annual Input-Output account database.

The detailed industry output price indexes are built using the same source data and methodology used by BEA to publish industry output price indexes and aggregated at a custom level of detail to match the featured R&D Satellite Account industries; thus their construction includes unpublished data from BEA's Industry Accounts. [11] Table B shows how the detailed industry output price indexes relate to currently published BEA indexes. Appendix table B details these price indexes for the years 1987-2004.

For the period 1997-2004, the indexes are computed using detailed item output prices grouped by the industries reported in the R&D satellite account (thirteen R&D intensive industries plus an "all other" category). In the Fisher formula above, the summation index g corresponds to various items produced by each of these reported industries. For the period 1987-1997, the indexes are computed using 6-digit NAICS industry output prices grouped into the reported industries. Here the summation index g corresponds to various 6-digit NAICS industries.

Charts B and C compare the detailed output price index for pharmaceutical and medicine manufacturing, and for semiconductor manufacturing to the residual intangible asset price indexes for each industry's R&D investment. For pharmaceutical and medicine manufacturing, chart B, the residual intangible asset price index and the detailed output price index tell a similar story—a rising price index for the R&D investment and the R&D output that is consistent with the product innovation scenario described in Section 1 of the paper.

[11] Industry output price indexes currently published by BEA's Industry Accounts can be found at http://www.bea.gov/industry/ . For more information on the detail prices used by the Industry Accounts, see the Survey of Current Business Article "Preview of the Comprehensive Revision of the Annual Industry Accounts" published March 2004. That article can be found online at http://www.bea.gov/scb/pdf/2004/03March/0304IndustryAcctsV3.pdf .

For semiconductor manufacturing, Chart C, rapidly falling output prices from about 1990 forward suggest a different measure of real R&D output compared with the residual intangible asset price index for the broad computer manufacturing industry (includes semiconductor manufacturing). One possible explanation for this is that semiconductor-related R&D investment prior to 1990 was primarily process-related rather than product-related, breaking the link between the price of the innovation and the price of the downstream product. Another alternative explanation is that the residual intangible asset price index is reflecting influences other than the price of the R&D, such as the recent boom and cycle in technology industries.

2.3 Aggregate R&D output price index

This approach, like the approach described above, infers the change in the price of R&D output from changes in the downstream output price. Unlike the detailed industry price approach, however, this approach develops a single R&D investment price that is used across all industries. The aggregate R&D output index is a weighted combination of the private industry downstream output prices described in section 2.2 . For the years 1957-2004, the aggregate output index is a chain-type Fisher index. Conceptually, the period-to-period growth of this Fisher-type price index for R&D is:

$$\frac{P_{R\&D(t)}}{P_{R\&D(t-1)}} = \sqrt{\left(\frac{\sum P_i(t)Q_i(t)}{\sum P_i(t-1)Q_i(t)} \times \frac{\sum P_i(t)Q_i(t-1)}{\sum P_i(t-1)Q_i(t-1)} \right)}$$

Here *Pi(t)* refers to the price of the detailed industry's output, and *Qi(t)* refers to the industry's quantity of R&D investment.

Because the real quantities of each industry's R&D investment are unobserved, we estimate the aggregate R&D price index by substituting industry R&D investment in current dollars, $E_i(t)$ and $E(t\text{-}1)$, for $Pi(t)Qi(t)$ and $Pi(t\text{-}1)Qi(t\text{-}1)$ respectively, where the subscript i indicate separate R&D intensive industries:

$$\frac{P_{R\&D}(t)}{P_{R\&D}(t-1)} = \sqrt{\left(\frac{\sum E_i(t-1) \times \frac{P_i(t)}{P_i(t-1)}}{\sum E_i(t-1)} \times \frac{\sum E_i(t)}{\sum E_i(t) \times \frac{P_i\ (t-1)}{Pi_i(t)}} \right)}, \quad (10)$$

The numerator in the first term under the radical revalues *(t-1)* expenditures at period *(t)* prices. This type of aggregate index is sometimes called a "Fisher of Fishers" because the price indexes used for the revaluation are Fisher price indexes.

For the 1987-2004 period the current dollar measures in the Fisher formula represent industry R&D investment published in the 2007 R&D Satellite Account. Using current dollar R&D investment by industry provides an annual updating of the weights; changes in the composition of R&D by industry are annually incorporated into the aggregate R&D output price index.

The thirteen industries comprising the index account for on average 64 percent of total R&D investment in the 1987-2004 period. The largest R&D investing industries are pharmaceuticals, semiconductors, motor vehicles, and aerospace. During the 1987-2004 period, R&D investment of pharmaceuticals and semiconductor manufacturing grew rapidly, with investment in transportation equipment R&D lagging behind (table C). These four industries, along with computer manufacturing, exert a large influence on the aggregate index. Computer-related manufacturing industries in general have experienced rapidly falling output prices, and thus their impact on the index is relatively large. The aggregate R&D output price index fell from 105 to 95.3 between 1997 and 2004 (Appendix table A); the detailed price index for computers and peripheral equipment fell from 202.1 to 53.1 over the same period and the detailed output price index for semiconductor manufacturing fell from 200.5 to 69.4 (Appendix table B).

Because the industry investment series developed in the 2007 satellite account begins in 1987, for earlier years the data are not available for the detailed annual industry R&D investment weights. For the 1957-1987 period, the current dollar measures in the Fisher formula represent industry R&D expenses rather than industry R&D investment. The output price data are made up almost exclusively by BLS producer price indexes (PPIs); the two exceptions being in professional and scientific instruments manufacturing and R&D in other non-manufacturing industries (see table D). The industries included in the index during this period are the top five R&D-performing industries on a 2-digit Standard Industry Classification basis measured according to R&D expenditures. The included industries are allowed to change on a year-to-year basis depending on which industries ranked highest in that given year. Four industries are always among the top five: chemicals and allied products (SIC 28), industrial and commercial machinery and computer equipment (SIC 35), electrical equipment except computer equipment (SIC 36), and transportation equipment (SIC 37). The fifth industry is generally professional and scientific instruments (SIC 38), though this industry is occasionally replaced by petroleum refining and extraction (SIC 13, 29) or other non-manufacturing industries. Transportation equipment manufacturing, followed by electrical equipment manufacturing, is the key drivers of the index. Their importance, however, is eroded over time by growth in other industries, especially growth in chemicals and machinery. The top five industries account for on average 86 percent of total R&D expenditures during the period. For years before 1958, the growth rate of the index is set equal to that of the BEA deflator for private fixed investment in equipment and software due to the scarcity of industry prices and weights in earlier years. Appendix table A shows the aggregate R&D output price index for 1987-2004.

2.4 Aggregate Input Price Index

The aggregate input price index for R&D output and investment provides a baseline for comparing the alternative price indexes. For the R&D input price index, prices for the various R&D inputs are used to deflate nominal R&D output at the most detailed cost level possible. Because the source data are performer-based, BEA first creates the input price indexes on a performer basis and aggregates them into an aggregate input price index. Using this aggregate input price index and two NIPA-based indexes for R&D funded by the Federal government, an index for non-Federal R&D purchases is derived residually. This non-Federal aggregate input price index is used to deflate business, non-profit, and academic R&D investment.

Unlike the detailed industry price indexes created in the residual intangible asset price index and the detailed output price index, all industry R&D investment is deflated with a single price index, rather than detailed industry R&D input price indexes. Industry specific data on composition of materials and supplies used for R&D are not available by investing industry, and for the largest component of cost, wages and salaries for scientists and engineers, consistent time series by industry were not available.

To create the performer-based indexes, expenditures and input price relatives are aggregated together using a Fisher chain-weighting process described in Equation (10) to generate total real R&D expenditures. The resulting aggregate input price index is calculated as:

$$\frac{P_{R\&D}(t)}{P_{R\&D}(t-1)} = \sqrt{\left(\frac{\sum E_j(t-1) \times \frac{P_j(t)}{P_j(t-1)}}{\sum E_j(t-1)} \times \frac{\sum E\ (t)}{\sum E_i(t) \times \frac{P(t-1)_i}{P_i(t)}} \right)}, \qquad (11)$$

Here expenditures with the subscript *j* are inputs to the R&D process, and the price relatives are the prices of each input. Table E lists the price indexes that are used to construct the aggregate input price index for input component for each performer.

For the aggregate business sector (private industry), BEA uses salaries for engineers in R&D organizations to deflate compensation costs for R&D personnel. Materials and supplies, overhead, and depreciation for business sector R&D are deflated using the input price indexes from costs incurred by the R&D services industry (NAICS 5417). These prices are based on detailed data for intermediate input costs available in BEA's industry accounts.

For R&D performed by colleges and universities, expenses for consumption of fixed capital (CFC) are deflated separately from all other expenses. All non-CFC R&D expenses funded by the Department of Health and Human Services are deflated using a biomedical R&D price index that BEA developed for the National Institutes of Health. The remaining non-CFC academic R&D expenditures are deflated using an overall academic R&D price series developed for the National Center for Education Statistics from 1960 to 1995. [12] This overall R&D index is extrapolated for the other years based on the BEA price index for personal consumption expenditures on other education and research.

The Federal sector uses a variety of NIPA price indexes for defense and non-defense R&D-related costs such as compensation, intermediate purchases of goods and services, and investment in structures, equipment, and software. These performer-based input price indexes are used in conjunction with a national income and product account (NIPA) price index for total Federal defense and non-defense purchases of R&D and an internally developed price index for R&D performed by the Federal government in order to develop the input price indexes for each sector's R&D investment.

To derive a price index for the remaining, non-Federally funded R&D, BEA uses the Federal price indexes described above and the overall (performer-based) price index to derive a residual index for non-Federally funded price index. When the Federal price indexes are combined with this derived non-Federal funder index using a chain-type formula, the total funder-based price index matches the total performer-based index. Table A shows the aggregate R&D input price index for 1987-2004.

3. Empirical Comparison of Price Indexes

The price indexes discussed above provide substantially different measures of R&D output's price change. The input price index steadily increases from 1987 to 2004, with an average price increase of 2.5% at an annual rate. In contrast, the aggregate

[12] National Center for Education Statistics, *Digest of Education Statistics*, 2004, Table 35.

output price index is relatively flat from 1987 to 1995, before declining from 1995 to 2003 at an average rate of 2.8 percent (see chart D).

The steady up-tick of the input price index highlights the limitations in using it as a deflator. Starting in the late 1990's, the US experienced a surge in productivity growth. This increase is most often attributed to the rapid technological progress and investment in the Information-Communications-Technology Producing industries.[13] Yet this explosion of activity in these R&D-intensive industries is not reflected in the input-cost price index, because the input-cost approach does not account for productivity increases in the R&D production process. Rather, this index records steady price indexes, missing how the infusion of R&D investment that occurred in the late 1990's likely influenced the price of R&D output.

In contrast to the input-price approach, the residual intangible asset price method focuses on measuring the downstream firm's gain from using R&D. Of the approaches discussed here, this approach most directly attempts to estimate the price of R&D output. The resulting set of price indexes, however, produced implausible estimates of R&D output price change in some industries. For example, chart E plots the residual intangible asset price index for semiconductors and for other transportation-equipment manufacturing industries. The extreme volatility of both these indexes signifies that this approach measures the price of R&D output with significant measurement error.

[13] See then-Governor Benjamin Bernanke's February 24th, 2005 speech, "Productivity", presented at the University of Arkansas in Little Rock, Arkansas and references therein for details on the US's surge in productivity growth.

The limitations of the input price and residual intangible asset price indexes led to our choice of the aggregate price index for the 2007 R&D satellite account estimates. It does not display excessive volatility. Further, unlike the input-cost price index, the aggregate price index seems to reflect the changing dynamics of the R&D sector. While relatively flat from 1987 to 1995, this index records a steady decline in the price of R&D output in the late 1990's, concurrent with large increases in R&D investment.

The aggregate price index is preferred to the set of detailed industry price indexes primarily because several of the industry price indexes are quite volatile. The detailed industry price index for semiconductors, for example, falls from over 500 to under 70 from 1987 to 2004, where 2000 is the base year (chart C). In these instances, the detailed industry price index is likely capturing other dynamics within the industry. By averaging across industries, the aggregate price index downplays the influence of the more volatile detailed industry price indexes. As detailed in section 1, we assume each detailed industry price index approximates the R&D output price index with measurement error. By taking the average, the aggregate price index should reduce the overall error, because there are likely off-setting errors that the averaging process combines. Importantly, the detailed industry and aggregate price indexes will produce similar measures of real total R&D output. These two approaches, however, produce different measures of industry-level real R&D output.

To uncover what is driving the movement in the aggregate price index, we chart the detailed industry price indexes for R&D output, of which the aggregate price index is a weighted average (see section 1.3). For our analysis, we categorize the R&D-intensive industries into 3 groups: biotechnology industries, transportation-equipment manufacturing, and information-communications-technology (ICT) producing industries. According to the detailed industry price indexes, the first two groups of industries experienced steady price increases of R&D output from 1987 to 2004 (see charts F and G). The price of pharmaceutical R&D output, for example, increased at an average annual rate of 4.8%. In sharp contrast, most industries within the third group, the ICT industries, saw large and sustained decreases in the price of R&D output (see chart H and I). This is particularly true for the semiconductor, software and computer and peripheral equipment industries.

From 1987 to 1995, the weighted average of all detailed industry price indexes resulted in a flat aggregate price index, because increases in biotechnology and transportation equipment manufacturing industries were offset by decreases in software, semiconductors, and other ITC industries. Recall however, that the weights used to construct the aggregate price index are updated each year based on R&D activity (see section 1.2). In the 1990's, the large surge in R&D activity within the ITC sector meant these industries received more weight within the aggregate industry price index. Thus, from 1995 onwards, the aggregate price index tends to reflect R&D output price movements within the ITC industries.

4. Conclusion

Once the scope of included current dollar R&D expenditures is estimated, the choice of the deflator for R&D investment is the major determinant of the impact on GDP that results from the change in the national accounting treatment. The reason for this is that the R&D satellite account measures only the direct effects of treating R&D as investment, and excludes separate estimates of spillovers, which are included in core GDP, but not separately distinguished.

If R&D were to be incorporated as investment into the core accounts today, the choice for an R&D investment deflator would be an input price index that is typically used when there are no available output prices. This alternative is consistent, repeatable, and internationally comparable, but it also substantially biases downward measures of R&D's impact as investment in the national accounts because it misses productivity improvement in the production of R&D output. For this reason, we have developed and tested a set of alternative price indexes for the 2007 R&D satellite account.

In the absence of observable market prices for R&D investment, we test three alternative approaches to the input price index. Theoretically, we view the residual intangible asset price index as the correct one. The price an innovator can command for an innovation is the discounted value of the gains that an investor will reap from using the innovation over a period of time. Although the model is presented as one with an innovator selling its output, it is suitable for internally created R&D production. In practice, the implementation of the residual profit price index provided implausible results for some industries, notably computer manufacturing and motor vehicle manufacturing. In part, the reason for this result is that there are little data that would allow for an isolation of the impact on downstream firm's profit from the acquisition of the R&D output.

Accordingly, the attention was directed to where the price data exist--the downstream industries. This approach treats the movement of the downstream output prices as reflective of the R&D output price. This approach is based on the following presumptions:

- U.S. R&D output is more oriented toward product improvement than process improvement.
- These exists a stable relationship between the movement of the downstream industry's output prices and the prices of the R&D output that the industry purchases or creates for its own use.
- The impact of R&D on output prices dominates all other factors influencing the output price.

The implementation of these detailed output price indexes obtained a wide range of results that in part may derive from the measurement error associated with these presumptions.

Our choice of the aggregate R&D output price index for the 2007 satellite account in principal overcomes the impact of measurement error for the detailed industry estimates of real gross output and value added by allowing for offsetting errors. Aggregation gives a stable price index series. Yet, the aggregation does not overcome the possibility that the relationship between movement of the output price of the downstream producer and the output price of the R&D producer may not be robust for all industries.

Nevertheless, we show that the aggregate output price index for R&D investment provides a qualitatively different price trend from the practical alternative for the R&D satellite account estimates, the aggregate input price index for R&D investment. The aggregate input price index is monotonically increasing, while the aggregate output price index falls notably in recent years. In sum, the aggregate output price index, at this point, makes more sense then the alternatives.

Table A. Aggregation Level for Residual Intangible Asset Price Index

Detail Level for Residual Intangible Asset Price Index (NAICS code)	Detail Level for Current dollar investment, gross output, and value added (NAICS code)
Chemical Manufacturing (325)	Pharmaceutical and medicine manufacturing (3254)
	Other chemical manufacturing (325 except 3254)
Computer and electronic products manufacturing (334)	Computer and peripheral equipment manufacturing (3341)
	Communication equipment manufacturing (3342)
	Semiconductor and other electronic component manufacturing (3344)
	Navigational, measuring, electro-medical, and control instrument manufacturing (3345)
	Other computer and electronic product manufacturing (3343, 3346)
Motor vehicles, bodies and trailers, and parts (3361-3363)	Motor vehicle and motor vehicle and parts manufacturing (3361-3363)
Other transportation equipment (3364, 3365, 3366, and 3369)	Aerospace products and parts manufacturing (3364)
	Other transportation equipment manufacturing (3365, 3366, 3369)
Publishing industries (511)	Software publishers (5112)
Computer systems design and related services (5415)	Computer systems design and related services (5415)
Miscellaneous professional, scientific, and technical services (541), less Legal services (5411) and computer services (5415).	Scientific R&D Services (5417)
Special aggregate of all private industries, less agriculture, FIRE, and the detailed industries listed above	All other private industries

Table B. Currently Published BEA Output Price Indexes (boldface) and R&D Satellite Account Detail Output Price Sub-Indexes (standard)

Industry NAICS Code	**Industry Output Price Index Series**
325	**Chemical manufacturing**
3254	Pharmaceutical and medicine manufacturing
325 except 3254	Other chemical manufacturing
334	**Computer and electronic product manufacturing**
3341	Computer and peripheral equipment manufacturing
3342	Communication equipment manufacturing
3344	Semiconductor and other electronic components manufacturing
3345	Navigational, measuring, electro-medical, and control instruments manufacturing
3343,3346	Other computer and electronic products manufacturing
3361-3363*	**Motor vehicle and motor vehicle parts**
3364-3369	**Other transportation equipment manufacturing**
3364	Aerospace products and parts manufacturing
3365-3369	Other transportation equipment manufacturing
511	**Publishing (includes software)**
5112	Software publishers
5415 *	**Computer systems design and related services**
541 excluding 5411,5415	**Miscellaneous professional, scientific, and technical services**
5417	Scientific research and development services

Note 1: Asterisk (*) indicates that index series is both a currently-published output price index and one of the detail output price indexes featured in the satellite account.
Note 2: There is also an all other private industries output price index represents prices for all private industries excluding the 13 industries featured in the R&DSA.

Table C. Share of Total R&D Investment, selected industries, 1987-2004 (percent)

	1987-1994	1995-2004
Pharmaceutical and medicine mfg (NAICS 3254)	9.4	12.4
Computer and peripheral equipment mfg (NAICS 3341)	4.6	3.5
Semiconductor mfg (NAICS 3344)	8.1	8.1
Motor vehicles and parts mfg (NAICS 3361-3363)	10.9	10.0
Aerospace products and parts mfg (NAICS 3364)	8.4	4.0

Table D. Industries Comprising Aggregate Output Price Index and Proxy Industry R&D Prices

Industries Comprising Aggregate Output Price Index	**Industry R&D Prices**
1987-2004 (NAICS)	
Pharmaceutical and medicine manufacturing (3254) Other chemical manufacturing (325 excluding 3254) Computer and peripheral equipment manufacturing (3341) Communication equipment manufacturing (3342) Semiconductor and other electronic component manufacturing (3344) Navigational, measuring, electro-medical, and control instrument manufacturing (3345) Other electronic product manufacturing (3343 and 3346) Motor vehicle and motor vehicle and parts manufacturing (3361-3363) Aerospace products and parts manufacturing (3364) Other transportation equipment manufacturing (3365, 3366, and 3369) Software publishers (5112) Computer systems design and related services (5415) Scientific research and development services (5417)	Corresponding industry output prices used in the detail output index scenario.
1957-1987 (SIC)	
Always among top 5 R&D performing industries	
Chemicals and allied products (28)	PPI for chemicals
Industrial and commercial machinery and computer equipment (35)	PPI for machinery
Electrical equipment except computer equipment (36)	PPI for electrical machinery and equipment
Transportation equipment (37)	PPI for transportation equipment or PPI for motor vehicles
Sometimes among top 5 R&D performers	
Professional and scientific instruments (38)	BEA deflator for private fixed investment in medical equipment and instruments
Petroleum refining and extraction (SIC 13, 29)	PPI for petroleum products
Non-manufacturing industries	BEA deflator for services exports
1929-1957 (No Industry Detail Used)	
Index growth rate corresponds to growth rate of BEA deflator for private investment in equipment and software	

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
Private sector		Aggregate of input price detail for all privately-performed cost components.
Business (industry)		For 1987-2004, aggregate of input price detail. For 1959-86, R&D deflation is performed at the total business level using the GDP implicit price deflator (IPD).
Compensation of R&D personnel	For 1987-2004, NSF reported distribution of wages of R&D personnel by industry.	
Scientists and engineers	For 1987-2004, based on 1987 detail from NSF working paper (Jankowski 1990[14]).	For 2000-04, judgmental estimates based on salaries for R&D scientists and engineers from R&D Magazine salary surveys and BEA's unpublished chain-type Laspeyres salary index based on engineer salaries in R&D organizations from the American Association of Engineering Societies (AAES) annual salary surveys. For 1987-99, BEA's unpublished chain-type Laspeyres salary index based on AAES data.
Support personnel	For 1987-2004, based on 1987 detail from NSF working paper (Jankowski 1990).	BEA unpublished index based on BLS average hourly earnings of production workers in research and testing services.
Materials and supplies	For 1987-2004, NSF reported distribution of R&D materials and supplies by industry.	BEA unpublished composite index for materials in the scientific R&D services industry (NAICS industry 5417) from the KLEMS data in the annual industry accounts.
Other R&D costs (overhead)	For 1987-2004, NSF reported distribution of R&D overhead costs by industry.	BEA unpublished composite index for overhead in the scientific R&D services industry (NAICS industry 5417) from the annual industry accounts.
Consumption of fixed capital (CFC) for structures and equipment	To identify the CFC cost component: For 2001-2004, NSF reported distribution of historical-cost depreciation. For 1959-2000, NSF reported distribution of historical-cost depreciation for 2001 was use To adjust CFC to an economic basis: For 1959-1987, historical-cost depreciation was adjusted to a current-cost basis using the ratio current-cost depreciation to historical-cost depreciation of assets used to perform R&D at private academic institutions. For 1988-2004, estimated by applying the NIPA CFC growth rates for total business.	NIPA price index for depreciation in NAICS industry 5412.
Federally funded research and development centers (FFRDCs) administered by business		Aggregate of input price detail

[14] Jankowski, John, Jr. "Construction of a Price Index for Industrial R&D Inputs," National Science Foundation Working Paper, August 1, 1990.

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
DOD- and NASA-funded FFRDCs	Weight of expenditures based on R&D obligations to industry-administered FFRDCs for the agencies that define the component.	NIPA price index for Federal defense purchases of R&D services.
HHS-funded FFRDCs	Weight of expenditures based on R&D obligations to industry-administered FFRDCs for the agencies that define the component.	For 1979-2004, NIPA unpublished biomedical R&D price index. For 1929-1978, extrapolated by NIPA personal consumption expenditures price index for "other" education and research.
DOE-funded FFRDCs and all other FFRDCs	Weight of expenditures based on R&D obligations to industry-administered FFRDCs for the agencies that define the component.	NIPA unpublished price index for Federal nondefense purchases of R&D services.
Private universities and colleges		Aggregate of input price detail
R&D expenditures excluding CFC HHS-funded	Estimate of HHS-funded R&D expenditures less research equipment expenditures, which were removed from current expenses and reclassified as investment. Based on HHS R&D obligations to academic performers.	For 1979-2004, NIPA unpublished biomedical R&D price index for academic grants and contracts. For 1929-1978, extrapolated by NIPA personal consumption expenditures price index for "other" education and research.
R&D expenditures excluding CFC non-HHS-funded	R&D expenditures less research equipment expenditures, which were removed from current expenses and reclassified as investment with HHS funded portion removed.	For 1960-95, academic R&D price index from the National Center for Education Statistics. For other years, extrapolated by NIPA personal consumption expenditures price index for "other" education and research.
CFC for structures	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D structures: Calculated as a percent of total NSF reported science and engineering space through 1989 then extrapolated to 2004 based on NIPA price index for gross government fixed investment in educational structures.	Direct valuation: Perpetual inventory calculations based on gross investment and investment prices. Investment prices: For structures, the NIPA index for private fixed investment in nonresidential structures by the educational services industry.
CFC for equipment	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D large equipment: Calculated as a percent of total science and engineering space. For small equipment: NSF reported current fund research equipment expenditures, which were removed from current expenses and reclassified as investment.	Direct valuation: Perpetual inventory calculations based on gross investment and investment prices. Investment prices: For equipment, the NIPA index for private fixed investment in equipment and software by the educational services industry (NAICS industry 61).
Federally funded research and development centers (FFRDCs) administered by private universities and colleges		Aggregate of input price detail
DOD- and NASA-funded FFRDCs excluding CFC	Expenditures for each FFRDC aggregated by Federal sponsoring agency, less research equipment, which were removed from current expenses and reclassified as investment.	NIPA price index for Federal defense purchases of R&D services.

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
DOE-funded FFRDCs and all other FFRDCs excluding CFC	Expenditures for each FFRDC aggregated by Federal sponsoring agency, less research equipment, which were removed from current expenses and reclassified as investment.	NIPA unpublished price index for Federal nondefense purchases of R&D services.
CFC for structures and equipment	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D structures and equipment: Federal obligations on plant to FFRDCs administered by private universities and colleges and BEA estimated research equipment expenditures, which were removed from current expenses and reclassified as investment.	Direct valuation: Perpetual inventory calculations based on gross investment and investment prices. Investment prices: For equipment, the NIPA index for private fixed investment in equipment and software by the educational services industry (NAICS industry 61); for structures, the NIPA index for private fixed investment in nonresidential structures by the educational services industry.
Other nonprofit institutions serving households	Expenditures for years surveyed by NSF. For years where data are unavailable, Federal funding interpolated or extrapolated by Federal obligations to nonprofit institutions; non-Federal funding interpolated or extrapolated by personal consumption expenditures for foundations and nonprofit research.	NIPA IPD for foundations and nonprofit research.
Federally funded research and development centers (FFRDCs) administered by other nonprofit institutions serving households		Aggregate of input price detail
DOD- and NASA-funded FFRDCs	For 2001-04, expenditures for each FFRDC, aggregated by Federal sponsoring agency categories. For other years, Federal agency obligations to FFRDCs administered by other nonprofit institutions.	NIPA price index for Federal defense purchases of R&D services.
DOE-funded FFRDCs and all other FFRDCs	For 2001-04, expenditures for each FFRDC, aggregated by Federal sponsoring agency categories. For other years, Federal agency obligations to FFRDCs administered by other nonprofit institutions.	NIPA unpublished price index for Federal nondefense purchases of R&D services.
Government sector		Aggregate of input price detail for all government-performed R&D components.
Federal Government	For 1929 to 1950, deflated at the aggregate Federal level. For 1951 to 2004, see detail below.	For 1929 to 1950, deflated in total using the average of the NIPA price indexes for defense and nondefense R&D services. For 1951 to 2004, aggregate of input price detail.
Compensation of employees		Aggregate of input price detail
DOD-funded R&D	Federal obligations to intramural R&D by agency and by cost type.	For 1972-2004, NIPA IPD for Federal defense compensation of general government civilian employees. For 1951-1971, NIPA IPD for Federal defense compensation of general government employees (all).
DOE funded R&D	Federal obligations to intramural R&D by agency and by cost type.	NIPA IPD for Federal nondefense compensation of general government employees.

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
HHS-funded R&D	Federal obligations to intramural R&D by agency and by cost type.	For 1979-2004, NIPA unpublished biomedical R&D personnel price index. For 1951-1978, extrapolated by NIPA IPD for Federal nondefense compensation of general government employees.
NASA and other Federal agency funded R&D	Federal obligations to intramural R&D by agency and by cost type.	NIPA IPD for Federal nondefense compensation of general government employees.
Materials and supplies		Aggregate of input price detail
DOD-funded R&D	Federal obligations to intramural R&D by agency and by cost type.	For 1972-2004, NIPA IPD for Federal defense installation support services. For 1951-1971, NIPA IPD for Federal defense services.
DOE funded R&D	Federal obligations to intramural R&D by agency and by cost type.	For 1972-2004, NIPA IPD for Federal defense services. For 1951-1971, NIPA IPD for Federal defense weapons support services.
HHS-funded R&D	Federal obligations to intramural R&D by agency and by cost type.	For 1979-2004, NIPA unpublished biomedical R&D nonpersonnel price index. For 1951-78, extrapolated by NIPA price index for Federal nondefense intermediate goods and services purchased.
NASA and other Federal agency funded R&D	Federal obligations to intramural R&D by agency and by cost type.	NIPA IPD for Federal nondefense intermediate goods and purchased services.
CFC on R&D equipment		Aggregate of input price detail
DOD-funded R&D	Perpetual inventory calculations at current cost based on gross investment and investment prices. Gross investment for R&D equipment: BEA estimate of small R&D equipment expenditures (6% of current Federal intramural expenses), which were removed from current expenses and reclassified as investment. BEA estimate of large R&D equipment, which is included in NSF R&D plant expenditure data. BEA assumes 15% of the plant expenditure total is for large equipment.	NIPA price index for Federal national defense investment in equipment and software.
DOE funded R&D	Perpetual inventory calculations at current cost based on gross investment and investment prices. Gross investment for R&D equipment: BEA estimate of small R&D equipment expenditures (6% of current Federal intramural expenses), which were removed from current expenses and reclassified as investment. BEA estimate of large R&D equipment, which is included in NSF R&D plant expenditure data. BEA assumes 15% of the plant expenditure total is for large equipment.	NIPA price index for Federal national defense investment in equipment and software.

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
HHS-funded R&D	Perpetual inventory calculations at current cost based on gross investment and investment prices. Gross investment for R&D equipment: BEA estimate of small R&D equipment expenditures (6% of current Federal intramural expenses), which were removed from current expenses and reclassified as investment. BEA estimate of large R&D equipment, which is included in NSF R&D plant expenditure data. BEA assumes 15% of the plant expenditure total is for large equipment.	NIPA price index for Federal national defense investment in equipment and software.
NASA and other Federal agency funded R&D	Perpetual inventory calculations at current cost based on gross investment and investment prices. Gross investment for R&D equipment: BEA estimate of small R&D equipment expenditures (6% of current Federal intramural expenses), which were removed from current expenses and reclassified as investment. BEA estimate of large R&D equipment, which is included in NSF R&D plant expenditure data. BEA assumes 15% of the plant expenditure total is for large equipment.	NIPA chain-type price index for Federal nondefense investment in equipment and software.
CFC on R&D Structures		Aggregate of input price detail
DOD-funded R&D	Perpetual inventory calculations at current cost based on gross investment and on investment prices Gross investment for R&D structures: Federal obligations for Federal intramural plant less estimate of large equipment.	NIPA price index for Federal national defense investment in industrial buildings.
DOE funded R&D	Perpetual inventory calculations at current cost based on gross investment and on investment prices Gross investment for R&D structures: Federal obligations for Federal intramural plant less estimate of large equipment.	NIPA chain-type price index for Federal national defense investment in industrial buildings.
HHS-funded R&D	Perpetual inventory calculations at current cost based on gross investment and on investment prices Gross investment for R&D structures: Federal obligations for Federal intramural plant less estimate of large equipment.	For 1997-2004, NIPA price index for Federal non-defense investment in new structures. For 1951-1996, NIPA price index for Federal nondefense investment in industrial buildings.
NASA and other Federal agency funded R&D	Perpetual inventory calculations at current cost based on gross investment and on investment prices Gross investment for R&D structures: Federal obligations for Federal intramural plant less estimate of large equipment.	For 1997-2004, NIPA price index for Federal non-defense investment in new structures. For 1951-1996, NIPA price index for Federal nondefense investment in industrial buildings.
State and local governments		Aggregate of input price detail

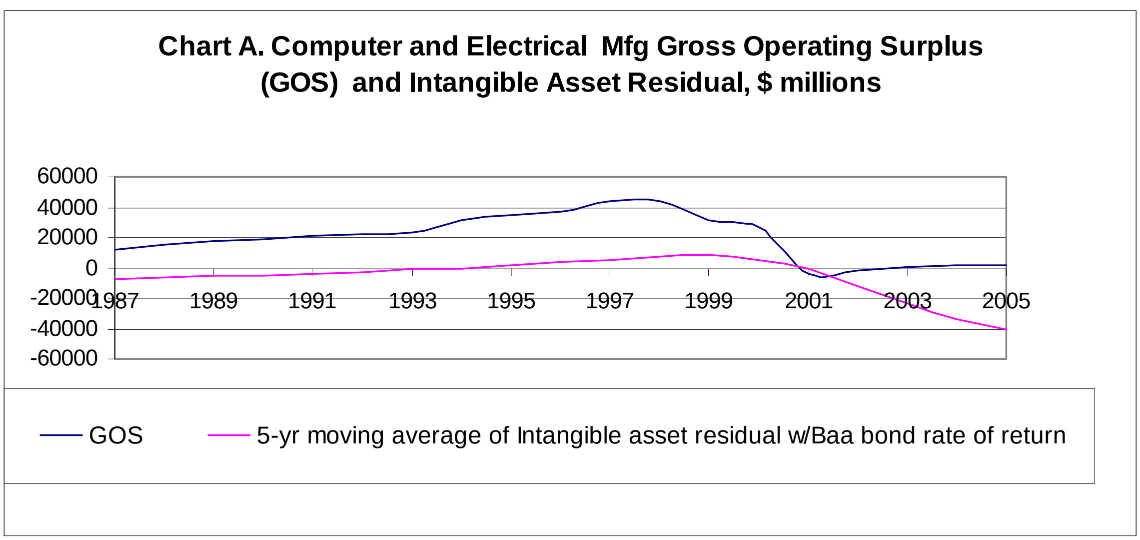
Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
R&D expenditures excluding CFC	For years available from NSF (varied), R&D expenditures excluding R&D plant less BEA estimated research equipment. For other years, interpolated or extrapolated by Federal obligations to state and local governments; non-Federal funding interpolated or extrapolated by NIPA state and local government consumption and gross investment estimates.	NIPA IPD for "other" education and research and NIPA IPD for foundations and nonprofit research.
CFC for structures and equipment	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D structures and equipment: Federal obligations on plant to state and local governments and BEA estimated research equipment expenditures, which were removed from current expenses and reclassified as investment.	Direct valuation: Perpetual inventory calculations based on gross investment and on investment prices. Investment prices: For equipment, the NIPA index for state and local fixed investment in equipment and software; for structures, the NIPA index for state and local fixed investment in health care structures.
Public universities and colleges		Aggregate of input price detail
R&D expenditures excluding CFC HHS-funded	Estimate of HHS-funded R&D expenditures less research equipment expenditures, which were removed from current expenses and reclassified as investment. Based on HHS R&D obligations to academic performers.	For 1979-2004, NIPA unpublished biomedical R&D price index for academic grants and contracts. For 1929-1978, extrapolated by NIPA personal consumption expenditures price index for "other" education and research.
R&D expenditures excluding CFC non-HHS-funded	R&D expenditures less research equipment expenditures, which were removed from current expenses and reclassified as investment with HHS funded portion removed.	For 1960-95, academic R&D price index from the National Center for Education Statistics. For other years, extrapolated by NIPA personal consumption expenditures price index for "other" education and research.
CFC for structures	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D structures: Calculated as a percent of total NSF reported science and engineering space through 1989 then extrapolated to 2004 based on federal plant obligations to academic R&D performers.	Direct valuation: Perpetual inventory calculations based on gross investment and investment prices. Investment prices: For structures, the NIPA price index for state and local government fixed investment in educational buildings.
CFC for equipment	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D large equipment: Calculated as a percent of total science and engineering space. For small equipment: NSF reported current fund research equipment expenditures, which were removed from current expenses and reclassified as investment.	Direct valuation: Perpetual inventory calculations based on gross investment and investment prices. Investment prices: For equipment, the NIPA price index for state and local government fixed investment in equipment and software.
Federally funded research and development centers (FFRDCs) administered by public universities and colleges		Aggregate of input price detail
DOD- and NASA-funded FFRDCs excluding CFC	Expenditures for each FFRDC, aggregated by Federal sponsoring agency, less research equipment.	NIPA price index for Federal defense purchases of R&D services.

Table E. Input Price Indexes: Source Data and Methods for Cost Components and Corresponding Deflation

Cost component	Data and methods for cost component	Method for deflation
DOE-funded FFRDCs and all other FFRDCs excluding CFC	Expenditures for each FFRDC, aggregated by Federal sponsoring agency, less research equipment.	NIPA unpublished price index for Federal nondefense purchases of R&D services.
CFC for structures and equipment	Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Gross investment for R&D structures and equipment: Federal obligations on plant to FFRDCs administered by public universities and colleges and BEA estimated research equipment expenditures, which were removed from current expenses and reclassified as investment.	Direct valuation: Perpetual inventory calculations at current cost, based on gross investment and on investment prices. Investment prices: For equipment, the NIPA index for public fixed investment in equipment and software by educational services industry (NAICS industry 61); for structures, the NIPA index for state and local fixed investment in educational buildings.

BLS Bureau of Labor Statistics
CFC Consumption of fixed capital
DOD Department of Defense
DOE Department of Energy
HHS Department of Health and Human Services
IPD Implicit price deflator
KLEMS K-capital, L-labor, E-energy, M-materials, and S-purchased services; BEA production framework
NASA National Aeronautics and Space Administration
NAICS North American Industrial Classification system
NIPA National Income and Product Accounts
NSF National Science Foundation
SIC Standard Industrial Classification system
Note. A Fisher chaining methodology used for aggregation of cost and sector detail.



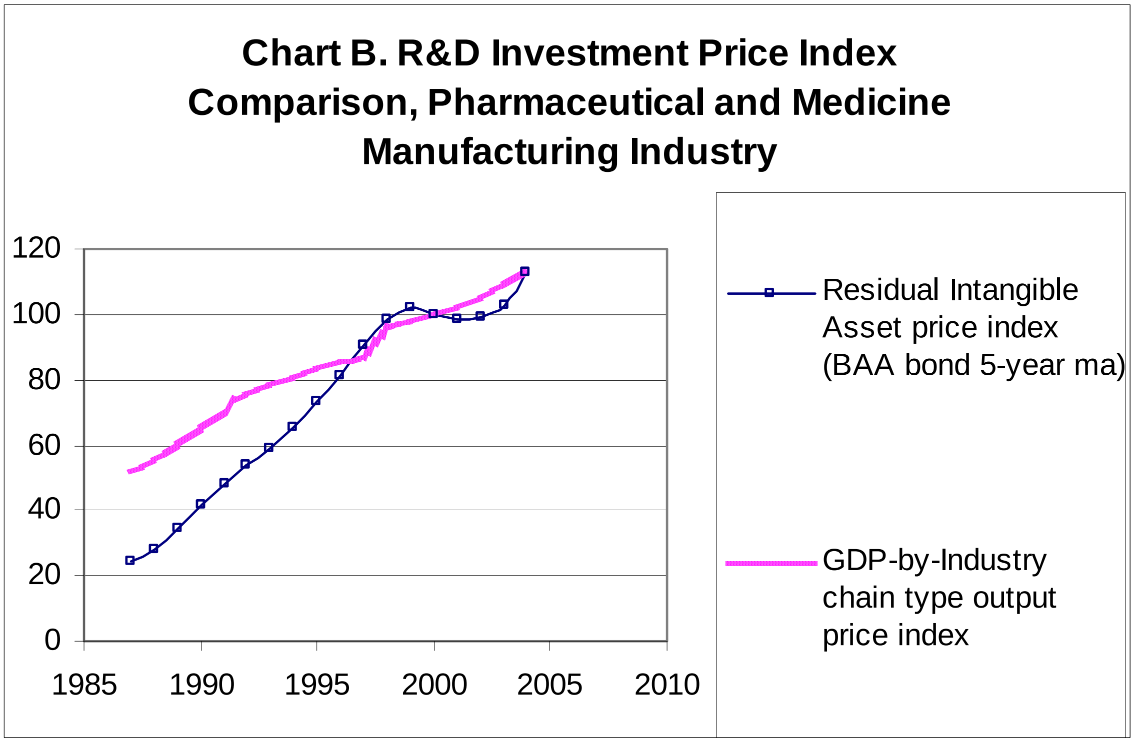


Chart B. R&D Investment Price Index Comparison, Pharmaceutical and Medicine Manufacturing Industry
120
100
80
60
40
20
0
1985
1990
1995
2000
2005
2010
Residual Intangible Asset price index (BAA bond 5-year ma)
GDP-by-Industry chain type output price index

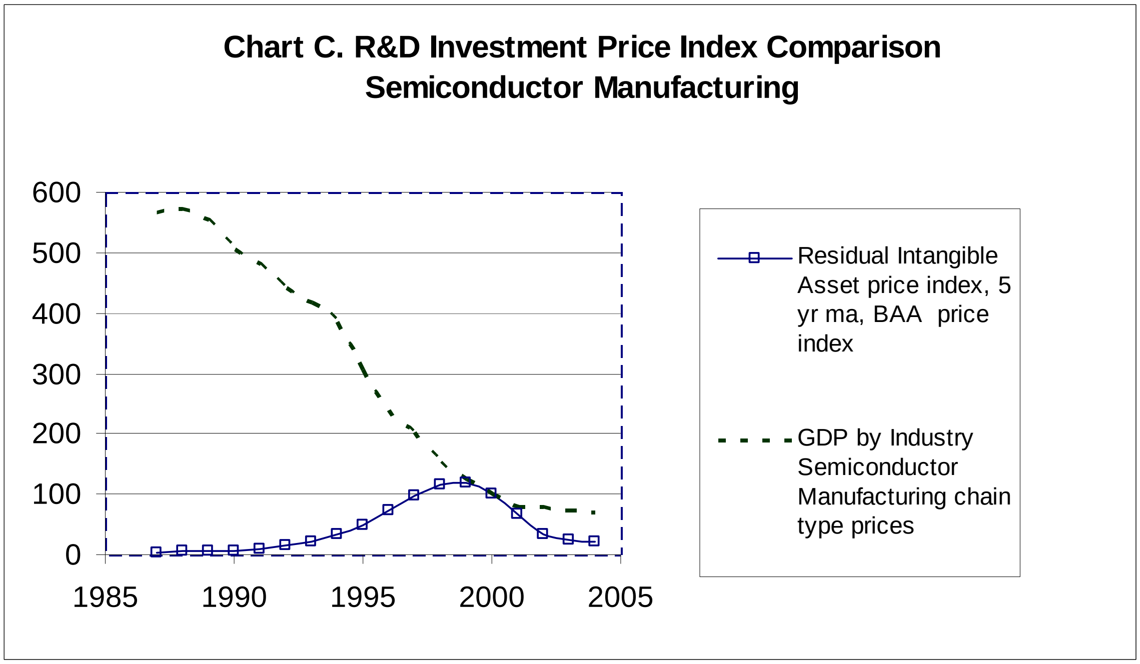


Chart C. R&D Investment Price Index Comparison Semiconductor Manufacturing
600
500
400
300
200
100
0
1985
1990
1995
2000
2005
Residual Intangible Asset price index, 5 yr ma, BAA price index
GDP by Industry Semiconductor Manufacturing chain type prices

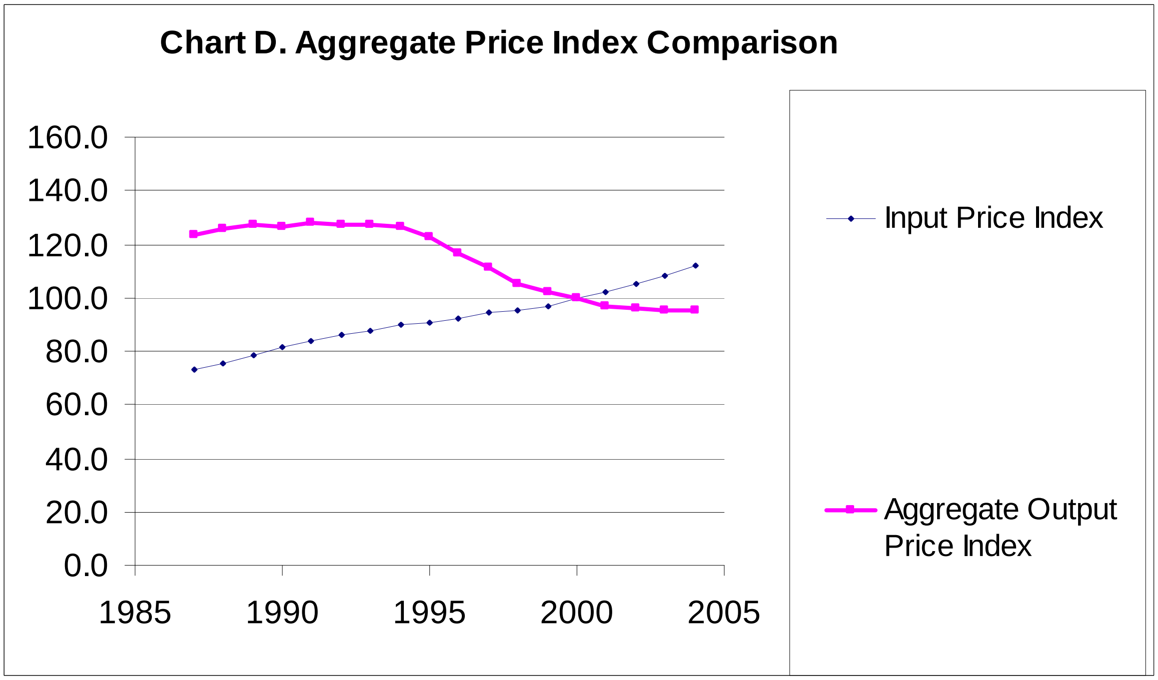


Chart D. Aggregate Price Index Comparison
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1985
1990
1995
2000
2005
Input Price Index
Aggregate Output Price Index

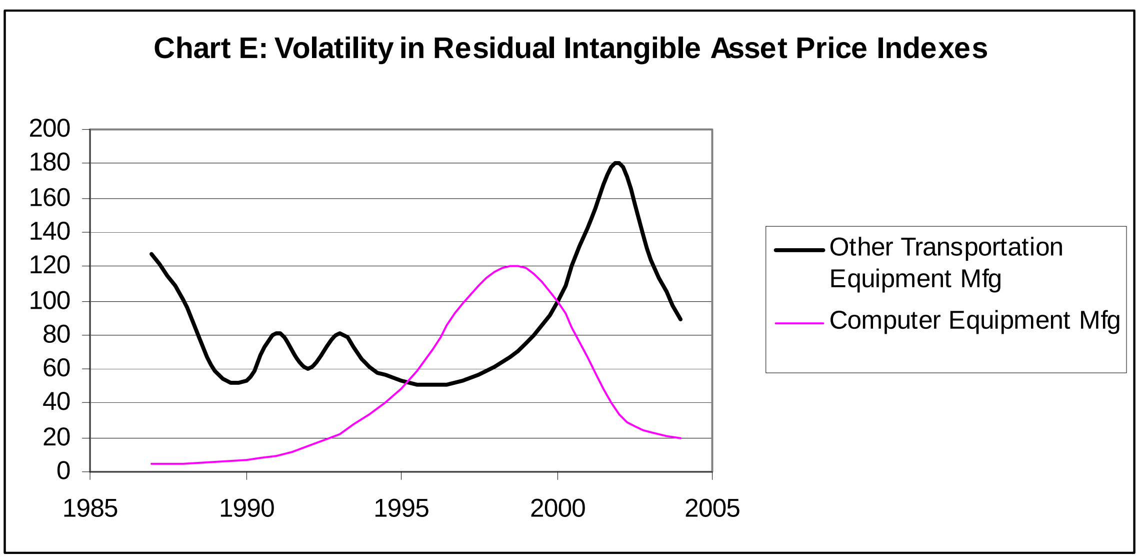


Chart E: Volatility in Residual Intangible Asset Price Indexes
200
180
160
140
120
100
80
60
40
20
0
1985
1990
1995
2000
2005
Other Transportation Equipment Mfg
Computer Equipment Mfg

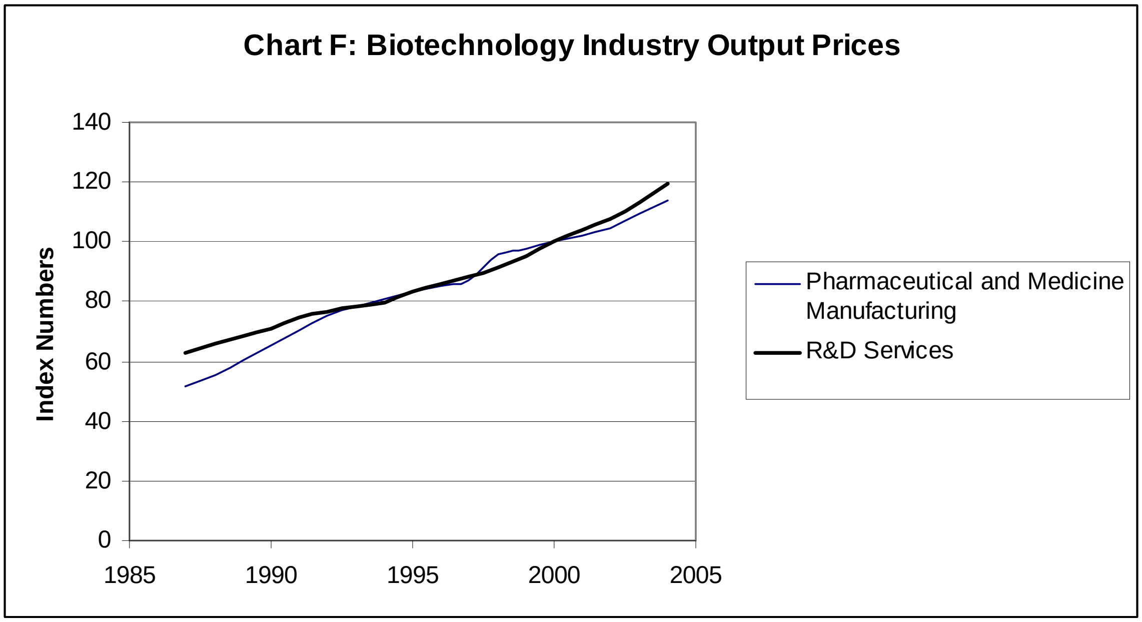


Chart F: Biotechnology Industry Output Prices
Index Numbers
140
120
100
80
60
40
20
0
1985
1990
1995
2000
2005
Pharmaceutical and Medicine Manufacturing
R&D Services

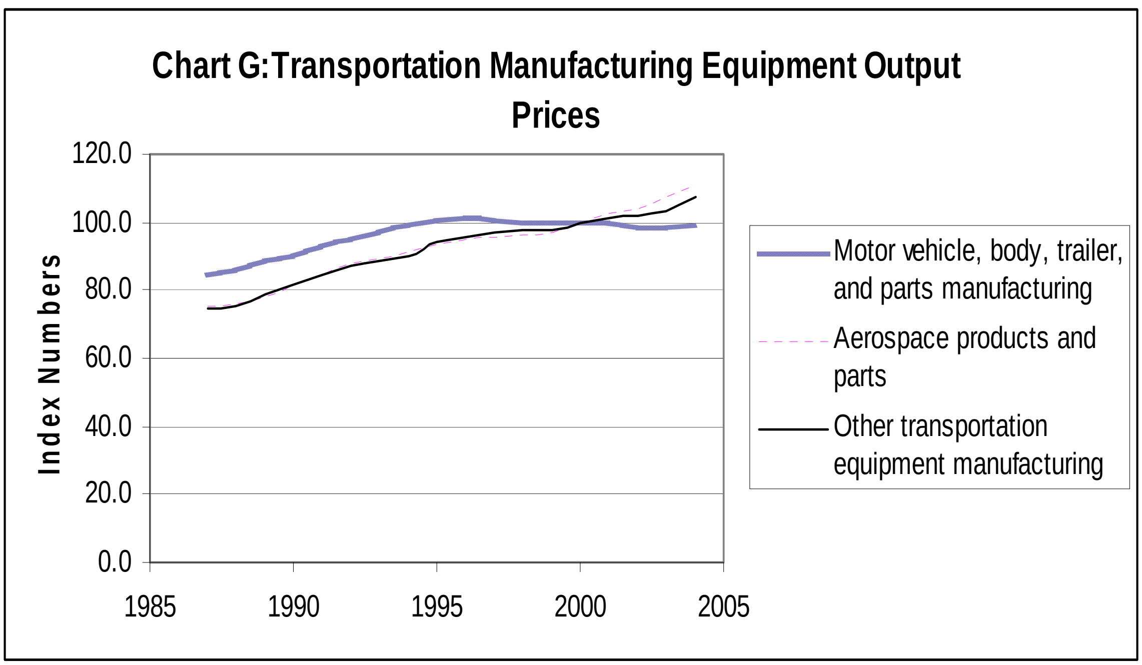


Chart G:Transportation Manufacturing Equipment Output Prices
Index Numbers
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1985
1990
1995
2000
2005
Motor vehicle, body, trailer, and parts manufacturing
Aerospace products and parts
Other transportation equipment manufacturing

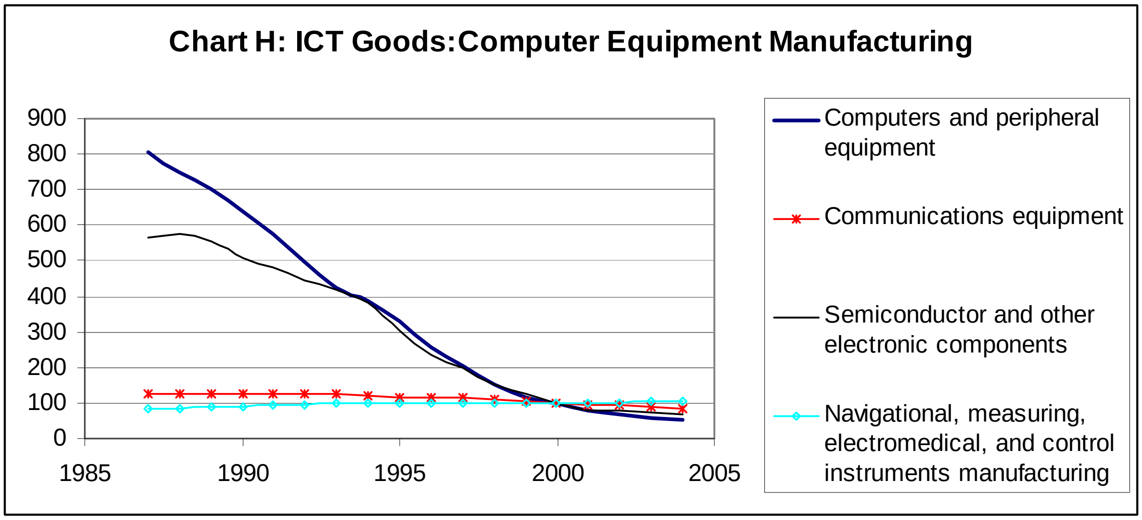


Chart H: ICT Goods:Computer Equipment Manufacturing
900
800
700
600
500
400
300
200
100
0
1985
1990
1995
2000
2005
Computers and peripheral equipment
Communications equipment
Semiconductor and other electronic components
Navigational, measuring, electromedical, and control instruments manufacturing

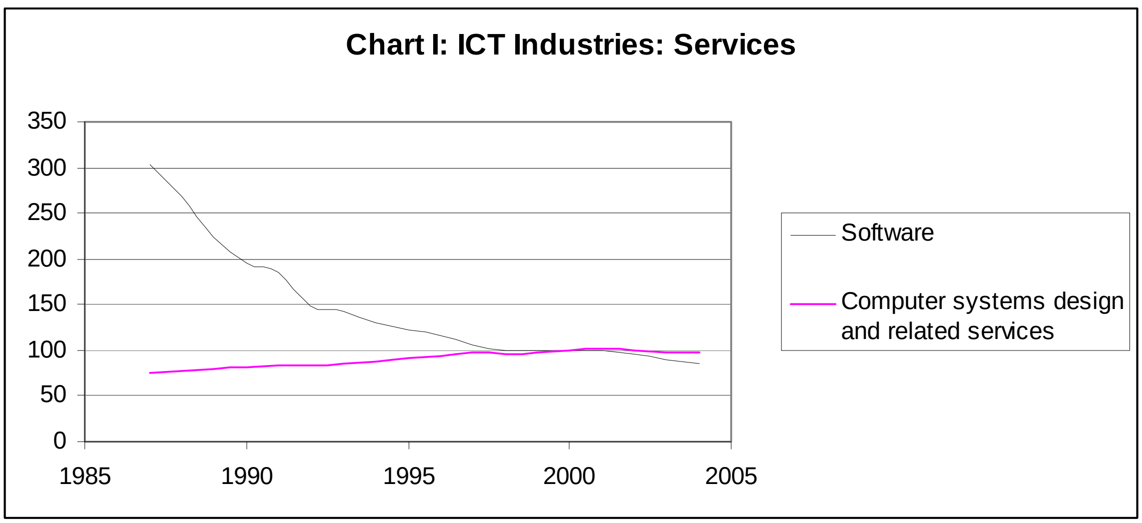


Chart I: ICT Industries: Services
350
300
250
200
150
100
50
0
1985
1990
1995
2000
2005
Software
Computer systems design and related services

Appendix

1) R&D Output, R&D Investment, and R&D Capital Stock

Diagram 1 provides a summary of three main aspects of R&D activity that need estimated prices, these are R&D output, R&D investment, and R&D capital stock. The diagram also shows how they relate to each other. Solid arrows between the steps indicate market transactions, where prices are potentially available from economic survey data. Dotted lines indicate uses that are internal to the firm and have no associated transaction data, or are transacted between parties without direct payment (cross-licensing agreements). The left side of the diagram represents domestic transactions and the right side of the diagram represents cross-border transactions. Because of their impact on GDP, more survey data are available for these transactions than for similar domestic ones.

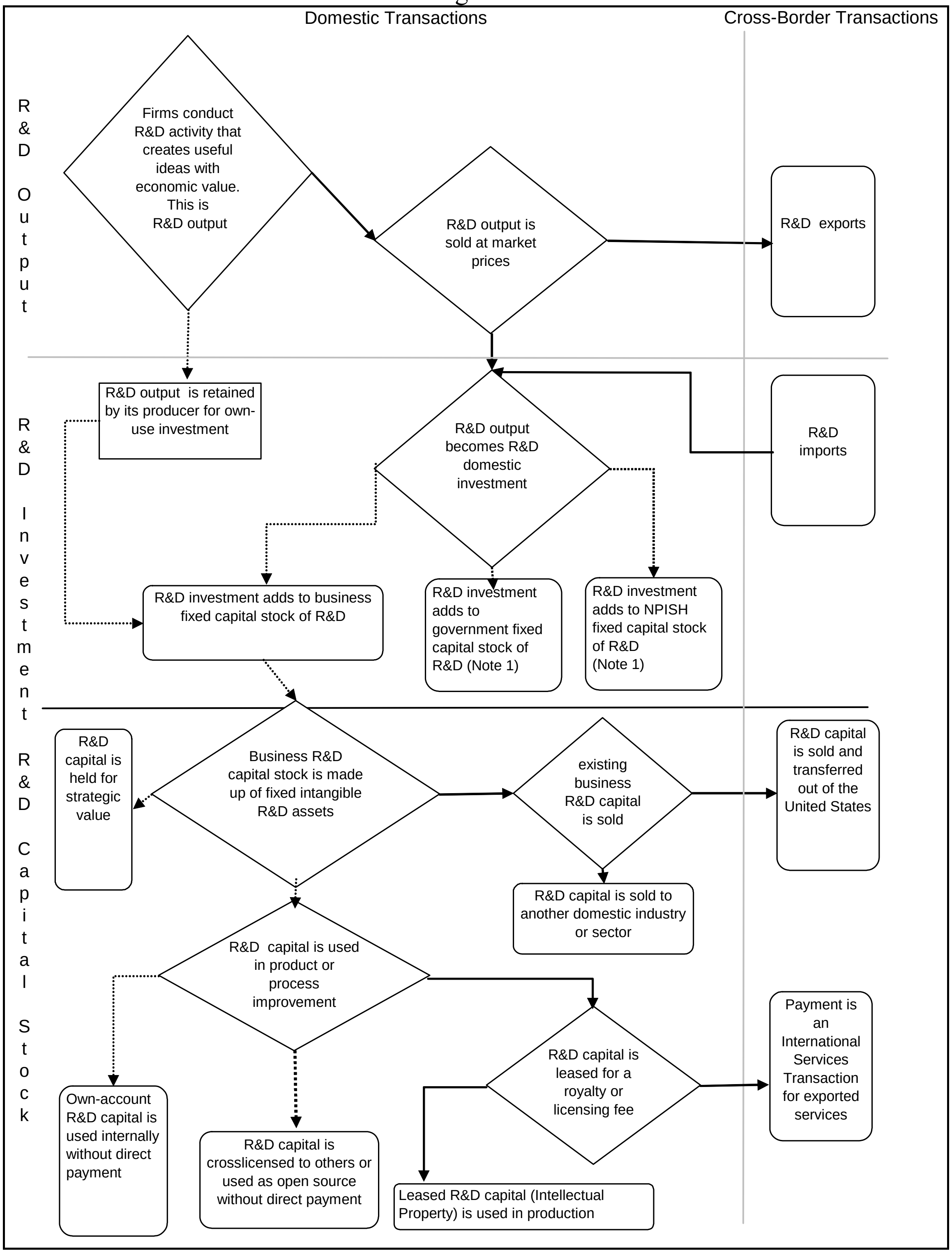
The first box in the upper left corner represents the firm that produces R&D as economic output and represents the activity of the innovator. Two things can happen to this output, the firm can sell it to another firm or the firm can retain it for its own use. If the output is sold the transaction can be captured in economic survey data. These transactions for R&D can result in exports or domestic sales.

In the R&D satellite account, R&D output is treated as investment, because its use in production extends over several time periods and it produces an economic benefit to its owner. The middle portion of the diagram represents the consumer of R&D output, where R&D is acquired as R&D as an investment good. It can be retained by its producer for own use, it can be purchased from another domestic firm, or it can be imported from another country. While a firm retaining R&D for its own use will be unobserved as a transaction, both domestic and international purchases of R&D are within the scope of existing survey data. This R&D investment adds to the stock of R&D capital for business, government, and non-profit institutions serving households.

The lower portion of the diagram illustrates the uses of R&D capital stock held by business to generate an economic benefit. There are three things that a firm can do with its R&D capital stock in a given time period: Hold for future use; use it in production; or sell it to some other entity. If the firm sells part or all or its R&D capital stock, there is a market transaction that could produce a market value measure. If the firm holds onto its R&D capital, either for future use or, if patented, to gain a strategic advantage in the market, the firm is gaining an economic benefit from the R&D capital, but this value will not be observed directly.

The R&D capital can also be used in production. The firm can license its patented or otherwise protected R&D assets out to other firms in exchange for royalties or licensing fees. These are market transactions; survey data records international transactions of this type and domestic transactions of this type are recorded for a few industries. The firm can cross-license its portfolio of R&D assets and related patents, allowing other firms access in exchange for access to their R&D assets and related patents. In this case there may be no direct payment involved, or only a small net payment when one portfolio is substantially larger than the other. Finally, the firm can use its R&D assets internally to create new products, improve old ones, or lower production costs. In this case there will be no observable price for the use of the R&D asset, but there will be a price for the product created or improved by the R&D.

Diagram 1.



Note 1: Similar relationships can be drawn for the use of government and NPISH R&D

Appendix Table A, Residual Intangible Asset Price Index, Aggregate Input Price Index, and Aggregate Output Price Index, 1987-2004

	1987	1988	1989	1990	1991	1992	1993	1994	1995
Residual R&D Price Indexes									
Chemical manufacturing /1/	24.1	28.1	34.2	41.4	48.2	53.7	58.6	65.3	73.4
Computer and electronic product manufacturing /2/	4.3	4.9	5.8	7.0	9.4	14.5	*22.1*	**33.1**	*49.0*
Motor vehicle, body, trailer, and parts manufacturing	14.8	14.2	10.2	*8.9*	**9.1**	*10.8*	*14.4*	**21.5**	*35.4*
Aerospace and other transportation manufacturing /3/	127.5	100.9	58.7	53.2	81.3	60.1	80.5	61.8	*53.2*
Publishing, including software	33.1	35.2	38.3	40.0	41.9	45.1	49.2	53.3	57.0
R&D Services and other Miscellaneous professional services	41.0	45.7	52.0	58.9	64.5	70.4	75.1	78.6	80.3
Computer Services	34.3	37.8	41.8	47.1	52.4	61.3	71.0	81.8	92.1
All Other Private Industries, excluding Finance, Real Estate, and Agriculture	33.2	35.5	39.0	42.2	45.8	50.9	58.4	64.9	72.2
All Private Industries Indexes									
Input Price Index	73.1	75.7	78.7	81.2	83.6	85.9	87.9	89.5	90.8
Aggregate Output Price Index	123.4	125.5	127.1	126.9	128.4	127.4	127.0	126.3	122.9

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Residual R&D Price Indexes									
Chemical manufacturing /1/	81.2	90.6	98.6	101.9	100.0	98.8	99.3	102.5	112.5
Computer and electronic product manufacturing /2/	71.6	98.6	117.0	*118.7*	**100.0**	*67.1*	33.5	23.5	20.0
Motor vehicle, body, trailer, and parts manufacturing	63.9	85.0	94.9	96.1	100.0	87.0	80.5	59.5	44.3
Aerospace and other transportation manufacturing /3/	**50.9**	*53.3*	*60.9*	**75.2**	*100.0*	142.3	180.1	123.7	88.6
Publishing, including software	64.5	72.2	80.1	93.4	100.0	104.6	110.7	119.3	126.7
R&D Services and other Miscellaneous professional services	84.1	88.7	92.9	96.9	100.0	101.9	104.0	110.0	120.0
Computer Services	107.0	126.8	139.0	133.6	100.0	67.0	44.8	33.0	28.1
All Other Private Industries, excluding Finance, Real Estate, and Agriculture	80.6	88.2	93.5	97.8	100.0	101.4	103.0	108.6	118.7
All Private Industries Indexes									
Aggregate Input Price Index	92.5	94.3	95.4	96.9	100.0	102.4	105.1	108.3	112.2
Aggregate Output Price Index	117	111	105	102	100	97	95.9	95.3	95.3

Note: Bold values are imputed because they were undefined. Italic values were imputed because they neighbored an undefined value.

/1/ Includes pharmaceuticals and medicine manufacturing (NAICS 3254), and chemicals minus pharmaceuticals manufacturing (NAICS 325X).

/2/ Includes computers and peripheral equipment manufacturing (NAICS 3341), communications equipment manufacturing (NAICS 3342), semiconductor and other electronic components manufacturing (NAICS 3344), navigational, measuring, electro-medical, and control instruments manufacturing (NAICS 3345), and other computer and electronic products manufacturing (NAICS 3343, 3346).

/3/ Includes Aerospace products and parts manufacturing (NAICS 3364) and other transportation equipment manufacturing (NAICS 3365-3369).

Appendix Table B, Detailed Industry R&D Output Prices

	1987	1988	1989	1990	1991	1992	1993	1994	1995
Detailed Output Price Indexes									
Pharmaceuticals and medicines	51.6	55.5	60.3	65.4	70.5	75.2	78.3	80.7	83.1
Chemicals minus pharmaceuticals	74.9	81.1	85.2	85.2	86.5	86.3	87.5	90.0	97.0
Computers and peripheral equipment	808.2	749.6	702.4	636.1	575.9	498.6	425.3	384.6	327.7
Communications equipment	126.8	126.0	125.6	124.1	124.1	123.6	123.4	122.1	117.4
Semiconductor and other electronic components	565.4	573.2	554.4	507.0	481.0	442.7	416.9	383.9	304.5
Navigational, measuring, electro-medical, and control instruments manufacturing	83.3	85.6	88.6	91.2	93.9	95.6	96.9	97.8	99.1
Other computer and electronic products	117.5	116.5	117.7	117.5	118.1	116.6	113.7	111.0	108.8
Motor vehicle, body, trailer, and parts manufacturing	84.7	86.2	88.6	90.1	92.6	94.8	96.9	99.1	100.2
Aerospace products and parts	75.6	76.0	78.4	81.5	84.5	87.7	89.6	91.6	93.6
Other transportation equipment manufacturing	74.4	75.5	78.6	81.7	84.7	87.1	88.5	90.0	94.0
Software	302.4	269.0	224.1	195.4	185.8	149.0	142.0	129.8	122.9
Computer systems design and related services	74.4	77.4	78.4	80.7	83.3	84.4	86.2	87.7	91.2
Scientific R&D services	62.8	66.2	68.7	71.2	74.4	76.6	78.1	79.7	83.3
All other for-profit industries	72.6	75.3	78.4	81.4	83.0	84.7	86.7	88.5	91.3

Detailed Output Price Indexes	1996	1997	1998	1999	2000	2001	2002	2003	2004
Pharmaceuticals and medicines	85.4	87.0	95.6	97.9	100.0	102.3	104.6	109.2	113.7
Chemicals minus pharmaceuticals	96.7	97.5	94.2	93.6	100.0	100.0	99.0	104.3	111.5
Computers and peripheral equipment	255.6	202.1	151.9	115.9	100.0	80.7	67.7	58.3	53.1
Communications equipment	115.7	114.7	109.8	105.2	100.0	95.9	91.9	87.3	82.6
Semiconductor and other electronic components	237.5	200.5	152.8	125.2	100.0	79.7	77.8	73.1	69.4
Navigational, measuring, electro-medical, and control instruments manufacturing	99.6	100.4	100.8	100.2	100.0	100.0	101.2	102.0	102.8
Other computer and electronic products	107.0	104.8	103.8	101.9	100.0	97.7	94.5	92.1	89.1
Motor vehicle, body, trailer, and parts manufacturing	101.1	100.5	99.5	99.7	100.0	99.5	98.3	98.2	99.3
Aerospace products and parts	95.0	95.8	96.4	97.3	100.0	102.7	104.0	107.2	110.9
Other transportation equipment manufacturing	95.8	97.0	97.6	98.0	100.0	101.2	102.0	103.2	107.3
Software	115.9	106.3	100.5	98.8	100.0	98.8	95.7	90.4	85.8
Computer systems design and related services	93.4	96.7	94.9	96.8	100.0	100.9	99.7	98.3	96.7
Scientific R&D services	85.9	88.5	91.4	95.2	100.0	103.9	107.7	113.1	119.3
All other for-profit industries	93.4	94.9	95.1	96.7	100.0	101.4	102.8	106.1	110.8