Bureau of Labor Statistics
Multifactor Productivity
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TECHNICAL NOTE ON PUBLIC R&D AND PRODUCTIVITY GROWTH

In the analysis of the effect of research and development (R&D) on productivity growth, a sharp distinction can be drawn between the impact of private R&D and public R&D. Private R&D usually refers to R&D financed by private firms; the economics literature contains abundant evidence that research financed by private firms is an important contributor to productivity growth.[1] Public R&D usually refers to research financed or conducted by government or by nonprofit institutions such as colleges and universities or foundations.[2]

Technological knowledge typically is not confined to its discoverer but often spills over to other potential users. For example, a pharmaceutical firm can develop a new means of treatment for a particular disease, but a competitor can often study an approved new product and build on that knowledge to develop an even better treatment. In this case, the first firm earns what is called direct returns by selling the initial product. However, the first firm's research makes a further contribution by making the second firm's research feasible. This second effect is called an indirect or spillover effect.[3]

As part of the Multifactor Productivity program, since 1989 the Bureau of Labor Statistics (BLS) has annually estimated how much spillovers from private R&D contribute to U.S. productivity growth.[4] The Multifactor Productivity press release and web page each year report estimates of the spillover from private R&D. For example, between 1987 and 2010 spillovers from private R&D contributed to 0.2 percent a year to productivity growth in the private nonfarm business economy, in the March 21, 2012 "Multifactor Productivity Trends" news release (USDL 12-0494).

Readers often inquire why BLS estimates of the impact of R&D are limited to R&D spillover effects. Measures of productivity growth produced by the Bureau of Labor Statistics typically already include the capital and labor used in R&D as factor inputs in measures of industry or national productivity. In equilibrium, the value of these inputs will approximately equal the value of the technology they produce. The private value of technology inputs is therefore already included through the factor inputs used to determine productivity growth. Any additional effects attributed to R&D therefore reflect additional social or spillover effects which extend beyond private returns.[5]

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[1] Although the formal definition is expressed in terms of R&D financed by the private sector, most privately financed R&D is also conducted in the business sector. Businesses finance only relatively small amounts of research in universities or in nonprofit institutions.

[2] Most government financed R&D is conducted by government or nonprofit institutions, but government also finances fairly large R&D expenditures conducted in private industry.

[3] For a more detailed discussion of how knowledge leaks out to other economic units, thereby creating spillovers, see Sveikauskas (2007).

[4] The central references describing the procedures and methodology are U.S. Bureau of Labor Statistics (1989), The Impact of Research and Development on Productivity Growth, Bulletin 2331, September 1989, U.S. Government Printing Office, Washington, D.C. and Sveikauskas, Leo (1986), "The Contribution of R&D to Productivity Growth," Monthly Labor Review (March 1986), pp. 16-20.

[5] To make the discussion in the text more concrete, multifactor productivity growth is calculated as:

$$M\dot{F}P/MFP = \dot{O}/O - \alpha_K \dot{K}/K - \alpha_L \dot{L}/L \ \frac{\dot{o}}{o}$$

where $M\dot{F}P/MFP$ is the percentage rate of growth of multifactor productivity, $\dot{O}/O$ is output growth, $\dot{K}/K$ is capital growth, and $\dot{L}/L$ is labor input growth. , α_K , and α_L represent the respective factor shares.

If the capital and labor used in R&D appear in the capital and labor inputs, private expenditures on these inputs will be subtracted from output growth and will therefore not appear in multifactor productivity growth. Any further impact on R&D such as that which appears in a supplementary equation

$$M\dot{F}P/MFP = \alpha + \Delta RD/O_{t-1}$$

where ΔRD is the change in the R&D stock and O_{t-1} is output in the previous year. The expression immediately above therefore reflects a social return to R&D which exceeds the direct contribution of private R&D to productivity growth.

More recently, the Bureau of Economic Analysis (Lee and Schmidt (2010)) has reported estimates of how much the R&D conducted by private firms contributes directly to productivity growth. Combining the BEA estimates of the direct contribution of R&D with the BLS estimates of productivity spillovers shows the overall impact of private R&D on productivity growth. For example, between 1987 and 2007 the BEA estimated that capitalization of R&D in the gross domestic product would increase estimated GDP growth by 0.20 percent a year.[6]

The Bureau of Economic Analysis is currently planning a major expansion of their work on R&D. Private expenditures on R&D will be treated as investment rather than considered to be an immediate expense. The official National Income and Product Accounts, and associated measures of industry and national output, will be revised to include R&D as an investment.[7]

The revised Bureau of Economic Analysis accounts will also treat R&D expenditures outside the private sector, such as research funded or conducted by government or research undertaken in universities or research institutions, as investment. The accounts will include an estimate of the direct return to such public sector research.

Now that the official measures of national output will include both private and public R&D as investment, it would clearly be useful for the Bureau of Labor Statistics to broaden its estimates of R&D spillovers to include spillovers from public R&D as well as private R&D. Though understanding of the magnitude of spillovers from public R&D is still somewhat limited, this memorandum uses the available evidence to generate estimates of the spillover from public R&D.

By far the most relevant paper for our purposes is Guellec and Van Pottelsberghe de la Potterie (2004), henceforth referred to as GVP.[8] The GVP study examined production in 16 economically advanced countries, included in the OECD, between 1980 and 1998. The study used a broad measure of public R&D, including research conducted in the government, universities and colleges, and other nonprofit institutions. However, GVP included government financed research conducted in industry as business research; we will later adjust their results to conform to BLS and BEA concepts, which separate government financed research conducted in industry from private industrial research.

Most important of all, GVP do not examine the private return to research, but instead concentrate on the same R&D spillovers which Bureau of Labor Statistics measures are designed to evaluate. As GVP (2004, page 351) state "That means we capture the social excess returns to R&D, and not the total effect on output growth (which includes the direct effect or private returns also.)" This is exactly the perspective we need for our measures.

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[6] Data are from Lee and Schmidt (2010, Table B). Estimates of how much capitalization of R&D increases GDP growth rely on a complex sequence of calculations which involve investment, return and depreciation on R&D. Such estimates therefore do not provide exact productivity contributions, but point in comparable directions.

[7] Robbins, Carol A. and Moylan, Carol E. (2007), "Research and Development Satellite Account Update, Estimates for 1959-2004", Survey of Current Business (October 2007), pp. 49-64. Page 49 states "Currently BEA plans to incorporate R&D spending as investment into its core accounts around 2013."

[8] There are several further studies of the return to public R&D, as GVP mention. However, the GVP study is much more general and more closely aligned with our purposes than any other study.

GVP conclude that the elasticity of multifactor productivity with respect to public R&D is 0.17.[9] This contrasts with an elasticity of private sector research which is estimated to be 0.13. That is, public R&D has an even greater effect on observed productivity growth than private R&D. However, as mentioned above, GVP include government financed research in industry in their basic measure of private sector research. As U.S. Bureau of Labor Statistics (1989, page 10) indicates, evidence indicates that in the United States federally financed research conducted in private industry has little discernable effect on measured productivity growth. Between 1980 and 1998, in the United States the federally financed share of industrial research declined from approximately 20 percent to 10 percent. Adjusting the return to private R&D upwards to account for the fact that in the United States, over this period, approximately one-sixth of R&D observed in the private business sector had little or no return would bring the estimated coefficient for purely private research to 0.16, somewhat more closely comparable to the 0.17 found for public research.[10]

Though the GVP work is a very fine study and very useful for our purposes, there are some limitations in its applicability to our work. Most importantly, the Bureau of Labor statistics measures the contribution of R&D to productivity growth in terms of the rate of return to R&D. Specifically, the contribution of R&D to growth in a given year is:

$$\dot{MFP}/MFP \quad = \quad r_{RD}\ \Delta RD/O_{t-1} \tag{a}$$

in which r_{RD} is the rate of return to R&D, ΔRD is the increase in the R&D stock between year $t-1$ and year t, and O_{t-1} is output in the previous year. In this case, ΔRD, the change in the research stock, is multiplied by r_{RD}, the rate of return on a unit of R&D, to determine the increased output attributable to increases in R&D. This amount is then divided by output in the previous year, to express the gains attributable to R&D as a percentage increase in output.

BLS has adopted this procedure because the alternative elasticity approach implies much sharper variation in the implied returns to research. To see this point, the elasticity effect on multifactor productivity growth, such as that used by GVP, can be expressed as:

$$\dot{MFP}/MFP \quad = \quad \varepsilon\ \Delta RD/RD_{t-1} \tag{b}$$

where ε is the elasticity of R&D with respect to MFP and $\Delta RD/RD$ is the percentage increase in the R&D stock.

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[9] Since much of the output in the government or nonprofit sector by definition does not allow for productivity improvements, GVP estimate the effect of public R&D by its impact on business sector productivity growth.

[10] If five/sixth of private sector research has a return of .16 and one/sixth earns a return of zero, this is equivalent to an overall private sector return of .13.

If expressions (a) and (b) are equivalent, so that both alternative versions express the same effect on R&D, then:

$$r_{RD}\,\Delta RD/O_{t-1} \quad = \quad \varepsilon\;\; \Delta RD/RD_{t-1}$$ or equivalently approximately

$$r_{RD} \quad = \quad \varepsilon\;(O/RD)_{t-1}$$

That is the elasticity effect has to be multiplied by O/RD, the ratio of output to the R&D stock, if the elasticity estimate is to provide a consistent rate of return. Since R&D typically grows far more rapidly than output, O/RD usually declines sharply, so that an unchanged ε implies that the return to R&D falls sharply. To avoid such an artificially sharp implicit decline in the return to R&D, BLS has chosen to specify the return to R&D as a rate of return, as in expression (a), rather than as an elasticity, as in expression (b). Consequently, the GVP study, though very useful and helpful, cannot directly be applied to yield as an estimate of the rate of return to public R&D.[11]

How are we to interpret the evidence from the GVP study that the rate of return on public R&D is generally higher than the return to private research, or, adapted to the situation in the United States, after suitably adjusting for the fact that GVP include some federally financed R&D in their business sector R&D, the indication that the return on U.S. public R&D is approximately equivalent to that on private R&D. As Sveikauskas (2007) remarks, there is clear evidence that certain public R&D investments, such as expenditures on the National Institutes of Health or on the Defense Advanced Projects Research Agency (DARPA) have had exceptionally high economic returns. On the other hand, large sums of government financed research have probably had very small or zero returns (Piekarz (1983). Similarly, some university research has had important commercial implications, but most university research is not really aligned with commercial goals.[12]

If large portions of public research make only a negligible contribution to productivity growth, and yet the overall contribution of public R&D is anywhere near as large as private, the few occasional successes must be extremely important. There is some evidence for this in terms of military support in the development of the computer or military aircraft, and DARPA's role in creating the Internet. As an additional example, specialists (Piekarz (1983)) generally think that government research on energy in the 1970s was not very effective. Nonetheless, Zakaria (2012) reports that fracking of natural gas deposits, a profoundly beneficial development for the United States economy, was based on Department of Energy support of crucial research conducted by Mitchell Energy Company. Such patterns suggest that truly remarkable returns on a very small minority of projects are part of the picture.

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[11] One might think that it would be a simple matter to reestimate the GVP analysis in a rate of return version. However, in the case of private R&D, the real improvements in understanding the rate of return came from studies which examined returns in highly disaggregated microeconomic evidence, on individual industries and firms and on studies of individual research projects, rather from a more refined analysis of the aggregate time-series data.

[12] As President Richard Levin of Yale University, a technology economist earlier in his career, remarked "We're not trying to drive university science by commercial objectives. We want to do great science. Some of that will have commercial potential; most of it won't." Also "Our technology transfer strategy is not to maximize revenue. Our primary goal is to get the findings of our laboratories out into practice." (Yale Alumni Magazine, November 2006).

In selecting the appropriate rate of return on private R&D, the Bureau was able to rely on a large group of studies which estimated this parameter in many different contexts. In addition, several studies which calculated the actual rate of return observed in individual corporate research projects provided very helpful supplementary information. In the case of public R&D, the relevant evidence is much more thin, essentially resting on the Guellac-van Pottelsberghe de la Potterie study. In contrast, GVP represents only a single study. We are therefore cautious about adopting its implication, that the rate of return to public R&D is essentially the same as that found for private research, in the case of the United States 30 percent. Instead, we believe that, on balance, the return to public R&D should be considerably below that for private R&D.[13]

Without the Guellac-van Pottelsberghe de la Potterie evidence, we might have concluded that spillover returns to public research are quite low, perhaps in the 5 to 10 percent range, largely because so much public research is not relevant to commercial matters or has very low returns. On the basis of the GVP study, we think the returns to public R&D are likely to be somewhat higher, perhaps in the 10 to 15 percent range. Since so much university or government research is not oriented towards economic growth or does not appear in measures of growth, such conclusions suggest that the spillovers which do occur, such as those associated with NIH, DARPA, or the research on fracking mentioned above, are remarkably strong.

Before turning to the implications that such rates of return have for empirical estimates of the effect of public R&D on productivity growth, it should be noted, before discussion of the appropriate framework concludes, that, in the context of growth accounting, counting both the effects of public research and private research presents certain problems. Growth accounting looks at only proximate influences on productivity growth. If technology progress permits better capital, then all the effect is attributed to the proximate effect, greater capital investment, rather than the technical progress which underlies the gains. In this context, including both the basic underlying research conducted in the public sector and the associated gains in private technology, in the context of growth accounting, potentially presents a problem.

<u>Implementation of the Suggestions Made Above</u>:

Certain decisions have to be made in calculating the public R&D stocks and determining their influence on productivity growth. The first is which deflator to use in calculating public (government plus university plus nonprofit) research. For the private nonfarm sector, the BLS has historically used a deflator which weights output price and compensation deflators approximately equally. One option would be to use similarly weighted indicators of the output and compensation deflators in the public sector. However, in many elements of the nonprofit sector output deflators are not calculated from actual prices, but are instead constructed from input prices. For that reason, we do not wish to adopt a deflator based upon public sector output prices. We shall instead assume that the same deflator for private nonfarm output, which we have used to deflate private research, can also be used to deflate public research. It seems reasonable to assume that costs of research increase at approximately the same rate for public and private research.[14]

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[13] Mansfield (1991; 1995) has tracked the effects of university R&D on industrial innovation. Nevertheless, much more work needs to be done to estimate a rate of return for all public R&D.

[14] Guellec and van Pottelberghe de la Potterie deal with business and public capital as defined by the sector of performance. Therefore, publicly financed research conducted in industry is included with private R&D.

It is also worth mentioning, however, that the Bureau of Economic Analysis has adopted U.S. R&D deflators which increase much more rapidly than the deflators used here. Guellec and van Pottelsberghe de la Potterie measure R&D as deflated by the GDP deflator, which is more closely similar to the deflator used here.

Another issue to be addressed is that economic analysis often suggests that federally financed research conducted in industry has no apparent effect on measured productivity growth. U.S. Bureau of Labor Statistics (1989, page 10) review evidence bearing on this question. For this reason, the main BLS estimates of the effect of research and development on productivity growth assume that federally financed research conducted in industry has no effect on productivity growth. In the application conducted below, however, we assume that federally financed R&D carried out in industry has the same rate of return as public research carried out in the public sector.

Still another matter in empirical implementation is exactly what R&D expenditures should be included in public R&D. The standard tables, published in National Patterns of R&D Resources, list, in the first column, total R&D for all performers from all sources. Later on, these same tables report industry financed R&D, included R&D conducted in industries, in universities and colleges, and in other nonprofit institutions. These three latter items constitute exactly our essential data on privately financed R&D which are the core of our R&D measures. All the rest of national R&D falls into the government plus university plus other nonprofits sector. Therefore, we proceed by subtracting the privately financed total from the more general all performers/all sources data. This provides us with annual estimates of the extent of public R&D spending. These calculations have to be carried out separately for basic R&D, applied R&D, and development, and then applied R&D and development must be added up into a single measure of annual applied R&D expenditures.

Private and public R&D stocks are calculated for every year beginning in 1987. The National Science Foundation publication National Patterns of R&D Resources, now updated in Science and Technology Indicators, reports comprehensive R&D expenditures beginning in 1953. Public R&D expenditures are defined as all R&D less private R&D; private R&D consists of industry financed expenditures in industry, in universities and colleges, or in other nonprofit institutions. Since 1953 is fully 34 years before the beginning of the stocks described here, we make no attempt to extend the National Science Foundation data on public R&D expenditures, which begin in 1953, back to prior years.

Private R&D stocks calculated through these procedures will be the same as shown in recent Bureau of Labor Statistics Multifactor Productivity Growth press releases. The public R&D stocks are calculated similarly, using the same R&D deflator, the same lags and depreciation rates, which differ between basic and applied research, as used in the calculation of private R&D stocks. The only difference is that public R&D stocks are built up from public R&D investment, the portion of total R&D not already included in the BLS data on privately financed research expenditures. Public research consists of research financed by government, universities and colleges, and other nonprofit institutions.

Note that government, universities and colleges, and other nonprofit institutions commit a greater proportion of their research resources to basic research than private firms do. Consequently, basic research will account for a larger proportion of public R&D stocks than of private stocks.

Finally, once R&D stocks are calculated, it is an easy matter to determine the annual contribution to productivity growth. In these calculations, the rate of return to public R&D is assumed to be 10 percent, as opposed to 30 percent for private R&D. To illustrate these calculations, the annual contribution of R&D to productivity growth within a sector can be expressed as:

$$r \; \Delta RD / O_{t-1}$$

The year to year increase in output attributable to R&D can be determined as the rate of return to research, r, multiplied by the change in the R&D stock, ΔRD. The percentage contribution which this additional output makes to productivity growth is then calculated by dividing the increased output due to R&D by O_{t-1}, the total output in the previous year. Note that the percentage point contribution of private R&D to productivity growth in the overall economy will be lower than the percentage point contribution for the private nonfarm economy. This occurs because, even though the additional output due to private research is still the same as shown in previous BLS press releases dealing with the private nonfarm economy, the denominator, O_{t-1}, is greater in the larger total economy so that the percentage contribution of private R&D is lower in the total economy than in the private nonfarm economy.

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