Treatment of Regional Research and Development as Investment Issues and Estimates

Bureau of Economic Analysis/National Science Foundation

R&D Satellite Account Background Paper

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Preface

This paper presents an analysis of regional issues related to treating R&D as an investment . It provides experimental estimates of the impact on gross domestic product by state of the new treatment of R&D. It also discusses several important conceptual and methodological issues pertaining to these estimates.

Acknowledgments

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Issues Related to Treating R&D as Investment In BEA's Regional Accounts

G. Andrew Bernat, Jr

Introduction. As part of the Bureau of Economic Analysis' (BEA's) ongoing commitment to adapt its measures of economic activity to changes in the structure of the economy, BEA has developed research and development (R&D) satellite accounts in conjunction with the National Science Foundation. The purpose of this paper is to discuss issues that will need to be resolved in order to capitalize R&D into the BEA regional accounts. This paper is one of the 2007 research and development satellite account background papers. The major findings of this report are:

- Treating R&D as investment will require identifying the location of both R&D performance and R&D investment.
- Identifying the location of R&D performance is straightforward but identifying the location of R&D investment involves difficult conceptual issues related to the fact that R&D is non-rival in consumption within a firm.
- Some of the data challenges might be overcome by utilizing microdata at the Census Bureau.
- Order of magnitude estimates indicate that current dollar gross domestic product by state (GDPS) could be over eight percent higher in some states when R&D is treated as investment.

The report has six sections. Following this introduction, the primary benefits to BEA's customers of treating state R&D activity as investment in BEA's regional accounts are discussed. The third section discusses the major methodological issues involved in

treating R&D as investment that are specific to the regional accounts. The fourth section discusses data issues involved in constructing state estimates of R&D investment. The fifth section presents order of magnitude (OM) estimates of how the new treatment of R&D in the accounts might affect current estimates of gross domestic product by state (GDPS). The OM estimates are rough approximations of the size and geographic pattern of the likely effects. The sixth section concludes the report with a discussion of subjects for further research.

The Need for Estimates of R&D Investment in the Regional Accounts. According to recent estimates, investment in R&D has played an important role in national economic growth, accounting for about 7 percent of real GDP growth in 1995-2004.[1] Many state policy makers view R&D investment as an important part of their state's economic development strategy. For example, enhancing and encouraging R&D and knowledge-based industries within states are among the highest priorities among state governors, with over three-quarters of the governors recently describing specific initiatives to develop state-private partnerships with R&D industries.[2] However, the absence of estimates of state R&D activity that are consistent with NIPA concepts substantially hampers efforts to measure and evaluate R&D's role in state economic performance. Incorporating R&D activities into BEA's regional accounts will be an important step in filling this gap and will provide state analysts and policymakers with a firmer foundation for formulating and evaluating programs related to R&D activity.

[1] Carol A. Robbins and Carol E. Moylan, "Research and Development Satellite Account Update." SURVEY OF CURRENT BUSINESS, October 2007.
[2] National Governors Association, "The Governors Speak—2007 (Final Report)," National Governors Association Center for Best Practices, April 2007.

Methodological Issues. Most of the major methodological issues involved in treating R&D as an investment will be resolved at the national level and will not require any special treatment in the regional accounts.[3] Issues that are essentially definitional in nature will not require special treatment at the regional level because the regional estimates will use the same definitions as the national estimates. For instance, the decision about what activities should be included as R&D investment will be made at the national level. Other issues potentially have a regional component but because of data limitations, the national estimates will be used in place of state estimates. For example, though price indexes may differ among states, national price indexes will be used because of the absence of estimates of appropriate state price indexes.

The major methodological issue that is fundamentally regional, or geographical, in nature is identifying the location of R&D investment. How GDPS in a particular state will be affected by the new treatment of R&D depends upon the type of R&D activity taking place in that state. Firms can be classified in several ways depending on how they engage in R&D activity, and these different ways have differential effects on GDPS. Firms can fund R&D activity, perform R&D activity, use R&D output as investment, or any combination of these. Data are available which make it possible to identify funding and performing firms but little or no information on R&D investment is available. As the funder (or purchaser) of R&D performance is considered to be the owner of the R&D output, and because the benefits of R&D output are assumed to accrue to the owner, the funder is also considered to be the investor. Hence, funder and investor will be used interchangeably in the remainder of this report.

[3] For a detailed discussion of these issues, see Sumiye Okubo, et al. "R&D Satellite Account: Preliminary Estimates." BEA Working Paper, September 2006, Section II. <www.bea.gov/newsreleases/general/rd/2006/pdf/rdreport06.pdf/>

The distinction between performing R&D and investing in R&D output is important because value added, and therefore GDPS, is affected differently depending on whether a firm's establishments invest in R&D performed by other establishments, referred to as purchased R&D, or invest in R&D that is performed in the same establishment, referred to as own-account R&D. In addition, R&D funded by governments and non-profit institutions primarily serving households also affects GDPS.

Purchased R&D. Private sector purchased R&D is primarily the output of the "Scientific Research and Development Services" industry (input-output industry 541700, or IO 541700). This type of R&D is called purchased R&D because the R&D performed by these establishments is purchased, and therefore owned, by other establishments and firms.[4] In other words, the performance of R&D and the investment in R&D involve separate establishments. The output of this industry is currently captured in the national economic accounts in the sense that the value of total industry output and the value of commodity use by other industries appear explicitly in the input-output (IO) accounts. The new treatment of R&D involves reclassifying purchases of IO 541700 output from intermediate purchases to investment, which is a final use. This reclassification increases value added for industries currently purchasing IO 541700 output because intermediate purchases are reduced without changing total gross output. The reclassification does not affect value added for IO 541700. Therefore, in order to properly account for the increase in value added in the GDPS estimates, it is necessary to know the location of the purchasing, or investing, industries.

It is important to note that while the location of R&D performance is unambiguous in the sense that the location of each establishment performing R&D is distinct and identifiable,

[4] Note that the performing and purchasing establishments can be owned by the same firm. In such a situation, the transfer of the output of the R&D performing establishment is considered to be equivalent to a sale.

the location of R&D investment is not well-defined. As discussed by Yorgason,[5] R&D performance is the production of new knowledge, and knowledge is largely non-rival in consumption, especially within a firm. This characteristic is important in the context of identifying the location of R&D investment because knowledge can be shared almost costlessly among all of the establishments within a firm. In the case of purchased R&D, while it may be possible to identify the location of the establishments which purchase (invest) in R&D output, it will be very difficult to know the extent to which this R&D is subsequently shared with other establishments in the firm.[6] If the firm has establishments in more then one state, determining where to locate R&D investment is problematic.

Two assumptions regarding the location of R&D investment by multi-establishment firms are possible. Under the first assumption, R&D investment takes place only in the establishment which purchased the R&D investment. Under the second assumption, the R&D investment is shared among all establishments within the firm.[7] Because R&D output is non-rival in consumption within a firm and sharing R&D output within a firm would be essentially costless, the second assumption is a reasonable approach. Adopting this assumption raises the issue of how to value the R&D investment. Using the value of the R&D transaction as the value of the R&D investment means that the total value of the purchased R&D is fixed and does not depend on the number of establishments within the firms investing in the purchased R&D. Allocating this value to the firm's establishments means that each establishment would get only a portion of the total value of R&D investment. This assumption will hold if the firm's decision to purchase a certain amount of

[5] Dan Yorgason, "Capitalization of International Research and Development Data: Issues and Estimates." Bureau of Economic Analysis, October 2007. <www.bea.gov/papers/pdf/yorgason_rd_paper.pdf>
[6] R&D can also be shared among firms participating in joint ventures and in technology sharing agreements.
[7] Because not every establishment engages in activities which would plausibly make use of a particular type of R&D output, the firm would share the R&D output only among the establishments which could make use of the R&D.

R&D is based on the firm's expectation regarding the return to R&D when allocated among its establishments.[8]

Own-account R&D. The second type of R&D investment is industry own-account R&D, which is R&D performed in an establishment for use in that establishment. Thus, R&D performance and R&D investment take place in the same establishment. While the costs of own-account R&D performance are currently included in the national economic accounts as intermediate purchases, the value of this R&D output is not currently measured as part of the output of the establishment. The new treatment of R&D will require imputation of the value of the own-account R&D, which will be considered an addition to gross output. Because intermediate inputs are unaltered by this imputation, value-added increases for industries performing own-account R&D. Therefore, in order to properly account for the increase in value added in the GDPS estimates due to own-account R&D investment, it is necessary to determine the location of the establishments in which own-account R&D performance and investment take place

Just as the non-rival nature of R&D makes it difficult to locate R&D investment for purchased R&D, it will be difficult to locate own-account R&D investment. By definition, own-account R&D investment is located in the establishments performing own-account R&D. In the case of single establishment firms, information on the location of the R&D performance is sufficient to properly locate R&D investment. However, this is not the case with multi-establishment firms because the non-rival nature of R&D output means that it is entirely possible, and even likely, that own-account R&D investment will be shared among other establishments in a firm. If establishments of the R&D-performing firm are in more

[8] An alternative assumption would be to assign the full value of the purchase to each establishment investing in the R&D. This assumption is consistent with the fact that R&D is non-rival in consumption because the full benefit of the value of the investment would be realized in each separate investment. However, it also implies that the total value of R&D investment is not fixed.

than one state, it will be necessary to locate some of the investment to these states. However, own-account R&D investment occurring in states other than the R&D performing state will not increase GDPS in the same way as with purchased R&D.

To see why the new treatment of R&D won't increase GDPS except through the CFC adjustment in states investing in but not performing own-account R&D, it is necessary to consider how the new treatment of R&D would affect the expenditure side of a full set of regional accounts. In a full set of economic accounts, any increase in value added resulting from the new treatment of R&D would be balanced by an equal increase in the expenditure side estimates, or final uses. In the case of purchased R&D, the increase in value added in the investing industries in a particular state would be balanced by an equal increase in R&D investment in that state because the expenditures on R&D are shifted from the intermediate portion of the accounts to the final use portion of the accounts.

For own-account R&D, investment and performance are located in the same state because own-account R&D is measured on an establishment basis. In these states, the increase in value added in the R&D performing industries would be balanced on the expenditure side by an increase in R&D investment. If the firm performing own-account R&D has establishments in other states, R&D investment could also occur in states other than the performing state.

While value added increases in states with R&D performance and investment and not in states with only own-account investment, it will still be necessary to identify the location of R&D investment because estimates of R&D net stocks are necessary for calculating the CFC for R&D investment, which is a further addition to GDPS.

Government Funded R&D. The third type of R&D activity is that funded by governments, nonprofit institutions primarily serving households, and educational

institutions, hereafter referred to as government funded R&D for simplicity. Reclassifying government funded R&D to investment will not affect GDPS in that same way as reclassifying the other two types of R&D because government funded R&D is already included in final uses in the national accounts. Reclassifying government funded R&D shifts the R&D expenditures of nonprofits primarily serving households from personal consumption expenditures (PCE) to investment and shifts government R&D expenditures from government current expenditures to investment. GDPS is unchanged by these shifts because they do not change total final uses. However, this shift does not leave GDPS entirely unchanged because the CFC associated with the investment must be added. In addition, under some assumptions regarding R&D investment, an estimate of net returns to government funded net R&D stocks is also added to GDPS.

Data Issues: Location of R&D Performance and Investment. Because of the differences in how purchased R&D and own-account R&D affect value added, different data sources will need to be used, with each source having important issues.

Purchased R&D. The industries affected by the new treatment of R&D can be identified at the national level by using the estimates of intermediate purchases of the R&D commodity, as recorded in the use table of the national IO accounts. However, BEA does not produce state-level use tables and no state-specific information is available from the national IO accounts. The National Science Foundation (NSF) provides information on the use of R&D by industry but does not publish state-level information on R&D use by industry. With access to the underlying NSF survey data, it will be possible to identify the location of the establishments purchasing R&D. However, the NSF data do not cover as many industries as the BEA IO use table and are not entirely consistent with the BEA data.

In the absence of information on the location of the establishments purchasing R&D output, it will be assumed that R&D purchases are distributed among states in proportion to each state's share of each purchasing industries' total industry output. For example, according to the 1997 use table, the semiconductor manufacturing industry purchased $1.097 billion of R&D. This value would be distributed to states based on each state's estimated share of total semiconductor output. To carry out this procedure, state estimates of total industry output are required. For years in which the Economic Census is conducted, estimates of state shipments of the R&D using industries from the Economic Census can be used as proxies for total industry output to allocate national estimates of R&D purchases to states. For intercensal years, other establishment-based data, such as data from the Annual Survey of Manufactures and wage and salary data from the Bureau of Labor Statistics, could be used.

Charts 1 and 2 illustrate the differences in state shares of the production of purchased R&D and state shares of the industry purchases of R&D output, using the national IO accounts to identify the industries purchasing commodity IO 541700 and the 1997 Economic Census to determine the location of these industries. The most obvious difference between these two charts is that the production of IO 541700 is more concentrated in a few states than is the case for the R&D-purchasing industries. This difference is consistent with expectations because nearly every industry purchases from IO 541700.[9] Therefore, the geographic distribution of R&D investment, under the assumption that R&D investment occurs in proportion to total industry output of the purchasing industries, more closely reflects the geographic distribution of all industries than of just IO 541700. Figures 1 and 2 show the geographic distribution of IO 541700 production and IO 541700 purchases.

[9] The distribution of R&D purchases among industries may change when R&D in fully incorporated as investment in the IO accounts.

Own-account R&D. The primary data source for estimating own-account R&D and government funded R&D by state is the NSF. The NSF collects state information on total R&D performance, R&D performance by funder, and R&D performance by industry. One of the most important issues related to using the information from the NSF is that the quality of the state estimates has changed over time. The NSF has published estimates of total R&D performance by state since 1963. As is often the case for surveys with a geographical dimension, a large number of observations were not published in some years. On average, estimates of total industry R&D were suppressed for at least10 states in each year up to 1998. These data suppressions primarily affect smaller states but also affect some relatively large states in some years. For example, only 15 states had no suppressions between 1963 and 1998. In addition, estimates are not available for every year. Between 1987 and 1997, state estimates are available only for odd-numbered years. Perhaps most importantly, the survey methodology has changed over time, affecting the comparability of the estimates over time. In particular, substantial changes were made to the sampling and estimation methodologies in 2001, with adjustments made to data back to 1998. This means the estimates prior to 1998 are not strictly comparable to the subsequent estimates.

While state estimates of total R&D performance (the sum of industry, government, and non-profit funded R&D) are fairly complete from 1998 onward, state estimates by funder and by industry are much less complete. The suppressions for estimates by funder are important because the R&D funded by private industry will be treated differently than R&D funded by government.

The suppressions of estimates by industry are also important because GDPS is estimated on an industry basis. NSF publishes industry data only for the top-ten R&D performing states in any given year, with all other states aggregated into a single group. This

will make it difficult to construct a time series of state estimates by industry. Because suppression is more extensive for state by industry, this aspect of the NSF data presents one of the most challenging aspects of using this information for incorporating the new R&D treatment into GDPS.

As is the case with purchased R&D investment, there is no direct information on the location of R&D own-account investment. However, the problem of determining the location of own-account investment is less difficult than it is for purchased R&D investment because own-account R&D investment is, by definition, used by the performing establishment. Hence, for single-establishment firms, performance and investment will take place in the same state. For firms with establishments in multiple states, the location of investment could be determined by assigning the value of investment proportionately to some measure of the output of the firm's establishments. One final challenge is that NSF data are company-based while the BEA regional accounts are establishment-based. If the industry of the reporting company is not the same as the industry that the R&D performing establishment would be classified under in an establishment-based classification, an adjustment will have to be made to assign the R&D to the appropriate industry. The extent of this type of misclassification is not expected to be large.

The difficulties involved in using the NSF estimates of government funded R&D are similar to those encountered in using the estimates of own-account R&D. Data suppression is more severe than for total R&D performance, requiring a method of estimating the missing observations. Likewise, there is no information on the location of government funded R&D investment. Because it will not be possible to rely on establishment ownership patterns for allocating R&D investment for government funded R&D, as may be possible for own-

account R&D, identifying the location of government funded R&D may be a more vexing problem than identifying the location of own-account R&D.

The relative importance of industry-funded R&D and government funded R&D differs among states. Charts 3 and 4 show the top-ten states in terms of shares of the performance of industry-funded R&D and of the performance of government funded R&D, as indicated by data from the NSF. The top-ten states differ slightly between the two types of R&D. The second and third ranked states in terms of industry-funded R&D are not in the top-ten states in terms of the government-funded R&D. Figures 3 and 4 show the geographic distribution of own-account R&D and government funded R&D. As expected, the larger economies tend to have larger shares of R&D in both cases. However, government funded R&D has a more even geographic distribution.

Exports and Imports. One final data issue related to identifying the location of R&D is the fact that R&D is both exported and imported. If exported R&D is not properly identified, domestic investment in R&D will be over estimated. Likewise, if imported R&D is not properly identified and located within a state, investment in R&D will be under estimated.

Data Issues: Price Indexes, Estimates of Real R&D Investment, and Net R&D Stocks. In order to fully incorporate R&D investment into the GDPS it will be necessary to estimate the increase in real value added by state and industry. Just as no reliable state price indexes are available for deflating GDPS, no reliable state price indexes are available for deflating R&D. This means that national price indexes will be used for calculating real GDPS and real R&D investment. Calculating real GDPS after accounting for the new treatment of R&D will involve deflating current dollar GDPS, adjusted for R&D investment, by the national implicit

price indexes for each industry. Calculating real R&D investment would likewise require deflating current dollar R&D investment by the appropriate national R&D price indexes.

The calculation of net stocks of R&D assets will be necessary to calculate CFC for R&D investment and doing so requires estimates of depreciation rates. Depreciation rates, like prices, may vary by state. If information regarding state differences in R&D depreciation rates is unavailable, national depreciation rates will need to be used in the estimates of state net R&D stocks. However, because some of the variation in depreciation rates among states would likely be the result of states having different industry compositions, any bias resulting from using national depreciation rates will be reduced if state data for detailed industries can be utilized.

Order of Magnitude Estimates

The forgoing discussion highlights data and estimation issues involved in incorporating the new treatment of R&D into the GDPS estimates. For illustrative purposes, order of magnitude (OM) estimates were calculated to provide a quick approximation of how the new treatment of R&D is likely to affect the estimates of GDPS. Because of the high degree of suppression in the NSF industry data, the OM estimates were calculated only for total GDPS, not for industries. The basic procedure was to allocate the expected national impact on total GDP to states based on state proportions of R&D performance from published NSF data.

The impact on GDPS due to the new treatment of R&D is calculated by decomposing the R&D into two components based on whether the R&D was funded by private industry or by government. R&D funded by private industry increases GDP by the full amount of the R&D expenditures because these R&D expenditures are currently not classified as final

uses.[10] In contrast, R&D expenditures funded by government increase GDPS by the value of current dollar CFC and net returns, not by the full value of R&D expenditures, because these expenditures are presently classified as a final use.

The OM estimate of the impact on states was calculated by allocating the national estimates of these two components to each state based on the state estimates of R&D expenditures by funder, as published by the NSF. Table 1 shows the derivation of these two components.

Calculating the OM estimates in this way implies the following assumptions.

- R&D investment occurs in the state of R&D performance, for both own-account R&D and purchased R&D. While the geographic distribution of investment in purchased R&D differs from that of own-account R&D, they are assumed to follow the same pattern for the OM estimates because own-account R&D accounts for most R&D investment.
- Industry R&D investment in states is proportional to the NSF estimates of industry funded R&D performance.
- CFC for government in states is proportional to the NSF estimates of government funded R&D performance.
- Current dollar net returns for government in states is proportional to the NSF estimates of government funded R&D performance.

Although there is no suppression for R&D totals for states in 1998-2002, roughly a quarter of the data cells for state R&D expenditures by funder are suppressed in the published NSF data. Estimates of these cells were calculated using a RAS procedure. RAS is

[10] The CFC adjustment was not made for the OM estimates.

a widely used procedure for balancing matrix cells so that rows and columns sum to known totals. In this case, total state R&D expenditures and national totals by funder were known. The use of a mechanical procedure such as RAS results in estimates of the missing cells that should be considered approximations but because the estimates are constrained to sum to the national totals and to the state totals, the size of the errors for most states are likely to be relatively small. However, errors in growth rates will be larger than the errors in levels, especially for small states or states with relatively slow growth.

After the missing cells were estimated, each state's share of R&D expenditures by industry funder, by government funder, and total R&D performance were calculated. The shares of total R&D are presented in table 2. California's dominance clearly stands out, with no other state accounting for more than 5.9 percent of total R&D.

Table 3 shows the current dollar impact of treating R&D as an investment on GDPS. According to these estimates, the average impact on GDPS for 15 states would exceed the average national impact of 2.8 percent over the period, while the impact on 8 states would be less than 1.0 percent.

The last column of table 3 shows industry funded R&D's share of total state R&D. These shares indicate which states rely the most heavily on industry-funded R&D and which on government funded R&D. There is a fairly wide range in these shares, ranging from over 85 percent in three states to less than 20 percent in five states.

Figure 5 shows the geographic pattern of the impacts on GDPS. The states likely to experience the largest impacts on GDPS are relatively dispersed. The top quintile includes relatively large states (California, New Jersey, and Michigan) as well as relatively small states (New Mexico and Rhode Island). No states in the Southeast, Plains, or Rocky Mountain regions were in the top quintile.

Further Research. The most important area of further research involves identifying the location of R&D investment. Identifying the location of R&D performance is relatively well documented in the NSF data, although challenges will be faced in using these data because of suppression issues. Access to the NSF survey microdata at the Bureau of the Census could improve estimates for many states. Linking the NSF survey data with microdata on establishments from the Longitudinal Research Database at the Center for Economic Studies, Bureau of the Census, would make it possible to identify the location of all the establishments owned by R&D performing firms. Identification of the location of purchased R&D investment, as well as government funded investment, will likely be more difficult. It may be possible to determine the salient characteristics of establishments which invest in R&D from the NSF survey data, and use these characteristics to determine which establishments are likely to have purchased R&D for investment. The use of such estimates in the regional accounts would likely hinge on the question of whether or not the modifications necessary for including the NSF data into the regional accounts are sufficient to overcome confidentiality issues.

Another important area of research relates to state-specific price indexes and depreciation rates. The first step would be to determine if, in fact, there is much variation among states in either prices of R&D or depreciation rates. This research could build upon ongoing work at BEA to construct state consumption price indexes.[11] If state differences are found, the second step would be to conduct further research to construct appropriate price indexes and depreciation rates.

[11] Bettina Aten. "Estimates of State Price Levels: A First Brush." Bureau of Economic Analysis. Presented at Federal Committee on Statistical Methodology Annual Meetings, November 6, 2007. <www.bea.gov/papers/pdf/estimates_of_state_price_levels_oct2007.pdf>

Chart 1. Total Industry Output of Purchased R&D, 1997

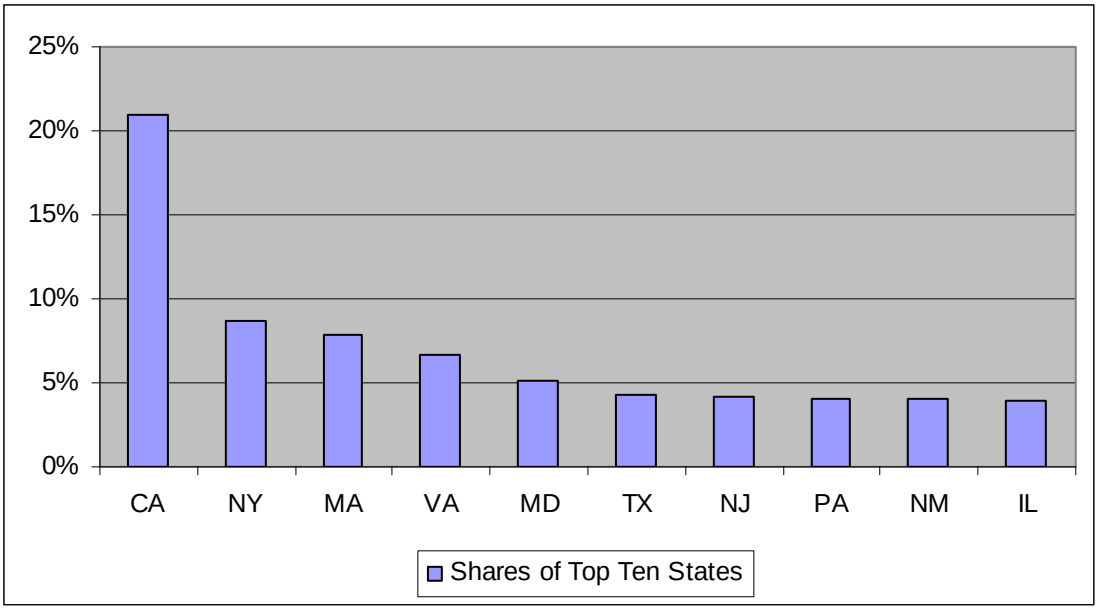

Chart 2. Purchases of R&D Output, 1997

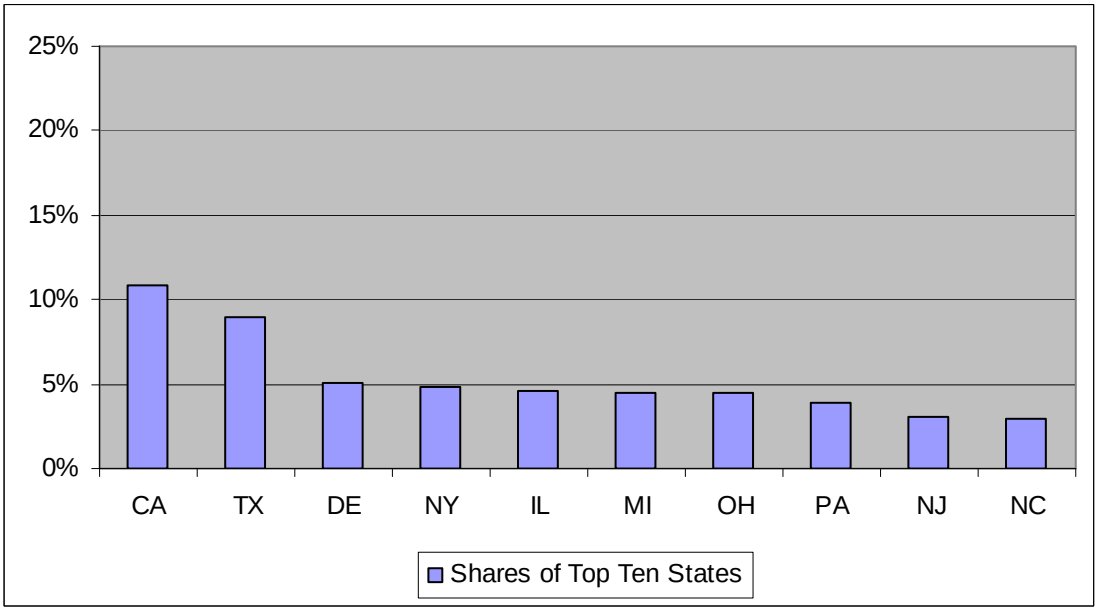

Chart 3. Performance of Industry Funded R&D, 2004

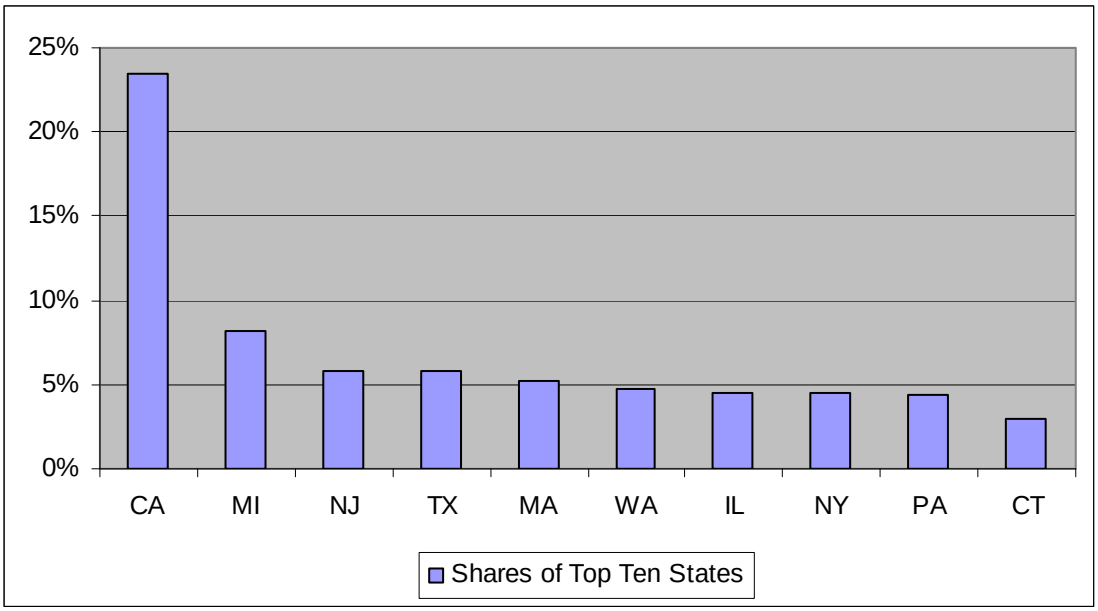

Chart 4. Performance of Government Funded R&D, 2004

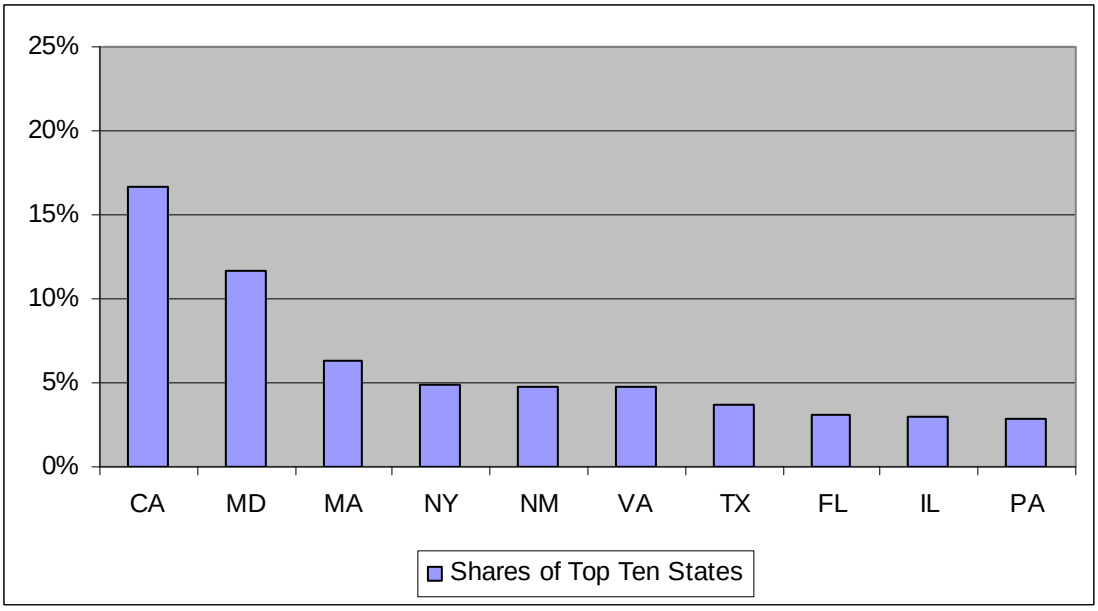

Figure 1. Total Industry Output of Purchased R&D, 1997

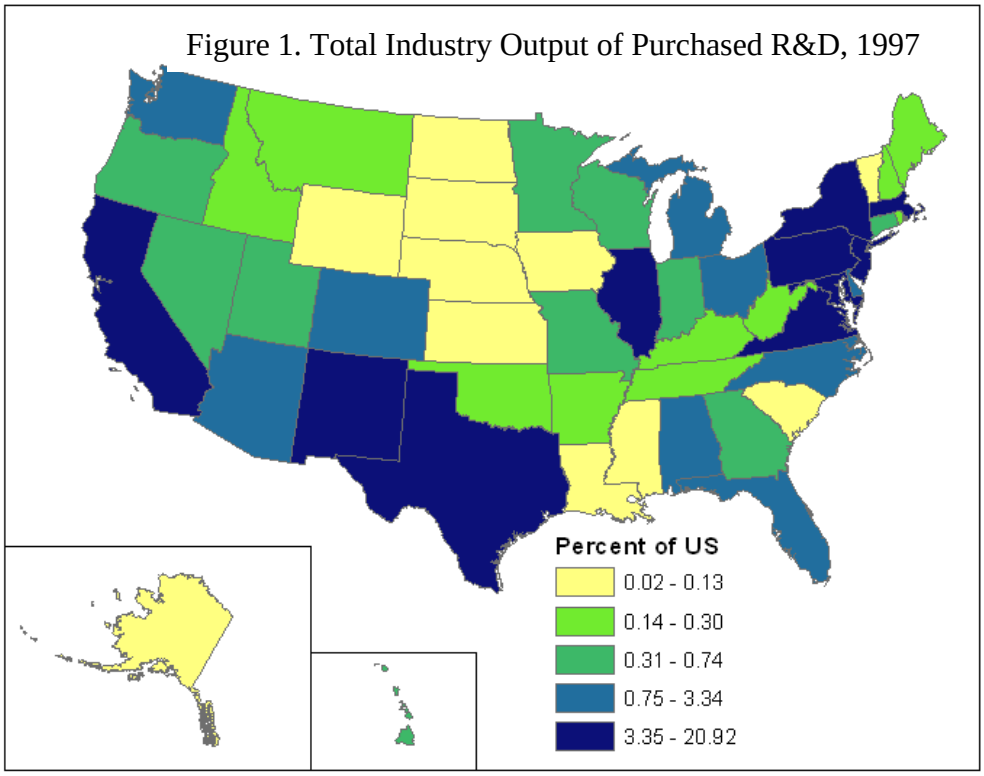

Figure 2. Industries Purchasing R&D Output, 1997

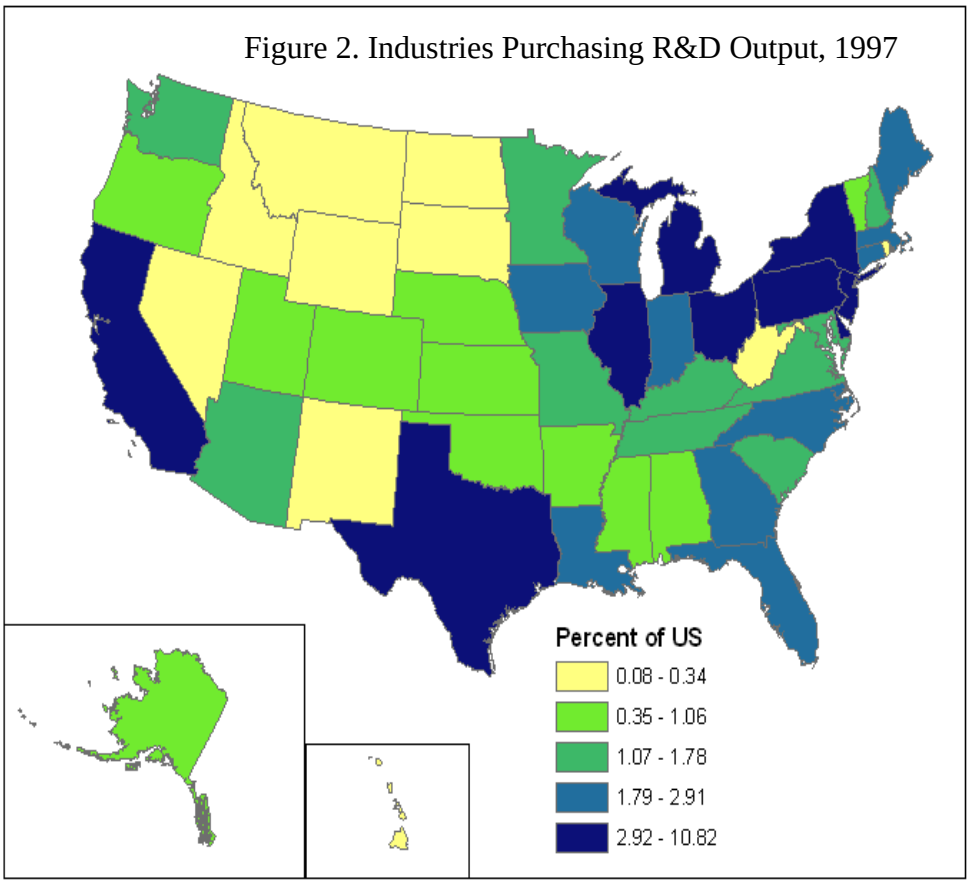

Figure 3. Performance of Industry Funded R&D, 2004

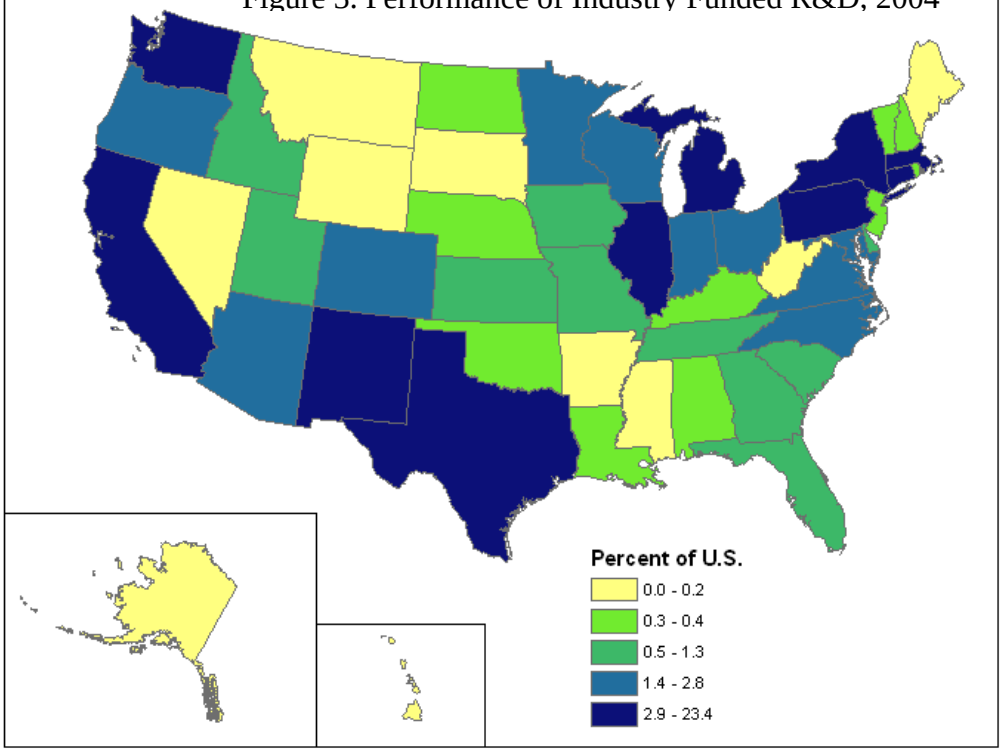

Figure 4. Performance of Government Funded R&D, 2004

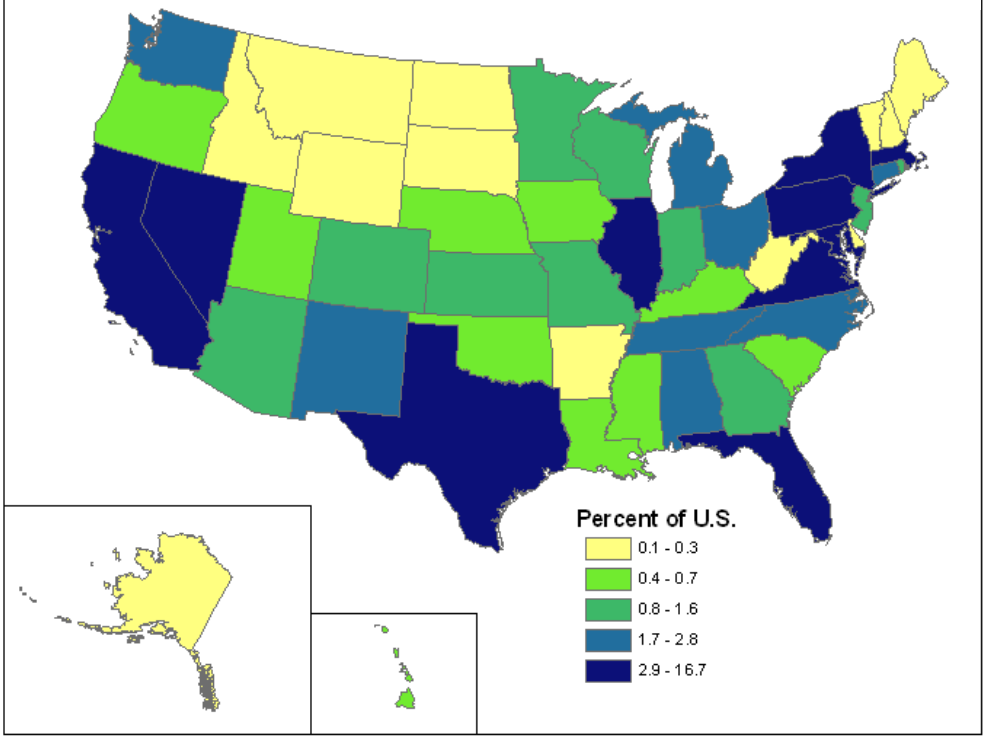

Figure 5. OM Estimates of Effect on GDPS, 1998-2004