Effects of imported intermediate inputs on productivity

A framework for estimating the effects of imported intermediate inputs on U.S. major-sector labor productivity is used together with the Solow multifactor productivity equation to show that private business sector multifactor productivity may have grown about 0.1 percent more slowly than what the BLS published series indicates

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Offshoring, or offshore outsourcing—the substitution of imported intermediate inputs for domestic labor or domestically produced intermediate inputs—affects U.S. economic performance. The existing framework for measuring productivity does not permit an analysis of offshoring; thus, the framework needs to be adjusted in order to assess the effects of imported intermediate inputs on the U.S. economy. The BLS Major Sector Productivity program develops measures of labor productivity for broad sectors of the economy: business, nonfarm business, manufacturing, and nonfinancial corporations. In addition, the program develops annual indexes of multifactor productivity for the private business sector, the manufacturing sector, and most manufacturing groups. This article focuses on BLS productivity measures for the private business sector and the manufacturing sector. Productivity measures for these two sectors are constructed under different methodologies: the private business sector productivity measures use a value-added output concept, while the manufacturing sector measures use a sectoral output approach. This difference in methodology influences the effects of imported intermediates on BLS measures of productivity.

In the sections that follow, the private business sector and the manufacturing sector are analyzed separately with an eye toward developing a framework for estimating the effects of imported intermediate inputs on U.S. major-sector labor productivity. First, the production model used to calculate the BLS private business sector multifactor productivity measures is expanded to treat imported intermediate inputs as an input, rather than as a subtraction from output. Then, the BLS framework for constructing manufacturing multifactor productivity is decomposed in order to isolate imported intermediate inputs. For both sectors, the Solow multifactor productivity equation is used to estimate the effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked.[1] The data reveal that growth in imported intermediate inputs contributed 14 percent to the average annual growth in labor productivity for the private business sector, and 23 percent to the average annual growth in labor productivity in the manufacturing sector, from 1997 to 2006.[2]

Data sources

Output. Real output measures used by the BLS to construct major-sector productivity statistics are produced by the Bureau of Eco-

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nomic Analysis (BEA) of the U.S. Department of Commerce. The most widely known measure of aggregate output for the U.S. economy is the gross domestic product (GDP): the sum of personal consumption expenditures, gross private domestic investment, government consumption expenditures and gross investment, and exports of goods and services less imports of goods and services. The BEA constructs nominal outputs for detailed components of GDP from various data sources, converts the outputs to real measures, and then aggregates them to calculate real GDP.

As a fundamental part of the national accounts, the BEA also distinguishes three primary sectors of GDP: business, household, and government.[3] The business sector accounts for the bulk of national output. The BEA calculates business sector output by removing from GDP the gross products of general government, private households, and nonprofit institutions.[4]

Ideally, productivity statistics measure the productivity of the U.S. economy at the most aggregate level of domestic output—that is, GDP. However, the BLS must exclude several activities from aggregate output in order to remove potential sources of bias that are specific to the measurement of productivity. The real gross products of general government, of private households, and of nonprofit institutions are estimated primarily from data on labor compensation. Trends in such output measures will, by definition, move with measures of input data and will tend to imply little or no labor productivity growth. Although these measures are the best available estimates of nonmarket components of GDP, including them in measures of the aggregate productivity of the economy would bias labor productivity trends toward zero.

The BLS business sector also excludes the gross product of owner-occupied housing and the rental value of buildings and equipment owned and used by nonprofit institutions serving individuals.[5] These components are excluded because no adequate corresponding labor input measures have been developed. To measure multifactor productivity, the BLS must further restrict output to the U.S. private business sector, excluding the output of government enterprises. Appropriate weights for labor and capital in government enterprises are not estimated because subsidies account for a substantial portion of capital income; therefore, there is no adequate measure of government enterprise capital income in GDP. In 2006, the BLS measure of the U.S. private business sector output accounted for approximately 76 percent of the value of GDP.[6]

In the manufacturing sector, the BLS measures output for productivity statistics differently. Output in the manufacturing sector is defined as the deflated value of production shipped to purchasers outside of the sector, including shipments to final users and establishments elsewhere within the private business sector. This is a *sectoral* output concept: output is gross output, excluding intrasectoral transactions (sales or transfers between establishments within the sector); sectoral output represents sales to final demand plus intermediate goods sent to other industries. The manufacturing multifactor productivity indexes are based on sectoral output in an effort to avoid the problem of double-counting that occurs when one establishment provides materials used by other establishments in the same sector.

Labor input. Labor input for the U.S. private business sector is measured as total hours actually worked by all persons, multiplied by a labor composition index. The measure of hours actually worked is based on the sources and methods used to measure the quarterly labor productivity of the business sector. The BLS labor composition index estimates the effects that shifts in age, education, and gender have on labor input growth and multifactor productivity growth.

Labor input is based on a jobs concept. The Current Employment Statistics (CES) survey is the primary source of data used to construct hours for the BLS productivity measures.[7] Data from the CES survey on average weekly hours paid are adjusted to an hours-at-work concept with the use of a ratio of hours worked to hours paid.[8] Current Population Survey (CPS) data on average weekly hours of nonproduction and supervisory workers are incorporated into the methodology to expand coverage to all employees.[9] To expand sectoral coverage, hours actually worked for employees of farms, proprietors, and unpaid family workers reported in the CPS are incorporated into the labor input measure; remaining data are obtained from various sources.[10]

Construction of the multifactor productivity labor composition measure begins with estimates of the number of hours worked by each type of worker, based on CPS data. The BLS assembles data on workers' hours, classified by their educational attainment, age, and gender, using actual wage averages for weights. The sum, over all groups, of the growth rates of hours, multiplied by the labor cost shares, gives the growth in adjusted labor input. Subtracting from this the growth in total (unweighted) hours yields the growth in labor composition.[11]

The same methods are used to construct the labor input measure for the U.S. manufacturing sector, except that no adjustment is made for labor composition (age, education,

and gender of the workforce) because the CPS sample size is too small for that purpose.[12]

Capital inputs. Capital inputs for private business and manufacturing multifactor productivity measures are similar. The BLS capital input measures include assets that are owned and operated by a business within the sector; rented capital services are included in intermediate inputs. Capital input measures the services derived from the stock of physical assets and software. Among the capital input measures are fixed business equipment, structures, inventories, and land. Financial assets, owner-occupied residential structures, and nonprofit capital are excluded from the capital input measures. The aggregate capital input measures are obtained by Tőrnqvist aggregation of the capital stocks for each type of asset within each of 60 NAICS industry groupings; estimated rental prices are used for each type of asset. Rental prices reflect the nominal rates of return and nominal rates of economic depreciation and revaluation for the specific types of assets. Rental prices are adjusted for the effects of taxes; rental prices of capital are computed for 18 three-digit NAICS industries within manufacturing. Data on investments in physical assets are obtained from the BEA.[13]

Energy, materials, and purchased business services. In the manufacturing sector, inputs include intermediate inputs, as well as capital and labor inputs. Data on intermediate inputs (energy, materials, and purchased business services) are obtained from BEA's annual input-output tables. Tőrnqvist indexes of each of these three input classes are derived at the three-digit NAICS level and then aggregated to total manufacturing. For manufacturing, materials inputs are adjusted to exclude transactions between manufacturing establishments, to maintain consistency with the sectoral output concept.[14]

Nominal values of materials, fuels, and electricity and nominal quantities of electricity consumed are obtained from economic censuses and annual surveys conducted by the U.S. Bureau of the Census. Purchased business services are estimated with the use of benchmark input-output tables and other annual industry data from BEA. Prices for many service inputs are based on the BLS price programs and obtained from the National Income and Product Accounts.

Imported intermediate inputs. The BEA produces import matrices as supplementary tables to the annual input-output accounts. For each commodity, the import-matrix table shows the value of imports of that commodity used by each industry. Because such information is not available from most businesses, the estimates must be imputed from data available in the annual input-output accounts. The imputed import values are based on the assumption that each industry uses imports of a commodity in the same proportion as the ratio of imports to domestic supply of the same commodity. (Domestic supply represents the total amount of a commodity available for consumption within the United States; it equals domestic output, plus imports, less exports.) Using this assumption to calculate the estimates implies that whatever variability of import usage there is across industries is not based on industry-specific information.[15]

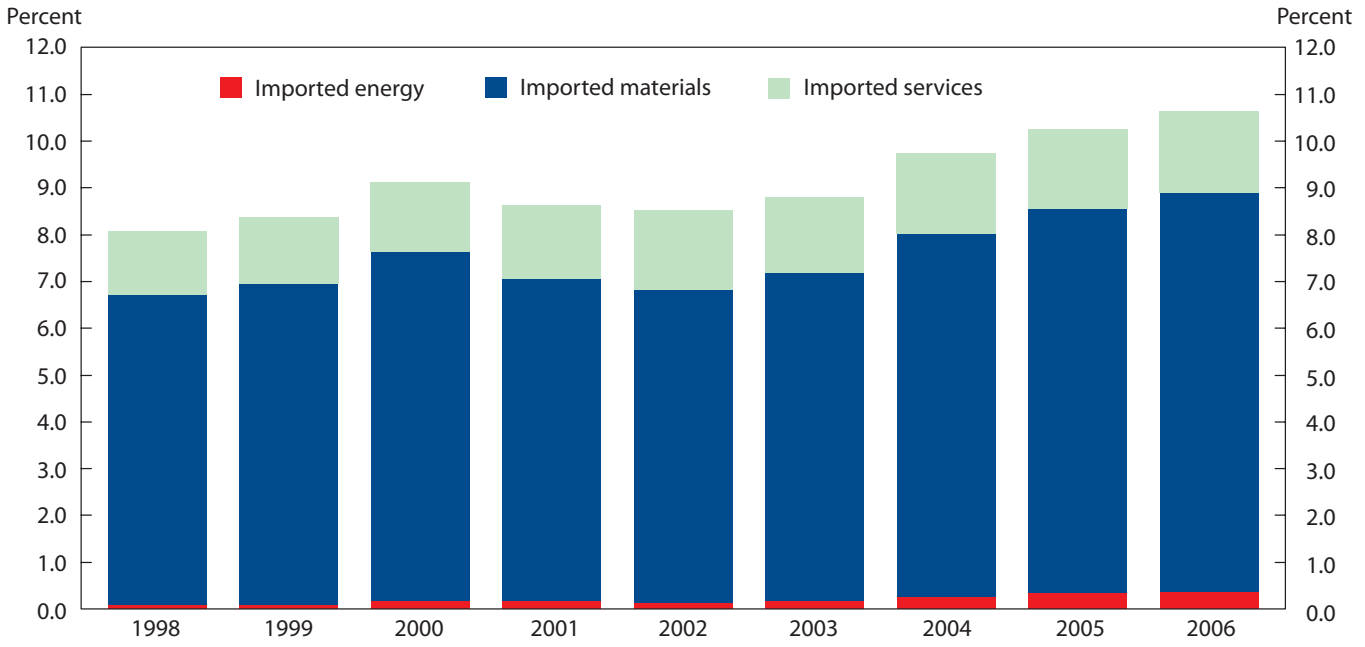
The BEA provided the BLS with detailed statistics on imported intermediates for this article. These data are not included in BEA published tables because their quality is significantly lower than that of the higher level aggregates in which they are included. Compared with these aggregates, the detailed statistics are more likely to be based on judgmental trends, on trends in the higher level aggregate, or on less reliable source data.[16]

The BEA data reveal trends in the shares of imported intermediate inputs. For all private industries, the share of intermediate inputs that is accounted for by imports grew from 8 percent in 1998 to more than 10 percent in 2006. Chart 1 shows that there was a decline in the share of imports used by private industries around the 2001 recession; however, beginning in 2002, the share increased steadily. Purchased materials account for the majority of imported intermediates, and their share grew steadily, again with a slight dip around the 2001 recession. Imported material inputs, which accounted for 15 percent of total materials used by private industries in 1998, saw their share grow to 21 percent by 2006.[17]

Although it was once thought that services were not subject to offshoring, there is evidence that service inputs are now being imported. Imported service inputs accounted for 1.4 percent of total intermediates used by private industries in 1998 and 1.7 percent in 2006. However, imported service inputs accounted for roughly 3 percent of all service inputs used by private industries, a percentage that stayed relatively steady from 1998 to 2006. Interestingly, the share of energy inputs that are imported appears to be growing: three percent of all energy inputs used by private industries were imported in 1998, and 8 percent were imported by 2006.[18] However, imported energy inputs are less than 0.4 percent of total intermediates used by private industries.

Looking at the imported intermediate data by industry reveals that the manufacturing sector consumed more than 60 percent of all imported intermediates used by

Chart 1. **Imported intermediate inputs' share of total intermediates, by type of input, private industries, 1998–2006**



SOURCE: Bureau of Economic Analysis.

private industries. For the manufacturing sector, the share of intermediate inputs that is accounted for by imports is significantly larger than it is for all private industries, and it grew at a faster rate. The BLS uses the term *sectoral intermediate inputs* to denote total intermediates less domestically manufactured inputs. Chart 2 shows imported intermediates' share of sectoral intermediate inputs, as well as the import share of total intermediates. The sectoral intermediate inputs for the BLS manufacturing sector are less than the total intermediates in the BEA annual input-output accounts because intermediates that are purchased from other firms within the U.S. manufacturing sector have been removed. Therefore, imports' share of sectoral intermediates is greater than imports' share of total intermediate inputs. The sectoral intermediate inputs for the manufacturing sector are 55 percent of the BEA total intermediates.

The data show that 24 percent of sectoral intermediates in manufacturing were imported in 1998; the percentage grew to almost 34 percent in 2006. Notice in chart 2 that, beginning in 2002, there has been a steady increase in the share of imported intermediates used by U.S. manufacturing firms relative to sectoral and total intermediates.[19] As observed for the private business sector, imported materials accounted for the majority of imported intermediate inputs. However, service inputs also were imported by the manufacturing sector. Imported services' share of sectoral intermediates in the manufacturing sector grew from 1.4 percent in 1998 to 2.1 percent in 2006, while imported energy's share grew slightly, from 0.1 percent to 0.3 percent, over the same period.

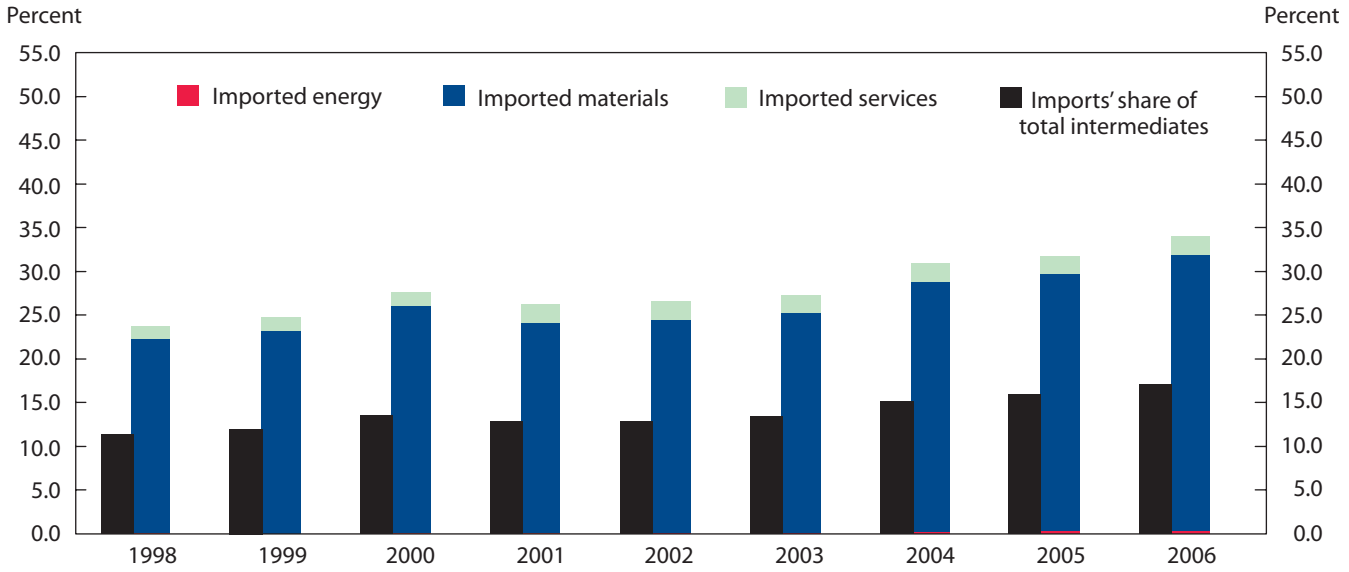
BLS multifactor productivity

Solow model of productivity. It is generally acknowledged that technical progress can best be captured with a total-factor productivity concept. The most common model of total-factor productivity is credited to Robert M. Solow. First proposed in 1957, the Solow residual model evaluates technical progress as the difference between the growth rate of output and the weighted aggregate of the growth rates of each factor of production. This measure of disembodied technological change evaluates the expansion of the production possibilities frontier without the addition of resources. Mathematically, given a production function $Y = f(X,t)$, the growth rate of total-factor productivity A can be written as

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \sum_i \left(\beta_i \frac{\Delta x_i}{x_i} \right), \qquad (1)$$

where Δ represents a time derivative, Y denotes real aggre-

Chart 2. **Imports' share of sectoral intermediate inputs and of total intermediates, by type of input, U.S. manufacturing, 1998–2006**



SOURCE: Bureau of Labor Statistics, Bureau of Economic Analysis.

gate output, X_i denotes the ith factor of production, and β_i represents the corresponding elasticity of output. This productivity growth model requires well-defined concepts of output and inputs that correspond to a specified production process. To construct measures of productivity, a discrete approximation for the time derivatives[20] must be made and cost-minimizing behavior is assumed in order to measure the β_i with cost shares.

BLS multifactor productivity for the private business sector. The BLS labor productivity measures for the private business sector compare output, measured as the real gross domestic product of all U.S. businesses, with hours worked by all U.S. workers who contribute to the production of that output. Real gross domestic product is measured by adding all exports and subtracting all imports from domestic final demand. Thus, imported intermediate inputs are excluded from the scope of the output measures, and as a result, the contribution of the labor hours worked overseas that produce the imported intermediate inputs also are absent from the analysis of U.S. productivity. The output measure used to construct the productivity measure for the private business sector removes the output of intermediate inputs produced and used within a sector, as well as all imported intermediate inputs and other domestic intermediate inputs produced outside the sector. Consequently, BLS multifactor productivity, A_{BLS}, contains only two factor inputs—labor (L) and capital services (K)—and can be written as

$$\frac{\Delta A_{\text{BLS}}}{A_{\text{BLS}}} = \frac{\Delta Y_{\text{BLS}}}{Y_{\text{BLS}}} - w_L \frac{\Delta L}{L} - w_K \frac{\Delta K}{K}, \qquad (2)$$

or

$$d\ln A_{\text{BLS}} = d\ln Y_{\text{BLS}} - w_L\, d\ln L - w_K\, d\ln K, \qquad (3)$$

where Y_{BLS} is BLS real private business sector output, $d\ln A_{\text{BLS}}$ denotes the difference in logarithms of A_{BLS} for successive years ($\ln A_{(\text{BLS},t)} - \ln A_{(\text{BLS},t-1)}$), and the weights for labor and capital, w_i, are the averages of each factor's nominal cost C_i relative to nominal output Y^N_{BLS} in two successive years, so that

$$w_{i=L,K} = \frac{1}{2}\left(\frac{C_{i,t}}{Y^N_{\text{BLS},t}} + \frac{C_{i,t-1}}{Y^N_{\text{BLS},t-1}}\right). \qquad (4)$$

Because of this design, it is impossible to observe the impact of offshoring intermediate inputs on production. To incorporate intermediate inputs into the model, a sectoral

output concept must be used.

Private business sector multifactor productivity adjusted to include imports. Sectoral output removes from the value of output only intermediate inputs that are produced elsewhere within the sector, to eliminate double counting. Intermediate inputs that are produced outside of the sector (that is, imported intermediates) remain in output.[21] To bring imported intermediate inputs inside the major-sector model framework requires not excluding them as a component of output and including them as a factor input to production. With imported intermediate inputs denoted as II, the production function becomes $Y_S = f(L, K, \text{II}, t)$ and multifactor productivity can be written as

$$d \ln A_s = d \ln Y_s - \theta w_L d \ln L - \theta w_K d \ln K - \sum_j \left[w_j \ d \ln \text{II}_j \right], \quad (5)$$

where the factor weights for imported intermediate inputs of energy (IE), materials (IM), and services (IS) are defined as

$$w_{(j=\text{IE,IM,IS})} = \frac{1}{2}\left(\frac{C_{j,t}}{Y^N_{S,t}} + \frac{C_{j,t-1}}{Y^N_{S,t-1}}, \right) \quad (6)$$

and an output adjustment ratio θ, used to correct the weights on labor and capital, is written as a two-period average:

$$\theta = \frac{1}{2}\left(\frac{Y^N_{\text{BLS},t}}{Y^N_{S,t}} + \frac{Y^N_{\text{BLS},t-1}}{Y^N_{S,t-1}} \right). \quad (7)$$

Algebraically working through the model yields an adjusted multifactor productivity measure that encompasses imported intermediate inputs in both the output and input indexes. Assuming that growth in sectoral output is a weighted average of growth in the BLS output measure and intermediate imports gives the multifactor productivity growth rate as a scalar of the existing BLS multifactor productivity growth rate:

$$d\ln A_s = \theta \ d\ln A_{\text{BLS}}. \quad (8)$$

Table 1 presents growth rates for the components of the multifactor productivity model for the private business sector.[22] Notice that imported intermediates grew faster than labor and capital in most years, except around the 2001 recession. The growth of imported intermediate inputs has an impact on the growth of sectoral output trends as well. Sectoral output grew somewhat faster than the published value-added output measure for all years except 2001 and 2002. The year-to-year growth rates of imported intermediates fluctuate quite a bit. Over the 1997–2006 period, energy and service imports grew faster than imported materials. However, because of the small share of all imports held by energy and service imports in comparison with imported materials, the growth in imported materials drove the growth in total imported intermediate inputs.

Using BEA estimates of imported intermediate inputs yields the adjustment scalar for the private business sector multifactor productivity measures. Table 2 shows the results of adjusting the published BLS multifactor productivity data. Notice that, by incorporating the imported intermediate inputs into the multifactor productivity framework, the annual growth in private business sector multifactor productivity is reduced by 0.1 to 0.2 percentage point in all but two of the years shown.

Substitution of imported intermediates for U.S. labor in the private business sector. The effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked are estimated with the Solow multifactor productivity equation. The growth in imported intermediate inputs, combined with both growth in capital inputs and technical change, directly influences labor productivity. Thus, labor productivity can be written as the sum of the intensity of each of the other input factors (increases in the factor's quantities relative to domestically employed labor):

$$d \ln Y_s - d \ln L = d \ln A_s + \theta w_K \left(d \ln K - d \ln L \right) + \sum_j w_j \left(d \ln \text{II}_j - d \ln L \right). \quad (9)$$

Chart 3 shows the contributions to private business sector labor productivity of the remaining nonlabor factor inputs. From 1998 through 2002, year-to-year growth in capital services accounted for the majority of labor productivity growth. Beginning in 2003, capital's contribution to labor productivity declined and was outpaced by multifactor productivity growth. Also, beginning in 2004, imported intermediate inputs contributed more to labor productivity growth than did capital growth. Again, the influence of imported material inputs dominated the contribution of all imported intermediate inputs.

The sectoral output approach reveals that, for the 1997–2006 period, approximately 14 percent (0.37/2.56) of labor productivity growth was attributable to growth in imported intermediate inputs, 11 percent (0.27/2.56) to materials, 3 percent (0.08/2.56) to services, and less than 0.5 percent (0.01/2.56) to energy. The following tabula-

Table 1. Growth of components of private business sector multifactor productivity, alternative output concepts, annual percent changes, 1997–2006

[Percent change from previous year]

Year	Original output	Sectoral output	Labor	Capital	Imported intermediates	Imported energy	Imported materials	Imported services
1998	4.9	5.3	2.3	6.3	10.7	3.8	10.9	10.3
1999	5.2	5.4	2.7	6.5	8.5	9.2	8.3	9.3
2000	3.9	4.4	1.0	6.3	9.6	11.2	9.5	9.7
2001	.5	.1	–1.4	4.6	–3.8	–1.9	–5.4	3.8
2002	1.5	1.4	–1.4	2.9	–.1	–6.5	–1.3	5.5
2003	3.1	3.1	–.3	2.3	3.1	3.4	4.4	–2.4
2004	4.3	4.9	1.5	2.3	11.8	27.3	10.3	16.4
2005	3.7	3.9	1.8	2.5	5.7	13.9	5.6	4.7
2006	3.2	3.4	2.6	2.7	4.9	2.8	4.7	6.8
Average annual percent change, 1997–2006	3.4	3.5	1.0	4.0	5.5	6.6	5.1	7.0

tion shows the contribution (average annual growth rates) of nonlabor inputs and multifactor productivity to labor productivity growth in the private business sector over that period:[23]

Factor	*Contribution to labor productivity growth (percent)*
Output per unit of labor (including imports)	2.56
Multifactor productivity (including imports)	1.31
Capital intensity	.88
Imported intermediates	.37
Imported materials	.27
Imported services	.08
Imported energy	.01

BLS multifactor productivity for the U.S. manufacturing sector. As mentioned earlier, BLS productivity measures for the manufacturing sector are constructed with the use of a sectoral output concept. Therefore, imported intermediates are within the productivity model framework. For the multifactor productivity measures, imported intermediate inputs are a component of measured output and intermediate inputs. To identify the impact of imported intermediates on manufacturing productivity, it is not necessary to adjust the measures to include imports; instead, the intermediates must be separated into domestic and imported components. This demarcation is achieved by using the BEA estimates of imported intermediates, which were provided to the BLS at the industry level of detail.

Table 3 presents the year-to-year growth rates and the average annual growth for the components of the manufacturing multifactor productivity model over the 1997–2006 period. Notice that in most years labor inputs declined and imported intermediates grew faster than capital and domestic nonmanufactured intermediate inputs. Prior to the 2001 recession, there was strong growth in capital services, imported intermediates, and domestic nonmanufactured intermediates. However, as the table shows, domestic nonmanufactured intermediates were affected by the recession sooner than imported intermediates were. Also, imported intermediates were able to rebound after the recession, whereas domestic nonmanufactured inputs shrank through 2004. Over the entire 1997–2006 period, labor and domestic nonmanufactured intermediates inputs declined, while capital services and imported intermediates grew.[24]

Table 4 compares the growth of domestic nonmanufactured intermediate inputs and imported intermediates by type of input. In general, imported intermediates showed stronger growth than domestic nonmanufactured inputs. It is interesting to note that domestic material inputs (excluding materials purchased from other manufacturing industries) declined in most years, while imported materials grew.

Table 2. Multifactor productivity growth for the private business sector, by alternative treatment of imports, annual percent changes, 1997–2006

[Percent change from previous year]

Year	Official BLS measure (excludes imported intermediate inputs)	Adjusted measure (includes imported intermediate inputs)	Difference (adjusted measure minus official measure)
1998	1.3	1.2	–.1
1999	1.3	1.2	–.1
2000	1.3	1.2	–.1
2001	.1	.1	.0
2002	1.7	1.5	–.2
2003	2.6	2.4	–.2
2004	2.5	2.3	–.2
2005	1.6	1.5	–.1
2006	.5	.5	.0
Average annual percent change, 1997–2006	1.4	1.3	–.1

Chart 4 presents the trends in constant-dollar factor input costs for the U.S. manufacturing sector. Note that labor represents the highest cost and was constant prior to the 2001 recession, when it declined together with falling employment in manufacturing. Energy and imported services represented a very small portion of the overall factor costs in manufacturing and were relatively constant over the 1997–2006 period. Interestingly, the cost of imported materials increased over the period, while the cost of domestic nonmanufactured materials declined. The factor costs of capital services and purchased domestic services increased somewhat.

Substitution of imported intermediates for U.S. labor in the manufacturing sector. In this subsection, the effects of imported intermediate inputs on labor productivity are estimated. The model used by the BLS to measure multifactor productivity for the U.S. manufacturing sector can be written as

$$d\ln A_G = d\ln Y_G - w_L\, d\ln L - w_K\, d\ln K - w_E\, d\ln E - w_M\, d\ln M - w_S\, d\ln S, \quad (10)$$

where Y_G is real sectoral output for the manufacturing sector; $d\ln A_G$ denotes the difference in logarithms of A_G for successive years ($\ln A_{(G,t)} - \ln A_{(G,t-1)}$); and the weights for labor, capital, energy, materials, and purchased business services, w_i, are the averages of each factor's nominal cost relative to nominal output Y_G^N in 2 successive years and are given by

$$w_{i=L,K,E,M,S} = \frac{1}{2}\left(\frac{C_{i,t}}{Y_{Gt}^N} + \frac{C_{i,t-1}}{Y_{G,t-1}^N}\right). \quad (11)$$

The growth in imported intermediate inputs, combined with growth in capital inputs, growth in domestic intermediate inputs, and technical change, directly influence labor productivity. Thus, labor productivity can be written as the sum of the intensity of each of the other input factors (increases in the factors' quantities relative to domestically employed labor):

$$d\ln Y_G - d\ln L = d\ln A_G + w_K\left(d\ln K - d\ln L\right) + \sum_j w_{\mathrm{DI}j}\left(d\ln \mathrm{DI}_j - d\ln L\right) + \sum_j w_{\mathrm{II}j}\left(d\ln \mathrm{II}_j - d\ln L\right). \quad (12)$$

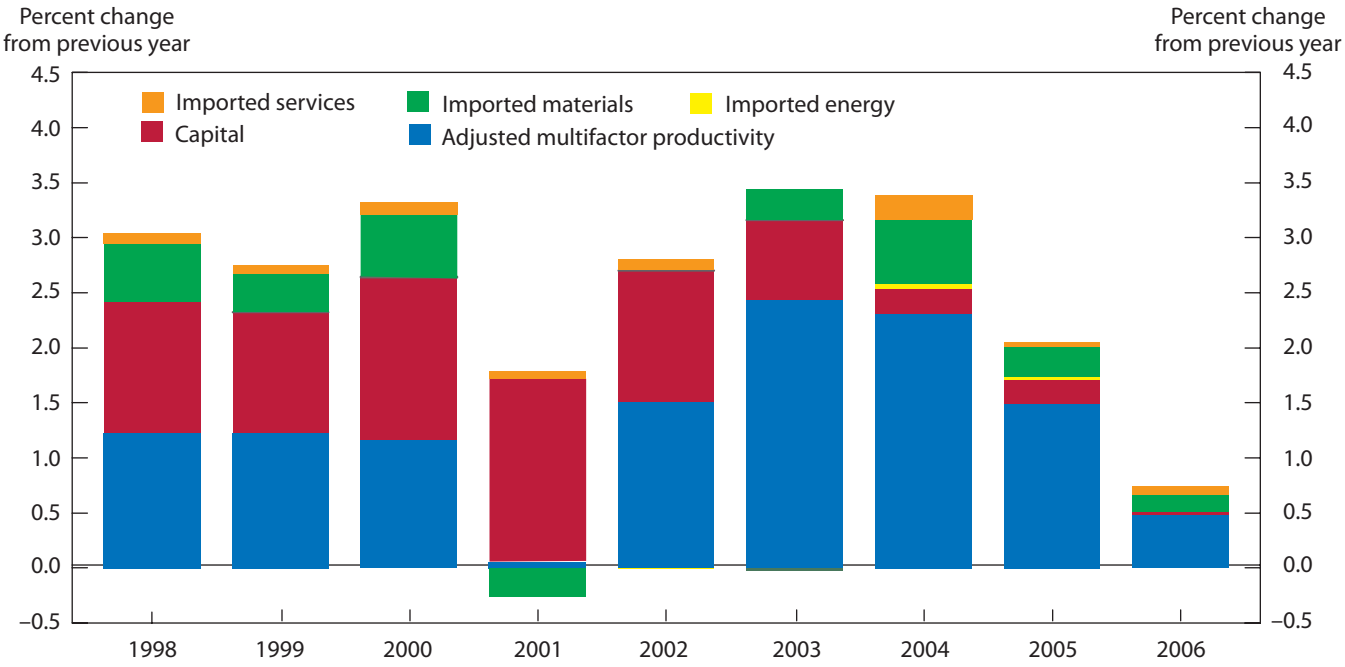
In the preceding equation, $w_{\mathrm{DI}j}$ denotes the weights on domestic intermediates $j = E,M,S$ and $w_{\mathrm{II}j}$ denotes the weights on imported intermediates $j = E,M,S$.

Chart 5 shows the contributions of nonlabor input factors to the year-to-year growth of manufacturing sector labor productivity. Notice that in most years multifactor productivity contributed the most to labor productivity growth. Notice also that growth in capital services contributed to labor productivity growth prior to 2004, but very little thereafter. Imported intermediate inputs made a relatively constant contribution to labor productivity growth in all years, with the exception of 2001. Over the period 1997–2006, multifactor productivity accounted for 45 percent (1.79/3.96) of productivity growth and imported intermediate inputs accounted for 23 percent (.92/3.96). The following tabulation shows the contributions of nonlabor factor inputs to the average annual growth of labor productivity in the manufacturing sector over the entire period from 1997 to 2006:

Factor	*Average annual growth (percent)*
Output per unit of labor	3.96
Multifactor productivity	1.79
Capital intensity	.64
Domestic intermediates	.65
Imported intermediates	.92
Imported materials	.80
Imported services	.10
Imported energy	.01

THIS ARTICLE DEVELOPS A FRAMEWORK for estimating the effects of imported intermediate inputs on U.S. major-sector labor productivity. The production model used to calculate the BLS private business sector multifac-

Chart 3. **Labor productivity growth, by contributing input factors, private business sector, annual percent changes, 1997–2006**



SOURCE: Bureau of Labor Statistics, Bureau of Economic Analysis (unpublished import data).

tor productivity measures is expanded to treat imported intermediate inputs as an input, rather than as a subtraction from output. Once the imported intermediate inputs are placed inside the framework, the Solow multifactor productivity equation is used to estimate the effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked. Separate effects are estimated for imported energy, materials, and services. The data show that imports increased as a share of total intermediates used by private industries, from 8 percent in 1998 to 10 percent in 2006. By including imported intermediates in the multifactor productivity model, the adjusted private business sector multifactor productivity is seen to have grown 0.1 percent to 0.2 percent per year more slowly than is indicated by the BLS published series. Also, the growth in imported intermediate inputs is estimated to have contributed 14 percent to the average annual growth of labor productivity for the private business sector from 1997 to 2006.

On the basis of the analysis presented here, it likely is not a good idea to alter the labor productivity model to incorporate imported intermediates, because then the trend could be considered biased to the extent that output would reflect the growth in imported intermediates while labor input would not include the corresponding hours worked overseas. However, as is attested to by the aforementioned 0.1-percent to 0.2-percent less growth than the BLS published series, the role of imported intermediates can be meaningfully assessed in the multifactor productivity model.

Because more than 60 percent of imported intermediate inputs purchased by private industries are used by the manufacturing sector, the role of imported intermediates in the U.S. manufacturing sector is also evaluated. The BLS methods for constructing manufacturing multifactor productivity include intermediates in the model framework. Therefore, the imported components are isolated to assess their impact on labor productivity. The data reveal that, over the 1998–2006 period, imported intermediate inputs grew as a share of total intermediate inputs. In addition, labor inputs and domestic nonmanufactured inputs declined over the entire period while capital services and imported intermediates grew. Finally, the analysis shows that growth in imported intermediate inputs contributed 23 percent to the average annual growth in labor productivity in the manufacturing sector.

Questions have been raised concerning whether the quantity of imported materials is measured accurately. The issue is that foreign imports may provide input of the

Table 3. Multifactor productivity and components in the U.S. manufacturing sector, annual percent changes, 1997–2006

[Percent change from previous year]

Year	Sectoral output	Labor	Capital	Domestic intermediates	Imported intermediates	Multifactor productivity
1998	5.2	–0.2	5.0	2.3	9.6	2.3
1999	3.8	–.7	4.1	4.2	7.1	.8
2000	2.7	–1.3	3.1	–4.1	5.5	3.5
2001	–5.1	–6.5	1.5	–3.0	–4.9	–1.3
2002	–.7	–7.1	.6	–4.4	–2.1	3.7
2003	1.0	–4.9	.0	–1.3	2.6	2.8
2004	1.7	–.5	–.6	–5.2	8.7	2.6
2005	3.7	–1.1	.0	7.7	4.9	.4
2006	1.8	.6	.5	–2.0	4.3	1.6
Average annual percent change, 1997–2006	1.5	–2.4	1.6	–.7	3.9	1.8

NOTE: Combined intermediates are constructed as a weighted aggregate of energy, materials, and purchased services.

Table 4. Comparison of imported and domestic intermediate inputs, by type of input, U.S. manufacturing sector, annual percent changes, 1997–2006

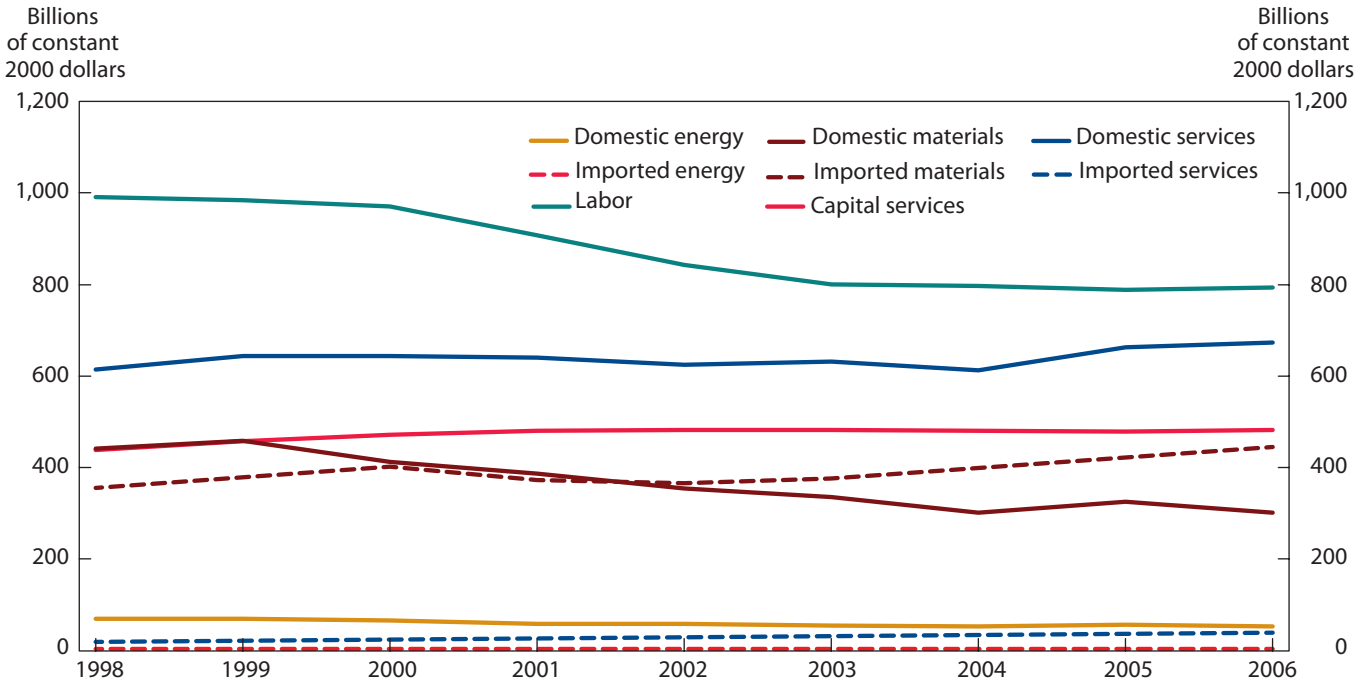
[Percent change from previous year]

Year	Total intermediates		Energy		Materials		Services	
	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
1998	2.3	9.6	–2.5	–7.8	1.9	9.7	3.0	8.5
1999	4.2	7.1	.1	.4	3.8	6.6	4.9	15.8
2000	–4.1	5.5	–5.0	–11.1	–10.1	5.9	–.1	1.5
2001	–3.0	–4.9	–9.5	–7.0	–6.1	–7.3	–.5	28.5
2002	–4.4	–2.1	–1.5	–1.2	–8.4	–2.1	–2.5	–1.8
2003	–1.3	2.6	–6.1	13.0	–4.9	3.2	1.1	–4.2
2004	–5.2	8.7	–2.2	35.1	–10.0	8.1	–2.9	13.9
2005	7.7	4.9	8.1	25.1	7.4	4.6	7.9	6.4
2006	–2.0	4.3	–6.8	10.7	–7.4	3.9	1.7	8.2
Average annual percent change, 1997–2006	–.7	3.9	–2.9	5.3	–3.9	3.5	1.4	8.1

NOTE: Combined intermediates are constructed as a weighted aggregate of energy, materials, and purchased services.

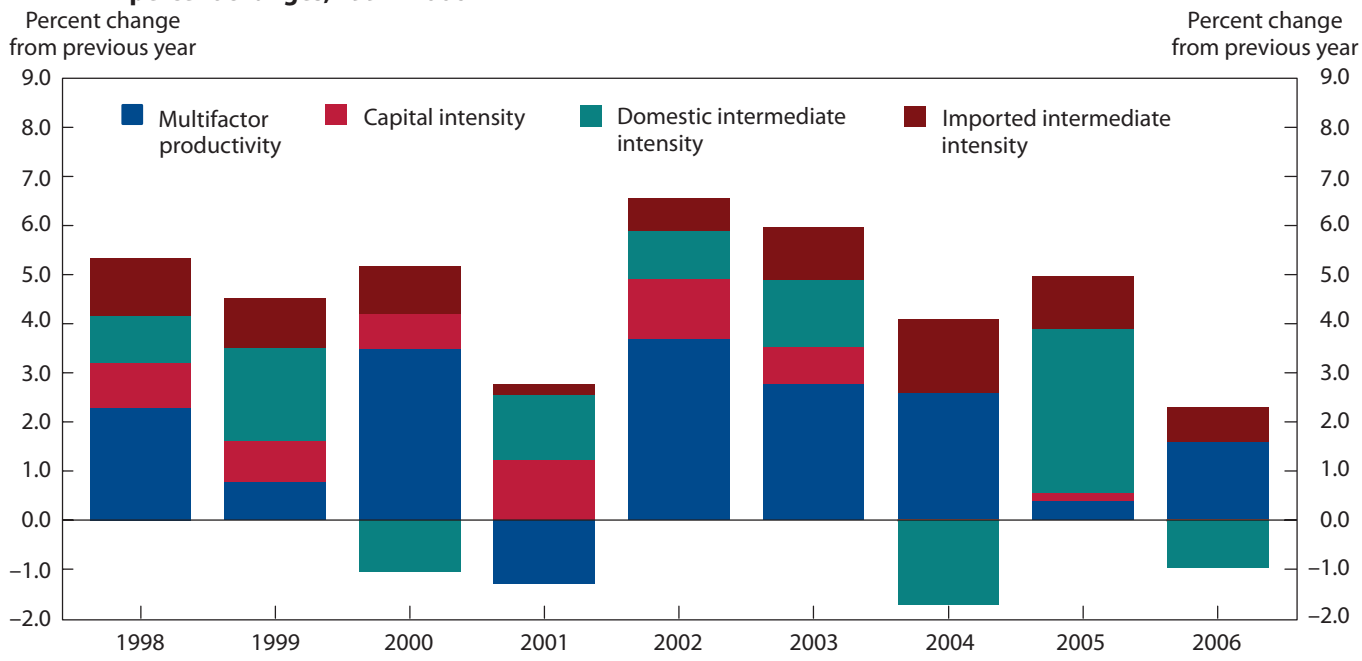
same quality at a lower price than domestic products and the advantage of substituting foreign for domestic inputs may not be reflected in the productivity statistics. Prices of imports enter the BLS business sector productivity measures when they are removed from real GDP by the BEA. Therefore, the impact of any possible inaccuracy in the measurement of import prices on the BLS business sector productivity measures would be weighted by the relative importance of imported intermediate inputs in measured business sector output, which has grown from 8 percent in 1998 to almost 11 percent in 2006. Prices of imports enter the BLS manufacturing sector multifactor productivity model when imports are included in the construction of purchased intermediate inputs. Thus, in the manufacturing sector, the impact of any possible inaccuracy in the measurement of import prices on the BLS multifactor productivity measures would be weighted by the relative importance of imports in measured intermediate inputs in that sector: 12 percent to 18 percent. Research is being carried out on this topic[25] both within and outside the statistical agencies, but economic analysis has not reached a definitive conclusion concerning its importance. □

Chart 4. **Input costs for the manufacturing sector, by type, 1998–2006**



SOURCE: Bureau of Labor Statistics, Bureau of Economic Analysis (unpublished import data).

Chart 5. **Labor productivity growth, by contributing nonlabor input factors, manufacturing sector, annual percent changes, 1997–2006**



SOURCE: Bureau of Labor Statistics, Bureau of Economic Analysis (unpublished import data).

Notes

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[1] Robert M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, August 1957, pp. 312–20.

[2] Annual input-output tables, as well as data on imported intermediate inputs, from the Bureau of Economic Analysis (BEA) are used in the analysis presented. (See Robert E. Yuskavage, Erich Strassner, and Gabriel W. Medeiros, "Domestic Outsourcing and Imported Inputs in the U.S. Economy: Insights from Integrated Economic Accounts," paper prepared for the World Congress on National Accounts and Economic Performance (Arlington, VA, Bureau of Economic Analysis, May 15, 2008).

[3] Allan H. Young and Helen Stone Tice, "An Introduction to National Economic Accounting," *Survey of Current Business*, March 1985, pp. 59–76.

[4] The gross product of general government is the sum of government expenditures on compensation of general government employees and the general government consumption of fixed capital, which measures the services of general government fixed assets. Government expenditures on goods and services purchased from the private sector are not excluded from private business sector output. The gross product of private households is the compensation of paid employees of private households; the gross product of nonprofit institutions serving individuals is the compensation paid to employees of those institutions.

[5] This value is measured as the sum of the consumption of fixed capital, indirect business taxes, and interest paid.

[6] BLS data in this article originate in the multifactor productivity program and cover the private business sector, which differs from the business sector covered by the BLS quarterly labor productivity program in that the former excludes government enterprises. In addition, the multifactor productivity measures are available only on an annual basis.

[7] The Current Employment Statistics (CES) survey is an establishment survey whose sample is benchmarked annually to levels based on administrative records of employees covered by State unemployment insurance tax records. Data on employee hours from establishments provide consistency with output data from industries and thus are well suited to producing industry-level measures. CES data on employment and average weekly hours paid for production workers in goods-producing industries and for nonsupervisory workers in service-providing industries are the building blocks of labor input.

[8] Information from the BLS National Compensation Survey program is used to construct the ratio of hours worked to hours paid. Prior to 2000, the annual Hours at Work Survey was used.

[9] In August 2004, the BLS introduced this new method of constructing estimates of hours for nonproduction and supervisory workers; see Lucy P. Eldridge, Marilyn E. Manser, and Phyllis F. Otto, "Alternative measures of supervisory employee hours and productivity growth," *Monthly Labor Review*, April 2004, pp. 9–28.

[10] Employment counts for employees in agricultural services, forestry, and fishing are reported from the BLS QCEW program and are based on administrative records from the unemployment insurance system.

[11] Additional information concerning data sources and methods of measuring labor composition can be found at **www.bls.gov/mfp/mprlabor.pdf** and in *Labor Composition and U.S. Productivity Growth, 1948–90*, Bulletin 2426 (Bureau of Labor Statistics, December 1993).

[12] The BLS is investigating the possibility of constructing labor composition estimates for the manufacturing sector productivity measures.

[13] See "Multifactor Productivity Trends, 2007," news release 09–0302 (Bureau of Labor Statistics, March 25, 2009).

[14] A nonprofit adjustment is made to intermediate inputs, but not to imported intermediates, because it is doubtful that nonprofits use a significant amount of imported intermediates. Note, however, that, absent a nonprofit adjustment to imported intermediates, the importance of imports may be slightly overstated.

[15] Erich H. Strassner, Robert E. Yuskavage, and Jennifer Lee, "Imported Inputs and Industry Contributions to Economic Growth: An Assessment of Alternative Approaches," paper presented at the Conference on Measurement Issues Arising from the Growth of Globalization, Washington, DC, Nov. 6–7, 2009. This study uses International Transaction Account data from the BEA to assess the import comparability assumption. The authors find that real imported materials may be understated in the annual input-output accounts. However, they indicate that the assumption provides reasonable results at the aggregate level. In another paper presented at the same conference ("Evaluating Estimates of Materials Offshoring from U.S. Manufacturing"), Robert C. Feenstra and J. Bradford Jensen use an alternative method for allocating imported input across industries to derive imported intermediates. Comparing the results with the BEA import matrix that uses the comparability assumption, Feenstra and Jensen find differences between the two approaches and identify cells in the input-output table in which the differences are greatest. Unfortunately, data limitations prevent them from resolving those differences.

[16] Notes about the imported intermediate input data are from BEA documentation that accompanied the data.

[17] Imported materials inputs include crude petroleum as a raw material for the refining and coal products industry. The increase in crude petroleum prices over the 1998–2006 period could be responsible for the increase in imported materials' share of intermediate inputs used by private industries and for the increase in imported materials' share of intermediate inputs in the manufacturing sector.

[18] Crude oil is classified as a nonenergy material input to U.S. refineries, rather than an energy input.

[19] In 2006, total materials imported by the petroleum industry accounted for 34 percent of material imports by the manufacturing sector. Over the 1997–2006 period, the price of imported intermediates for the petroleum industry grew 14 percent, compared with the 4-percent average growth of prices in the manufacturing sector as a whole.

[20] W. Erwin Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, vol. 4, 1976, pp. 15–145.

[21] Evsey Domar, "On the Measurement of Technological Change," *Economic Journal*, vol. 71, 1961, pp. 709–29.

[22] The time series does not cover the business cycles sufficiently to divide the data into subperiods that would allow a meaningful analy-

sis. A categorization of the data into subperiods of 1997–2000 and 2001–2006, as well as 1997–2002 and 2003–2006, and a comparison of results revealed a high sensitivity to the years into which the data were divided. Accordingly, no subperiod analysis is presented in this article.

[23] Note that because output has been expanded to include imports, labor productivity growth is 2.6 percent per year, rather than 2.4 percent per year.

[24] Christopher Kurz and Paul Lengermann, "Outsourcing and U.S. Economic Growth: The Role of Imported Intermediates," paper presented at the 2008 World Congress on National Accounts, May 12–17, 2008, Washington, DC, construct a gross output productivity measure in order to keep U.S. manufactured intermediates in the model. The Kurz-Lengermann model allows an analysis of the shift from domestic to imported intermediate inputs.

[25] See, for example, papers presented at the Conference on Measurement Issues Arising from the Growth of Globalization, sponsored by the Upjohn Institute, Washington, DC, November 6–7, 2009.