INTERNATIONALLY COMPARABLE SCIENCE, TECHNOLOGY AND COMPETITIVENESS INDICATORS

1. Overview

This project will create quantitative measures of the efforts, efficiency and competitiveness of the nation's Science and Technology (S&T) Enterprise using purchasing power parities (PPPs) at the industry level for the United States and five major industrial countries—The United Kingdom, France, Germany, The Netherlands, and Japan.[1] Internationally comparable measures of output will be coupled with newly developed measures of PPP-adjusted R&D expenditures to assess R&D effort across countries. The analysis will also make comparisons of the R&D indicators with those obtained from current procedures to evaluate the significance of the new S&T indictors. Benchmark comparisons will be undertaken for 1987 and 1997, providing a number of new competitiveness indicators and assessing changes associated with the development of the knowledge economy.

The project consists of two phases. In the first phase, development of industry output and R&D PPPs and PPP-adjusted outputs and R&D inputs will be undertaken.[2] The initial phase will primarily rely on two-digit manufacturing industries where the data are best developed and most R&D is conducted. This will provide direct competitiveness indicators that measure the relative costs of industry output and R&D inputs across countries. Comparisons of the share of R&D in each industry's output and the efficiency of the transformation of R&D into output will also be provided. The first phase will provide an overview of the seriousness of the measurement problem in using GDP deflated R&D expenditures in current Science and Engineering (S&E) Indicators (such as those in NSF 2000), which will be specified more clearly in phase two.

The second phase of the project will examine similar issues to those in the first phase; however, it will focus on more detailed industries that are intensive users of R&D and interviews with large R&D producers.[3] High and medium technology industries include pharmaceuticals, office and computing machinery, telecommunications equipment, and motor vehicles. Services industries have become increasingly important over the past decade, but data for services are still not very extensive. To the extent that data availability allows, we will provide measures for two service industries, ideally including software. Aside from interest in these industries because they are important R&D performers, the second phase affords several possibilities to refine and extend the

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[1] The importance of international S&T comparisons was summed up nicely by Bond (1998): "From a data and indicators perspective...assessing national S&T strengths and systems in isolation is no longer terribly meaningful, even for a large economy such as that of the US. International comparisons are essential and they increasingly need to be done, not just in a national or bilateral mode, but in multilateral form."

[2] This research focuses on business sector R&D expenditures. Because the project supplies detailed information on PPP measures for R&D cost categories, it should also be useful in developing similar measures for governmental and university expenditures. In-depth interviews in the second phase will allow for some comparisons with increasingly common outsourced R&D efforts.

[3] Second phase industries were selected based on an analysis of intensity and scale of reported R&D across all firms in Standard and Poor's domestic *Compustat* database.

analysis. This phase will explore quality and related product composition and mix adjustments. In particular, it will enable us to focus on the applicability of the unit value approach in those industries where R&D generates many new products. Related two and four-digit industries will be compared in order to assess the sensitivity of results to the product mix of industry categories, as well as aggregation effects.

Throughout both phases, biases associated with the use of current S&E Indicators that use only "nominal" prices (as with R&D/GDP ratios) or aggregate level PPPs (as with R&D expenditures) will be assessed and their effects examined. Comparisons of correctly adjusted results with unadjusted values at multiple levels of aggregation should help assess the magnitude of errors. A final evaluation stage will allow for a general appraisal of the implications of the new and enhanced PPP-based measures for S&T analysis.

Output PPPs will largely be derived from a unique set of industry-of-origin PPPs developed in the International Comparisons of Output and Productivity (ICOP) project, part of collaborative work with The Conference Board for the past four years.[4] Unlike conventional PPPs, ICOP PPPs also cover intermediate outputs.[5]

PPP-converted R&D measures will be constructed from R&D cost breakdowns together with PPPs for cost categories. For this purpose, the project will make use of detailed wage and salary information derived from internationally comparable labor surveys and information on the shares of materials and other costs in R&D. PPPs for other cost categories in R&D will be derived from the ICOP PPPs supplemented with expenditure PPPs where appropriate.

The accuracy of R&D PPPs will be improved through the use of interviews of intensive R&D performers.[6] In-depth interviews will seek to understand the complexities of R&D investments, including the composition of internal R&D costs, the *prima facia* validity of the first phase estimates, and the relative price of increasingly common outsourced efforts. Results of the cost component approach will be compared with the prices paid by firms for outsourced R&D, and appropriate adjustments to these results will be made where systematic differences can be identified.

The proposal is organized as follows. The next section discusses the need for PPP measures. The third section describes exactly how the new measures will be developed, including the basic methodology, primary data sources, and techniques for quality adjustment. In the fourth section, the standards for evaluation of the S&T indicators are outlined. Sections five and six describe the plan for executing the research and the merit of the principal investigators. The last section is the Bibliography, followed by a brief Appendix on the difference between ICOP and standard PPPs.

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[4] Maddison and van Ark (1988) and van Ark (1993) initially applied the industry-of-origin approach. Recently this approach has been applied to a wide range of countries and been used by many researchers as well as by international organizations (van Ark and McGuckin 1999, van Ark and Pilat 1993, Pilat 1994, van Ark 1996b, ILO 1999, Timmer 2000).

[5] Gilbert and Kravis (1954) and Gilbert and Associates (1958) pioneered the final expenditure approach. It has made considerable progress through the work of Kravis, Heston and Summers (see, for example, 1978 and 1991) and has been embedded in the statistical programs of international organizations, such as the UN, World Bank, OECD and Eurostat.

[6] The Conference Board's business membership includes a majority of the largest companies in the US, who typically offer our researchers in-depth access to their management. A previous R&D survey was conducted of over 500 firms by the Conference Board in 1987 under NSF grants 87-01478 and 87-01479.

2. The Need for PPPs

The importance of adjusting nominal input expenditures and outputs for differences in local currencies using purchasing power parities (PPPs) has long been recognized. A purchasing power parity (PPP) is defined as the number of currency units of a comparison country required to buy goods equivalent to what can be bought with one unit of the currency of a base country (the U.S. in our study). Thus, a PPP is simply a rate of equivalence for comparable goods in local currency prices. It has the same units as an exchange rate. Using PPPs to adjust outputs or inputs in national currency values produces comparable values in the spatial dimension. In this sense PPPs are comparable to commonly used deflators that transform the nominal values of time series like GDP into *real* values that account for inflation.

Market exchange rates measure a currency's relative international buying power. They appear to be a natural substitute for PPPs but are not suitable for most spatial adjustments of prices in national currencies.[7] There are many reasons why exchange rates are not good substitutes for PPPs. Of particular relevance to comparisons of R&D expenditures is that there is no necessary reason why the relative prices of goods that are not traded internationally should conform to exchange rate values.[8] Aside from theoretical considerations, use of exchange rates can be highly misleading because the magnitude of the difference between exchange rates and PPP adjustments is often very large. For example in 1995, Japan's R&D expenditures were close to those of the U.S. using exchange rates, but less than half as large when using an economy-wide PPP.[9]

Use of shares of R&D in GDP based on nominal values *does not* solve this dilemma. As the Frascati Manual states in its conclusions (OECD 1994, ¶56): "[R&D share] indicators are fairly accurate but can be biased if there are major differences in the economic structure of the countries being compared." Since R&D is not traded and one of the major inputs into its production is labor—the prices of which exhibit great differences across countries—establishing "structural" R&D indicators is likely to provide important new insights. Recent experience with industry-level PPPs from the ICOP project offers support for this argument. For many countries, industry output price levels are significantly different from overall GDP price levels, implying that using only overall PPPs gets the prices *wrong*, potentially leading to incorrect comparisons (van Ark 1993, 1996b). Thus PPP adjustments—taking account of differences in the structure of relative prices across economies—appear to be worth the considerable effort required for measurement.

Current practice often has researchers and analysts using economy-wide (GDP) PPPs rather than industry specific PPPs because more detailed data is not available. In fact, The

[7] Exchange rates can be very useful as a reference point, when considering relative price levels, defined as the ratio of a PPP to the exchange rate. These price levels are straightforward measures of price competitiveness.

[8] Exchange rates are vulnerable to a number of distortions—e.g., currency speculation, political events such as wars and boycotts, and official currency interventions—that have little or nothing to do with the differences in relative prices across economies.

[9] This example is taken from a feature box in *Science and Engineering Indicators*, "Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data" (NSF 1998, 2000).

National Science Foundation (NSF) uses the same PPPs both for GDP and R&D expenditures, instead of adjusting the latter with an R&D PPP. Unfortunately, this procedure does not solve the problem of distortions in comparisons of R&D shares in output across countries.

Comparisons of R&D investments across countries requires a measure of the *real amount of effort*. This requirement demands an R&D PPP-adjusted share (based on the prices of a numeraire country) be used as the S&T indicator. Measures of "real" costs of R&D in one country relative to another are very important for informed policy analysis. For example, recent concerns of policy makers about the shift of R&D activity from the U.S. to lower wage countries would benefit greatly from the use of PPP-adjusted comparisons that take account of relative price differences between R&D and non-R&D sectors of the economy.

3. Methodologies to Construct Output and R&D PPPs

Developing the necessary output and R&D PPPs is not an easy task since what PPPs are available from official statistical programs are incomplete: they only cover final goods and services. The absence of PPPs for intermediate goods was highlighted in the Frascati Manual (OECD 1994) as the binding constraint for creation of R&D PPPs.[10] This was because neither R&D labor inputs nor the outputs of intermediate industries (inputs to other industries, including R&D activity) were covered. Recently available industry-of-origin producer-based PPPs, supplemented by wage and salary surveys and in-depth interviews with large R&D performers, should overcome this major limitation.

The industry-of-origin approach and the International Comparisons of Output and Productivity (ICOP) database derived from it have many advantages as a starting point for this project. First, a unique feature of the ICOP database is that it contains PPPs for both intermediate and final demand outputs at detailed industry levels. One of the main reasons that PPPs have not been created for scientific and technology inputs as well as for detailed industries is that major data programs such as the ICP only construct final goods (expenditure) PPPs.

Second, aside from an extensive set of PPPs already available for 1987 and 1992, the extensions of the data to 1997 and the filling of gaps in the detailed industry data should be possible at reasonable costs.

Third, while developed relatively recently, ICOP PPPs have been used with success in a wide variety of studies, including many studies that focused on productivity comparisons.[11] This provides some assurance that the methods used to derive the PPPs and the estimates themselves are reasonable.

Fourth, the data are available for a wide range of industries and countries. Systematic bilateral comparisons based on production census data for hundreds of product categories are available between the U.S. and many countries at two-digit industry levels. For the

[10] The distinction between producer and expenditure PPPs is described in more detail in the Appendix. Castles (1997) and Ryten (1998) discuss the difficulties in extending the expenditure approach to intermediate goods.

[11] Op cit., note 4.

more detailed high and medium technology industries the coverage is less systematic and additional work will be required in constructing the PPPs.

Output PPPs

The ICOP project has developed industry-specific conversion factors using unit values for product groups by matching country to country as many products as possible and then weighting these ratios up to the industry level. The weights are the share of the product in industry output. These conversion factors are then used to express output for different countries in a common currency.

The data supporting these calculations is largely provided by industrial censuses and surveys of production undertaken by the national statistical agencies in each country. Various international databases such as Eurostat's PRODCOM and Japan's MITI product data also provide valuable information. All of these sources contain great detail on output and input structures by industry and the sales values and quantities on a wide range of products. These data form the basic infrastructure used to support the national accounts.

Although comprehensive, the production censuses and industry surveys are not well harmonized across countries. This has meant that ICOP has focused on comparisons between two countries at a time, using the U.S. as the base country.[12] In this study comparison to the U.S. will be made with five countries: France, Germany, Japan, The Netherlands and The United Kingdom.

A key issue in the construction of industry-of-origin PPPs is comparability of the product structures in each country. The issues involved are analogous to those encountered in traditional price indexes for time series. In the spatial context differences in relative output prices relate to differences in product mix and product quality (see Gersbach and van Ark 1994, van Ark et al. 1999). A study of several industries in the U.S., Japan and Germany found that adjustments on the order of three to five percent were required for comparability in most industries. These adjustments were based on highly detailed case studies of product price, mix, and quality differences in the industries under consideration (Gersbach and van Ark 1994, as part of the McKinsey Productivity Studies 1993).

In order to examine the reliability of the unit value approach, we plan to examine two general types of adjustments: experimentation with alternative price index functions and application of specific hedonic results. First, we plan to experiment with alternatives to the implicit matched-model functional form of the unit value approach, including an interspatial equivalent of the results derived in Feenstra (1994), to account for the introduction of new product varieties. Feenstra's results suggest that the introduction of new or improved products will reduce measured changes in a matched model index, and that the retirement of products will tend to have the opposite (increasing) effect. Such analysis may be useful in ensuring the robustness of the unit value approach in the face of new product varieties.

Second, we plan to apply consistent quality methods to improve the results for the four detailed high and medium technology industries we target in the second phase of this project. For this work we will make use of results from cooperative research on hedonic

[12] Bilateral PPP comparisons do not always satisfy the property of transitivity. This should not be a serious problem for NSF S&T analysis, because the comparison country in each case is the US. For industry-of-origin studies, considerable complications arise in creating multilateral indexes. Preliminary results suggest, however, that multilateralization can be achieved in many situations (Rao and Timmer 2000).

price indexes on automobiles and telecom equipment at the University of Groningen and OECD-supported research being conducted by Jack Triplett on computers at the Brookings Institution. The latter project is part of the work of an international research consortium on productivity comparisons in which The Conference Board participates.[13] For pharmaceuticals we hope to make use of international price measures that are developed in the framework of the NBER program on pharmaceuticals and work by Danzon and Percy (1999).

Consistent quality estimates obtained for detailed industries in phase two will be compared with phase one estimates for parent two-digit industries. These comparisons will be used to verify if output PPPs for broad industries accurately reflect the producer prices of both traditional and new products—those most closely associated with the output of the R&D process. Furthermore, they will aid in verifying that the most up-to-date product mix for industry-wide output is reflected in output PPPs.

Within services, there has been a blossoming of literature on computer software and substantial work on other sectors at the statistical agencies, Brookings and the NBER. We plan to survey this work to supplement the interviews of large R&D performers. Moreover, the interviews will provide us with a degree of understanding regarding R&D outsourcing in computer and related areas.

PPPs for R&D

There has been virtually no investigation into intercountry differences in R&D price levels. One of the few substantial inquiries was in 1965 (Freeman and Young), before PPP programs were underway. There have been a number of examinations of inter-temporal price change in R&D, mainly in the United States. These studies provide a useful starting point for work in the spatial domain.

Several studies have found that while the implicit GDP price index is a reasonable approximation of overall R&D inflation, at the industry level R&D inflation appears to be quite heterogeneous (Mansfield 1987, Jankowski 1993).[14] In fact, the divergence of some industries from the overall inflation trend has been quite significant. For instance, an experimental biomedical R&D price index developed by the National Institutes of Health shows over 50 percent more inflation than the implicit GDP deflator (one and a half percentage points of inflation per year) over the period 1980 to 1999 (NIH 2000). Given the wide differences in international price structures noted earlier, these studies suggest that price adjustment in the spatial domain may also be important.

This project will construct R&D PPPs by combining the PPP-adjusted prices of individual inputs to the R&D process for each industry and country. We intend to use breakdowns of cost types from consistent country-specific R&D surveys to the largest

[13] The KLEMS project is a large-scale collaborative effort to create comparable quality-adjusted international measures of highly disaggregate inputs, outputs, productivity and growth. The Conference Board is seeking support for this project through the NSF Infrastructure program. The collaboration is more fully described in Timmer (2000) and at http://www.conference-board.org/economics/klems.

[14] An approach similar to that of Mansfield and Jankowski was applied by the Bureau of Economic Analysis (BEA) in the creation of implicit R&D deflators for use in the US Satellite R&D Accounts (see Fraumeni and Okubo 1999, Carson et al. 1994), currently available from 1953 through 1992.

extent possible.[15] On an international basis, although there are some gaps, adequate data for the six selected countries are available for 1987 and 1997, or for a nearby year. Many industry-level breakdowns are available in the OECD R&D Database (2000c: DIRDE/BERD). Table 1 below shows the type of breakdown that is available for the countries in this study for overall manufacturing. OECD data will be supplemented with country-specific data sources and interpolation, if necessary.

While labor costs account for the bulk of the cost composition in most countries, in Germany they represent 60% of total costs, and only 46% in the U.S. Since labor costs and other current costs represent such a large proportion of the R&D cost structure, it is desirable to further disaggregate the costs of these categories. In particular, we will: (*i*) use OECD R&D Database information on R&D personnel to separate engineers and scientists from support personnel, and (*ii*) take advantage of supplemental data on other current costs to gauge the breakdown between material inputs, energy, and other costs.

Data from the OECD R&D Database separates researchers, technicians, and support personnel at the industry level in most countries (2000c: PRDE/BEMP). In addition, some country-specific data sources may be used to ensure full comparability of functional definitions. This information will be used in conjunction with industry-specific productivity weights from the ICOP databases and function-specific labor cost data from the Eurostat Labour Force Survey and comparable data sources in Japan and the United States. Indexes weighted for productivity differences will define PPPs for each industry's R&D labor cost component.

The composition of the other current cost category is uncertain, and must be investigated more fully in the survey. We intend to use techniques similar to those in Mansfield (1987) and Jankowski (1993) to further disaggregate cost categories. We surmise that intermediate materials and service inputs from other sectors will be a major component of this category. These PPPs will largely derived from ongoing ICOP work and the KLEMS project, as described above.

For the remaining cost categories, PPPs for the instruments and equipment industry are available through ICOP and the ICP PPPs for new investment goods may also be used. ICP PPPs exist for land and building categories and may be used with adjustments.

TABLE 1: OVERALL MANUFACTURING R&D COST COMPOSITION

Cost Category	France	Germany	Japan	Netherlands	U.K.	U.S.
1: Labor costs	51%	60%	43%	52%	42%	46%
2: Other current	42%	34%	48%	38%	47%	55%[16]
3: Instruments and equipment	6%	6%	8%	8%	8%	
4: Land and buildings	1%	—	2%	2%	3%	—
Total	100%	100%	100%	100%	100%	100%

Note: Data are for 1997 except for France (1996), Germany (1995), and the U.K. (1989).

[15] This approach comports with the Frascati Manual that recommends starting with breakdowns of cost shares, and then matching as closely as possible the cost categories to production input PPPs (OECD 1994, Annex 10). It is also analogous to work on military PPPs conducted by Heston and Aten (1993).

[16] The NSF survey data for the US are broken out in slightly different categories than those for other countries. For example, materials and supplies are separated, while instruments and equipment are not (in the table, materials and supplies represent 19%, and other costs, 36%). Furthermore, while capital expenditures are *not* included as R&D costs, the most recent R&D surveys report R&D depreciation.

This information will be enhanced as a result of the current National Science Foundation R&D survey, since depreciation will be distinguished. Once the PPPs have been constructed, they will be weighted using the cost shares to create bilateral industry-specific R&D PPP comparisons with the U.S.

To enhance and validate the R&D PPPs based on cost components, we plan to conduct in-depth interviews with a selection of the most R&D intensive firms in the *Compustat* database (see NSF 1999). These interviews will take advantage of the high level of access that businesses typically offer Conference Board researchers.[17] The survey will examine the precise composition of R&D costs in different countries, including the makeup and appropriateness of each cost category, and explore means for improving the accuracy of results. Similar interviews were successfully used by Mansfield et al. (1983, 1987) in order to supplement and validate his estimation of price changes over time and across industries.

In addition to examining the *prima facia* validity of first phase results, the interviews will be used to evaluate the price and extent of R&D outsourcing. Results may allow for adjustments to be made to reflect systematic differences between the cost approach and prices of outsourcing.

4. Assessing the New S&T Indicators: Analysis and Deliverables

The potential benefits of price structure-adjusted R&D shares and levels are discussed extensively in Section 2. A key question is how much difference there is between new and existing S&T indicators. Given the difficulties in constructing our PPPs, it is important that the new methods provide significant improvements over existing procedures. Analysis of the changes in both R&D share and level indicators associated with the new procedures will be a key deliverable from the research.

Although the preferred method of assessment involves tests of each set of indicators in an analytical model consistent with a given application, a complete analysis is well beyond the scope of this proposal. Analysts use the indicators in a variety of ways and we cannot reasonably consider every possible model. Nonetheless, there are several useful ways to evaluate the indicators that we develop.

A key facet of the evaluation is to assess the importance of the level of aggregation on the indicators. Aggregation is a useful tool for summarizing data and simplifying analytical work, but it can have great costs because it adds errors and distortions. The risks are evident in the work of Jankowski (1993), that shows price change in detailed industries as being very different movement from the overall. Aggregation has also been an important issue in analysis of the knowledge economy, where the impact of computers on productivity was hidden for many years due to the use of economy-wide data (see McGuckin and Stiroh 1998a, 1998b, and 2000). Examination of the level of aggregation for the S&T indicators will be a key feature of our analysis and should complete the information the Division of Science Resource Studies (SRS) needs to determine whether to integrate the new measures into their regular programs.

[17] Op cit., note 6.

Aside from the R&D indicators that are now part of the program, the project will create new measures of competitiveness and R&D efficiency. The new competitiveness indictors will be of two types: (*i*) direct comparisons of price levels across countries, and (*ii*) measures of R&D efficiency. Each type of indicator will provide independent, but related information. Thus, while the "adjusted price level" is conceptually the best measure of competitiveness, "real"[18] R&D productivity efficiency measures—similar to "real" labor productivity measures—can be useful analytical tools for assessing S&T differences across countries.

Adjusted Price Levels

Adjusted price levels are the most comprehensive measure of competitiveness. They are based on the ratio of the real cost of industrial output (or input) to exchange rates. These measures will be calculated for all industries, and we anticipate that SRS will be particularly interested in the measures—for both outputs and inputs—in the high technology industries, that utilize the larger fraction of science and technology resources. Thus, the second phase of the project focuses specifically on these industries, to supplement the systematic PPP-adjusted measures that should be of interest throughout the science community. These adjusted price levels provide comparable output measures in the spatial domain at two points in time and represent a key competitiveness indicator for each industry.

Adjusted price levels are forward-looking, and are likely to suggest how an economy will develop in the future, since they measure the difference between "real" and market exchange rates. They reflect a wide range of institutional and market-based factors, including the character of human capital, government policy, availability of natural resources, and a wide range of other factors. Adjusted price levels offer a direct measure of competitiveness, and can be tremendously useful in comparative evaluations of countries (Kravis and Lipsey 1988, Jorgenson and Kuroda 1992, van Ark 1995).

R&D "Productivity"

Productivity is one of the most important determinants of competitiveness. Improvements in productivity—particularly labor productivity—are a necessary pre-requisite for producing high quality products at a reasonable cost. Average productivity growth indicates how much increase in inputs it takes for an industry to raise output. Since the research will generate both "real" output and "real" R&D expenditures, it will be possible to create a productivity ratio for each industry and country. Since the results of R&D efforts take more than a single period to be realized, the ratio should not be thought of as an all-encompassing measure of innovation efficiency, but rather a broader measure of longer run industry competitiveness.

This kind of exercise is to some extent analogous to that usually carried out for labor. But this analogy is imperfect, as the actual output of R&D—innovative input to the firm's output—is not observed and not measured directly (see Fraumeni and Okubo (1999) for a discussion). This means that we measure the productivity of R&D on industry output, not the productivity of R&D input in producing R&D output. Therefore, we need to be aware that our estimates of R&D productivity are likely to represent lower

[18] The use of "real" here is in the interspatial as opposed to intertemporal sense, based on international (comparable) prices, as opposed to domestic currency prices ("nominal").

bound estimates. The difficulties with this type of analysis are well known in the economics literature, and are described further by Griliches (1979).

Since substitution among inputs can occur in the production of output, analysts must be careful in assessing differences in single-factor productivity measures (NRC 1979). Therefore, the efficiency of the R&D indicator will be compared to other productivity-oriented measures. For example, since labor is one of the major components of R&D costs, we expect R&D efficiency measures to be related to labor productivity and unit labor costs. While such comparisons are not entirely straightforward, they should give us an idea of the effectiveness of the new indicators.

The new competitiveness indicators should be particularly helpful in the evaluation of shifts in the locational patterns of science and technology activities as well as the worldwide flows of traded goods. Studies by Kravis and Lipsey (1982, 1988, 1992) suggest that price levels are central for export and investment flows. Moreover, with the dramatic rise in foreign direct investment over the last two decades, the influence of factor cost now has a greater impact than ever before. In fact, sales of foreign affiliates of multinational corporations now exceed the value of world trade in goods and services (Soboleva 1999). We plan to examine how well the indicators explain trade flows, export shares, and other factor movements. This type of assessment should improve indicator research by offering a way to link S&T indicators to economic outcomes.

The research outlined in this proposal will provide the National Science Foundation Indicators Program with fundamental improvements in the value of many key indicators and enhance the methodology for assessment of the competitiveness of science, technology, and engineering enterprise in the United States.

5. Merit of the Researchers

The work involved in this research effort is extremely demanding in terms of its data requirements and measurement difficulty. Expertise in both industry-level PPP development and S&T indicator delivery is imperative. Few organizations have the capabilities necessary to carry out the required research tasks.

Uniquely, The Conference Board and the International Comparisons of Output and Production (ICOP) project have accumulated considerable experience in developing multicountry industry-of-origin PPPs and measuring scientific and technological progress. Moreover, with its intimate access to numerous member firms worldwide, The Conference Board has the ability to gather proprietary knowledge to ensure that the complexities of actual firm R&D efforts are adequately captured in the results. In addition, in its role as provider of the U.S. Leading Economic Indicator (LEI) as well as other key domestic and international indicators, The Conference Board has created considerable institutional know-how about the creation and use of high-profile economic indicators.

A central deliverable in this proposal will include an infrastructure for distribution, education, and updating of the new S&T indicators. The Conference Board has demonstrated capacity in these types of activities, and in its partnership with the ICOP, will be able to support, maintain, and improve the database that results from this project.

Currently, related economy-wide and sectoral databases are freely distributed on the Internet at http://www.conference-board.org/economics/research.

The principal investigators have a wealth of directly relevant experience to offer the project. Prior to joining The Conference Board in 1996, Robert H. McGuckin was Chief of the Center for Economic Studies (CES) at the U.S. Bureau of the Census, where he guided development of the Longitudinal Research Database (LRD) and a broad research program in both statistics and economics. Under his leadership, CES became a world leader in the development of microdata approaches to economic theory and policy.

As Director of Economic Research at the Conference Board, McGuckin has developed a research program focused on Technology and Productivity issues in the U.S. and internationally. He has regularly served on committees and as a consultant to the Division of Science Resource Studies.

During his tenure at The Conference Board, McGuckin has forged a remarkable partnership with Professor Bart van Ark and the International Comparisons of Output and Productivity (ICOP) project, a consortium of researchers working on comparisons of output using production methods. Van Ark is one of the foremost authorities on international price comparisons, and leads the ICOP project. He has been the Consulting Director for International Economic Research at The Conference Board since early 1997. In addition, he holds an endowed economics chair in the field of Productivity and Technology Policy, at the University of Groningen in the Netherlands.

Van Ark and ICOP have been involved in a range of high-impact international comparison studies, including the McKinsey Global Institute Manufacturing and Services Productivity Studies, as well as major productivity and labor force studies for the OECD, Eurostat, and the International Labor Organization. Presently, ICOP is conducting a large scale pan-Europe innovation study focusing on services, commissioned by the Dutch Ministry of Economic Affairs.

Sean Dougherty will be involved in much of the actual analytical work, in addition to two half-time research assistants. Dougherty is an Economist in the Productivity and Living Standards Research Program of The Conference Board. He has spent the past few years examining international price differences as a Research Fellow at the Center for International Comparisons at the University of Pennsylvania and at The Conference Board. Prior to his training as an economist, he was a practitioner in the two of the most R&D-intensive service industries: software development and direct marketing advertising. His current research specialty is in the economics of technology.

6. Plan for execution of research

The basic three-year plan for the execution of the research work is envisioned to proceed as follows:

First year (Phase I):

- Extension of output PPPs in two-digit manufacturing industries to the 1997 base year,
- Compilation and completion of R&D cost data from country surveys and databases,
- In-depth interviews with firms regarding R&D cost composition and outsourcing,
- Development and computation of R&D PPPs using cost structures for manufacturing.

Second year (Phase II):

- Use of price data and application of methods to make consistent quality and mix adjustments to output PPPs for detailed high and medium technology industries,
- Extension of R&D and output PPP estimation for selected service sectors,
- Further in-depth interviews of large R&D performers,
- Development and computation of R&D PPPs for detailed industries.

Third year (Evaluation):

- Evaluation of the resulting PPPs and price levels, and R&D cost efficiency measures using other measures of competitiveness,
- Final adjustments to R&D PPPs based on evaluation,
- Wide dissemination and publication of the data and methodology.

Refer to the budget for breakdowns on costs. Primary expenditures will be for research personnel time on data development, survey efforts, and evaluation. The Conference Board, as a non-profit business education and research organization, will undertake the task of publicizing the uses and applications of the resulting data and indicators, to academic, government, business, and public audiences. All of the data resulting from the project will be made easily available over the World Wide Web, so that anyone with an Internet connection could access the data in whole or part, in an easy-to-use format. Importantly, The Conference Board will lay the foundation for long-term continuation, extension, and improvement of the project through documentation and publication of the research methods and results.

7. Appendix: Expenditure versus Production Approaches

There are two basic ways of computing PPPs for international comparisons: the expenditure approach and the industry-of-origin approach. The expenditure approach concentrates on comparisons of categories of private consumption, government consumption and capital formation.[19] Comparisons by industry of origin deal with sectors of the economy, such as agriculture, industry and services, and branches and industries within these sectors. For comparisons of the economy as a whole, the expenditure approach is applied because it concentrates on comparisons of final products, as found in national accounts, and therefore avoids duplication of output that is used as an intermediate input elsewhere. As a result, until recently, purchasing power parities derived from the expenditure side have been more readily and widely available than similar conversion factors by industry-of-origin on the aggregate level.

For comparisons by sector and industry, only the industry-of-origin approach can be correctly applied (see van Ark 1996c). This is because industry-level output consists of final products as well as intermediate products used by other sectors. The most common method of deriving an industry-specific PPP is to use unit value ratios (UVR). Unit values are obtained as the ratio of values and quantities of item types that are reported for many products in national production statistics, including economic census and sectoral survey materials. The products for each are matched across countries.

In manufacturing, product information is detailed enough to match values and quantities of items covering 20 to 30 percent of output. Typically 300 to 500 product categories are matched for all of manufacturing, and between 20 and 60 for individual industries. For non-matched products the PPPs are typically assumed to be the same as for matched products in the same industry or sector. This implicit weighting of UVRs by their value in production makes them more representative of output than most combinations of expenditure PPPs. Expenditure PPPs tend to cover more specific items, they do not cover intermediate goods. Moreover, since they refer only to total expenditures, they are difficult to assign to particular industries, and even then, considerable adjustment is necessary. For example, Jorgenson and Kuroda (1992) and Hooper and Vrankovich (1995) have peeled-off distribution margins and indirect taxes to create proxy producer PPPs, but the procedures are very rough.

[19] Recent reviews of the International Comparisons Program (ICP), the most prominent program for collection of expenditure PPPs, have pointed out shortcomings, including some problems with consistency in particular categories (Castles 1997, Ryten 1998). While both studies strongly argue for the use of PPPs in international comparisons, they suggest that more resources are necessary to create adequate PPPs. Some measures to improve the PPPs have been undertaken in adjustments of the most recent 1996 benchmarks (OECD 1999).

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