Effects of Imported Intermediate Inputs on Productivity*

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There is significant interest in determining the effects of off-shoring on U.S. economic performance. Off-shoring, or off-shore outsourcing, is the substitution of imported intermediate inputs for domestic labor inputs in production. It is difficult to assess the effects of imported intermediate inputs on the BLS private business sector productivity measures because these inputs do not enter the measurement framework. The BLS labor productivity measures compare output, measured as the real gross domestic product of U.S. businesses, to hours worked by all U.S. workers who contribute to the production of this 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 labor hours worked overseas to produce the imported intermediate inputs are also absent from the analysis of U.S. productivity. To introduce imported intermediate inputs into the model of U.S. productivity, it is necessary that they appear as both a component of output and a component of factor inputs.

We develop 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 multifactor productivity (MFP) measures is expanded to treat imported intermediate inputs as an input, rather than as a subtraction from output. Once the imported intermediate inputs are inside the framework, we use the Solow MFP equation to estimate the effects on labor productivity of substitution between imported intermediate inputs and U.S. hours worked.[1] Separate effects are estimated for imported energy, materials and services.[2] The data show that imports have increased as a share of total intermediates used by private industries from 8 percent in 1997 to 10 percent in 2006. By including imported intermediates in the MFP model, we find that private business sector multifactor productivity would grow 0.1-0.2 percent

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[1] Solow, Robert M. "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics,* 39(1957), pp. 312-320.

[2] We implement the framework using BEA annual input-output tables, as well as data on imported intermediate inputs provided by BEA. See Yuskavage, R., Strassner, E., and Medeiros, G. (2008). "Outsourcing and Imported Inputs in the US Economy: Insights from Integrated Economic Accounts." Bureau of Economic Analysis, paper prepared for the World Congress on National Accounts and Economic Performance.

per year slower than the BLS published series. Also, we estimate that the growth in imported intermediate inputs contributed 14 percent to the average annual growth of labor productivity for the private business sector from 1997-2006.

Because over 60 percent of imported intermediate inputs purchased by private industries are used by the manufacturing sector, we also evaluate the role of imported intermediates in the U.S. manufacturing sector. The BLS methods for constructing manufacturing multifactor productivity include intermediates in the model framework. Therefore, we isolate the imported components to assess their impact on labor productivity. The data reveal that over the 1997-2006 period, imported intermediate inputs have grown as a share of total intermediate inputs. We find that labor inputs and domestic nonmanufactured inputs are declining over the entire period, while capital services and imported intermediates show growth. In addition, we estimate that growth in imported intermediate inputs contributed 23 percent to the average annual growth in labor productivity in the manufacturing sector.

The study also addresses the difficulties surrounding the deflation of the imported intermediate inputs, since the coverage of IPP price indexes is sparse. We assess the impact on productivity growth of possible mis-measured prices of imported intermediates.

Data Sources

Output

Real output measures used by BLS to construct major sector productivity statistics are produced by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The most widely known measure of aggregate output for the U.S. economy is gross domestic product (GDP). GDP is the sum of (1) personal consumption expenditures, (2) gross private domestic investment, (3) government consumption expenditures and gross investment, (4) exports of goods and services, less (5) imports of goods and services. BEA constructs nominal output for detailed components of GDP from various data sources, converts them to real measures and then aggregates them to calculate GDP.

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

[3] Young, Allan H. 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 these institutions.

Ideally, BLS productivity statistics would measure productivity for the U.S. economy at the most aggregate level of domestic output, GDP. However, the BLS must exclude several activities from aggregate output in order to remove potential sources of bias specific to productivity measurement. The real gross products of general government, of private households, and of nonprofit institutions are estimated primarily using data on labor compensation. The 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 non-market components of GDP, including them in measures of aggregate productivity for the economy would bias labor productivity trends toward zero.

The BLS private 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 can be developed. To measure multifactor productivity, BLS must further restrict output to the U.S. private business sector, excluding the output of government enterprises. Estimates of the appropriate weights for labor and capital in government enterprises cannot be made 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, BLS measures output for productivity statistics differently. Output in manufacturing sector is the deflated value of production shipped to purchasers outside of the domestic industry, not just production for final users as is used for the major sector multifactor productivity indexes. The manufacturing multifactor productivity indexes are based on sectoral output—sales to final demand plus the intermediate goods sent to other industries. Sectoral output is defined as gross output excluding intra-industry transactions. This measure defines output as deliveries to consumers outside the sector in an effort to avoid the problem of double-counting that occurs when one establishment provides materials used by other establishments in the same industry.

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 hours actually worked measure is based on the sources and methods used to measure quarterly business sector labor productivity. The BLS labor composition index estimates the effects that shifts in age, education, and gender have on labor input growth and multifactor productivity growth.

[5] This value is measured as the sum of consumption of fixed capital, indirect business taxes, and interest paid.
[6] Data in this paper originates in the multifactor productivity program, whereas methods for labor input are from the same source, coverage differs from BLS quarterly labor productivity measures for business sector. MFP measures also differ, in that they are available only on an annual basis and exclude government enterprises from sectoral coverage, Private business sector measures incorporate labor composition and capital inputs; manufacturing sector measures differ from private business sector measures, in that they do not account for labor composition, but they do account for more detailed inputs of energy, materials, and business services.

Labor input is based on a jobs concept. The CES is the primary source of data used to construct hours for the BLS productivity measures.[7] The CES average weekly hours paid data are adjusted to an hours-at-work concept using a ratio of hours-worked to hours-paid.[8] 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]

The MFP labor composition measure estimates the number of hours worked by each type of worker based on CPS data. 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 hour's growth rates multiplied by the labor cost shares gives the growth in adjusted labor input. Subtracting this from the growth in total (un-weighted) hours yields the growth in labor composition.[11]

Labor input for the U.S. manufacturing sector is constructed using the same methods, except that no adjustment is made for labor composition (age, education, and gender of the work force).

Capital Inputs

Capital inputs for rivate business and manufacturing multifactor productivity measures are similar, except for the fact that capital inputs for manufacturing include intermediate inputs. Capital input measures the services derived from the stock of physical assets and software. The assets included are fixed business equipment, structures, inventories, and land. Financial assets are excluded from capital input measures, as are owner-occupied residential structures. The aggregate capital input measures are obtained by Tornqvist aggregation of the capital stocks for each asset type within each of 60 NAICS industry groupings using estimated rental prices for each asset type. Rental prices reflect the nominal rates of return and rates of economic depreciation and

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[7] Labor input measures for productivity are based primarily on establishment data. The CES sample is benchmarked annually to levels based on administrative records of employees covered by state unemployment insurance tax records. Both output and hours data are are based on data collected from establishments. In addition, hours data from establishments provide consistent reporting and coding on industries and thus are well-suited for producing industry-level measures. CES data on employment and average weekly hours-paid for production workers in goods-producing industries and nonsupervisory workers in service-producing industries are the building block of labor input..

[8] The hours worked to hours paid ratio is constructed using information from the National Compensation Survey program; prior to 2000, the annual Hours at Work Survey was used.

[9] In August 2004, BLS introduced this new method of constructing estimates of hours for nonproduction and supervisory workers; see Eldridge, Lucy P., Marilyn E. Manser and Phyllis F. Otto. 2004. "Alternative Measures of Supervisory Employee Hours and Productivity Growth," *Monthly Labor Review*, Vol. 127, No.4 (April), pp. 9-28.

[10] Employment counts for employees in agricultural services, forestry and fishing are reported from the BLS's 202 program, 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 BLS Bulletin 2426 Labor Composition and U. S. Productivity Growth, 1948-90 (December 1993).

revaluation for the specific asset types. Rental prices are adjusted for the effects of taxes. Data on investments in physical assets are obtained from BEA.[12]

Capital input for the manufacturing sector is measured as it is for the major sector multifactor productivity indexes; rental prices of capital are computed for 18 3-digit NAICS industries within manufacturing.

Energy, Materials and Purchased Business Services

In the manufacturing sector, inputs include intermediate inputs, as well as capital and labor inputs. Intermediate inputs (energy, materials, and purchased business services) are obtained from BEA's annual input-output tables. Tornqvist indexes of each of these three input classes are derived at the 3-digit NAICS level and then aggregated to total manufacturing. At this more detailed level, materials inputs are adjusted to exclude transactions between establishments within the same sector to maintain consistency with the sectoral output concept. [13]

Nominal values of materials, fuels, and electricity and quantities of electricity consumed by each industry are obtained from economic censuses and annual surveys of the Bureau of the Census, U.S. Department of Commerce. Purchased business services are estimated using benchmark input-output tables and other annual industry data from the Bureau of Economic Analysis, U.S. Department of Commerce. Prices of many service inputs are available from the BLS price program, from the National Income and Product Accounts.

Imported Intermediate Inputs

BEA produces import matrices as supplementary tables to the annual input-output (I-O) accounts. For each commodity, the import-matrix table shows the value of imports of that same 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 I-O accounts. The imputed-import values are based on the assumption that each industry uses imports of a commodity in the same proportion as 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.) The implication of using this assumption to calculate the estimates is that all variability of import usage across industries reflects the assumption and is not based on industry-specific information.

The data used in this study underlie the estimates presented in the paper "Domestic Outsourcing and Imported Inputs in the U.S. Economy: Insights from Integrated Economic Accounts." The BEA provided these detailed statistics to BLS for this research study. These data are not included in the published tables because their quality is significantly less than that of the higher level aggregates in which they are included. Compared to these aggregates, the more detailed

[12] See Bureau of Labor Statistics [2009], Multifactor Productivity Trends, 2007, News Release, U.S. Department of Labor, #09-0302 (March 25).

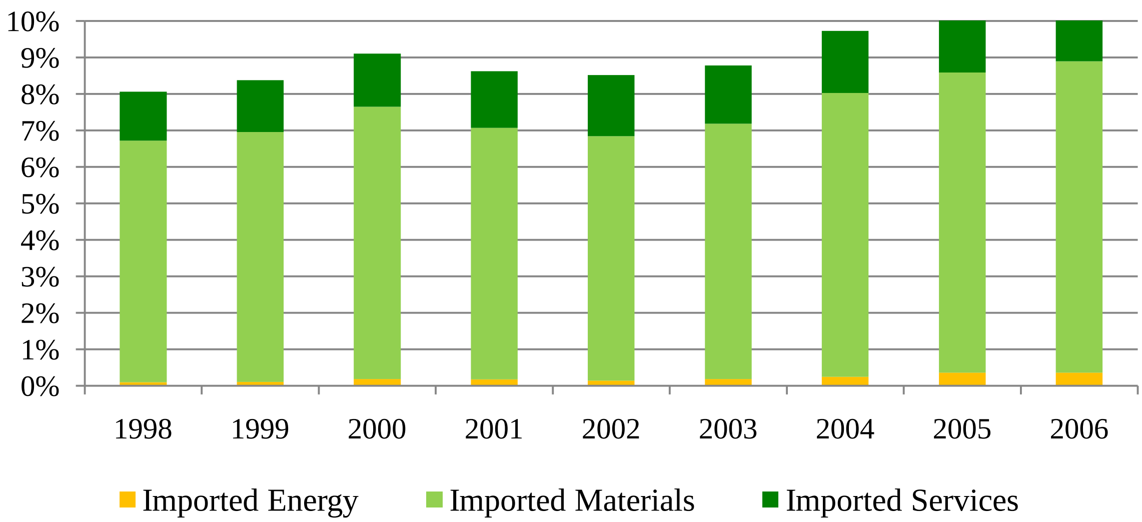
[13] A nonprofit adjustment is made to intermediate inputs, but not to imported intermediates because it is doubtful that nonprofits are using a significant amount of imported intermediates. By not making a nonprofit adjustment to imported intermediates, we may overstate the importance of imports slightly.

statistics are more likely to be either based on judgmental trends, on trends in the higher level aggregate, or on less reliable source data.[14]

Using this data set we can observe trends in the shares of imported intermediate inputs. The share of intermediate inputs that is accounted for by imports has grown from 7.6 percent in 1998 to almost 10 percent in 2006. Notice in Figure 1 that there was a decline in the share of imports used by private industries around the 2001 recession; however beginning in 2002, there has been a steady increase. Purchased materials account for the majority of imported intermediates, and have been growing steadily, again with a slight dip around the 2001 recession. Imported material inputs accounted for 15 percent of total materials used by private industries in 1998 and grew to 21 percent by 2006. Imported materials inputs include crude petroleum as a raw material for the refining and coal products industry. The increase in crude petroleum prices over this time period could be responsible for the increase in imported materials share of intermediate inputs used by private industries, and more significantly the increase in imported materials share of intermediate inputs in the manufacturing sector.

Although it was once thought that services were not off-shorable, we are seeing evidence that service inputs are also 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 services inputs account for roughly 3 percent of all service inputs used by private industries, and this has stayed relatively steady from 1998 to 2006. Interestingly, there has been growth in the share of energy inputs that are imported; 4 percent of all energy inputs used by private industries were imported in 1998 and we see 12 percent imported by 2006. However, imported energy inputs are less than 0.4 percent of total intermediates used by the private industries.

Figure 1. Imported Intermediate Inputs Share of Total Intermediates, by type of input, private industries, 1998-2006



Source: Bureau of Economic Analysis

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

Solow Model of Productivity

It is generally acknowledged that technical progress can best be captured by a total factor productivity concept. The most common model of total factor productivity is credited to Solow (1957). The Solow residual model evaluates technical progress as the difference between the time derivative of production and the weighted aggregate of the time derivatives for all factors of production. This measure of disembodied technological change evaluates the ability to expand the production possibilities frontier without the addition of resources. Given a production function $Y = f(X, t)$, the growth rate of total factor productivity, A, can be written as:

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

where Δ represents a time derivative , Y denotes real aggregate output, X_i denotes the i^{th} factor of production, and β_i represents the corresponding production elasticity. This productivity growth model requires well defined concepts of output and inputs that correspond to a specified production process. To construct measures of productivity, we must make a discrete approximation for the time derivatives[15] and we must assume cost minimizing behavior in order to measure the β_i with cost shares.

BLS Multifactor Productivity for the Private Business Sector

As mentioned above, GDP is the starting point for measures of output for the BLS private business sector productivity measures. Therefore, the private business sector productivity measures, in effect, use a value added approach to measuring output. Measures of final demand remove 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. Thus, BLS multifactor productivity, A_{BLS}, contains only two factor inputs, labor (L) and capital services (K), and can be written as:

$$\frac{\Delta A_{BLS}}{A_{BLS}} = \frac{\Delta Y_{BLS}}{Y_{BLS}} - w_L \frac{\Delta L}{L} - w_K \frac{\Delta K}{K} \tag{2}$$

or

$$d \ln A_{BLS} = d \ln Y_{BLS} - w_L \, d \ln L - w_K \, d \ln K \tag{3}$$

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

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15 Diewert, W.E. "Exact and Superlative Index Numbers," *Journal of Econometrics*, 4(1976), pp15-145.

$$w_{i=L,K} \quad = \quad 1/2 * \left(\frac{C_{i,t}}{Y^N_{BLS,t}} + \frac{C_{i,t-1}}{Y^N_{BLS,t-1}} \right) \tag{4}$$

Because of this design it is impossible to observe the impact of off-shoring intermediate inputs on production. To incorporate intermediate inputs into the model, we need to use a sectoral output concept.

Private Business Sector Multifactor Productivity Adjusted to Include Imports

Sectoral output removes from the value of output only those intermediate inputs that are produced elsewhere within the sector to eliminate double counting. Intermediate inputs, which are produced outside of the sector, (i.e. imported intermediates) remain in output.[16] To bring imported intermediate inputs inside the major sector model framework, we must not exclude them as a component of output, and they must be included as a factor input to production. Denoting the imported intermediate inputs as II, the production function becomes $Y_S = f\,(L, K, II, t)$. We can define sectoral output as $Y_S = Y_{BLS} + II$. Using this output concept, we can write multifactor productivity as:

$$d\ln A_S \;=\; d\ln Y_S - \theta\, w_L\, d\ln L - \theta\, w_K\, d\ln K - \sum_j \left(w_j\, d\ln II_j \right) \tag{5}$$

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

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

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

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

Algebraically working through the model, we can derive an adjusted MFP measure that encompasses imported intermediate inputs in both the output and input indexes. This resulting MFP growth rate is a scalar of the existing BLS MFP growth:

$$d\ln A_S \;=\; \theta \;\; d\ln A_{BLS} \tag{8}$$

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[16] Domar. "On the Measurement of Technological Change," *The Economic Journal,* 71(1961), pp. 709-729.

Table 1. Growth of Components of Private Business Sector Multifactor Productivity, Alternative Output Concepts, 1997 to 2006

	Original Output	Sectoral Output	Labor	Capital	Imported Intermediates	Imported Energy	Imported Materials	Imported Services
annual growth from previous year								
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	0.5%	0.1%	-1.4%	4.6%	-3.8%	-1.9%	-5.4%	3.8%
2002	1.5%	1.4%	-1.4%	2.9%	-0.1%	-6.5%	-1.3%	5.5%
2003	3.1%	3.1%	-0.3%	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 growth								
1997-2006	3.4%	3.5%	1.0%	4.0%	5.5%	6.6%	5.1%	7.0%

Table 1 presents growth rates for the components of the multifactor productivity model for the private business sector.[17] Notice that the imported intermediates grow 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, which grow somewhat faster than the published output measure for all years except 2001 and 2002. The year-to-year growth rates of the imported intermediates fluctuate quite a bit. Over the 1997-2006 period, energy and service imports tend to grow faster than imported materials. However due to their small size, imported materials growth is driving the growth in total imported intermediate inputs.

Using BEA estimates of imported intermediate inputs, we derive the adjustment scalar for the private business sector MFP measures. Table 2 shows the results of adjusting the published BLS MFP data. Notice that by incorporating the imported intermediate inputs into the MFP framework, the annual growth in private business sector MFP would be reduced by 0.1 - 0.2 percentage points.

[17] The time series does not cover the business cycles sufficiently to divide that data into sub-periods that would allow a meaningful analysis of the data. We constructed sub-periods of 1997-2000 and 2001-2006, as well as, 1997-2002 and 2003-2006. The comparison of results between period 1 and period 2 was very sensitive to the year that the data was divided. Therefore, we will not present sub-period analysis in this paper.

Table 2. Multifactor Productivity Growth for the Private Business Sector, by alternative treatment of imports, 1997 to 2006

	Excluding Imported Intermediate Inputs: BLS published data	Including Imported Intermediate Inputs	Difference
annual growth from previous year			
1997	0.94%	0.87%	-0.07%
1998	1.30%	1.20%	-0.10%
1999	1.29%	1.19%	-0.10%
2000	1.28%	1.18%	-0.10%
2001	0.11%	0.10%	-0.01%
2002	1.65%	1.53%	-0.13%
2003	2.63%	2.43%	-0.20%
2004	2.49%	2.28%	-0.20%
2005	1.63%	1.48%	-0.15%
2006	0.54%	0.49%	-0.05%
annual average growth			
1997-2006	1.43%	1.32%	-0.12%

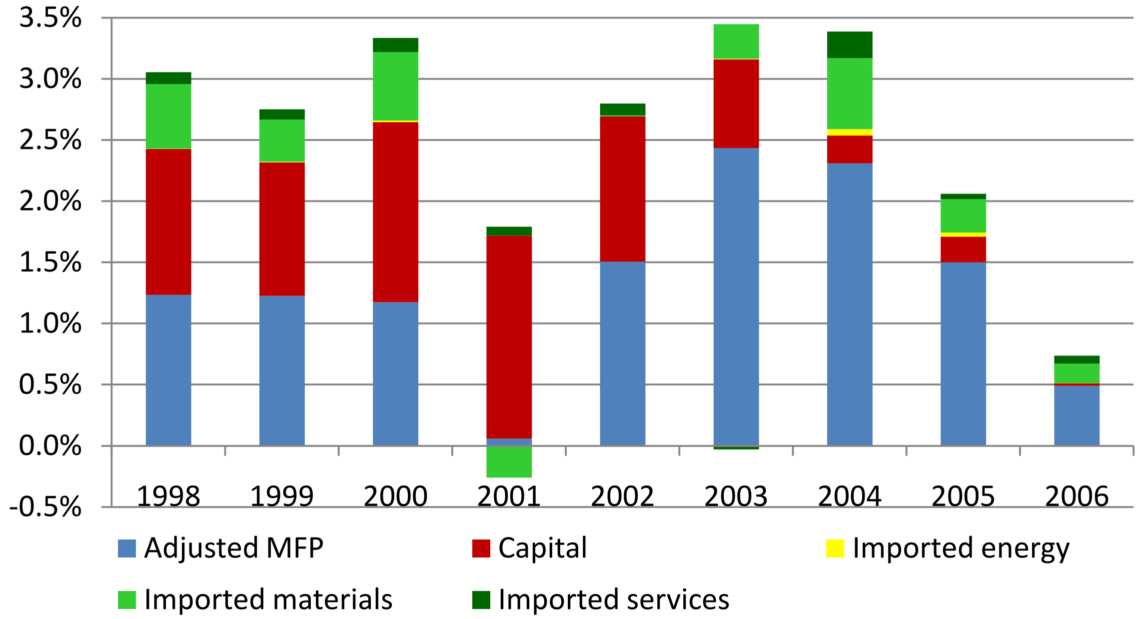
Substitution of Imported Intermediates for U.S. Labor

Using the Solow MFP equation, we estimate the effects of substitution between imported intermediate inputs and U.S. hours worked on labor productivity. The growth in imported intermediate inputs, combined with growth in capital inputs and technical change, directly influence labor productivity. Thus, labor productivity can be written as the sum the intensity of each of the other input factors (increases in the factor's quantities relative to domestically employed labor):

$$d\ln Y_s - d\ln L = d\ln A_s + \theta w_K \left(d\ln K - d\ln L \right) + \sum_j \left(w_j \left(d\ln II_j - d\ln L \right) \right) \quad (9)$$

Figure 2 shows the contributions to private business sector labor productivity of the remaining non-labor factor inputs. From 1997 through 2002, growth in capital services is contributing to the majority of labor productivity growth. Beginning in 2003, capital's contribution to labor productivity declines and is outpaced by multifactor productivity growth. Also, beginning in 2004 the contribution of imported intermediate inputs contributes more to labor productivity growth than capital growth. Again, we note that the influence of imported material inputs dominates the contribution of all imported intermediate inputs.

Figure 2. Labor Productivity Growth by Contributing Input Factors, Private Business Sector, 1997-2006
(annual growth rates)



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

The published BLS measures of major sector productivity exclude imported intermediate inputs in the construction of output. In table 3, we observe that if imported intermediates are included in the output measure, labor productivity would grow at an annual rate of 2.6 percent, rather than 2.4 percent. For the 1997-2006 period, approximately 14 percent of labor productivity growth can be attributed to growth in imported intermediate inputs (11 percent to materials, 3 percent to services, and less than .5 percent to energy).

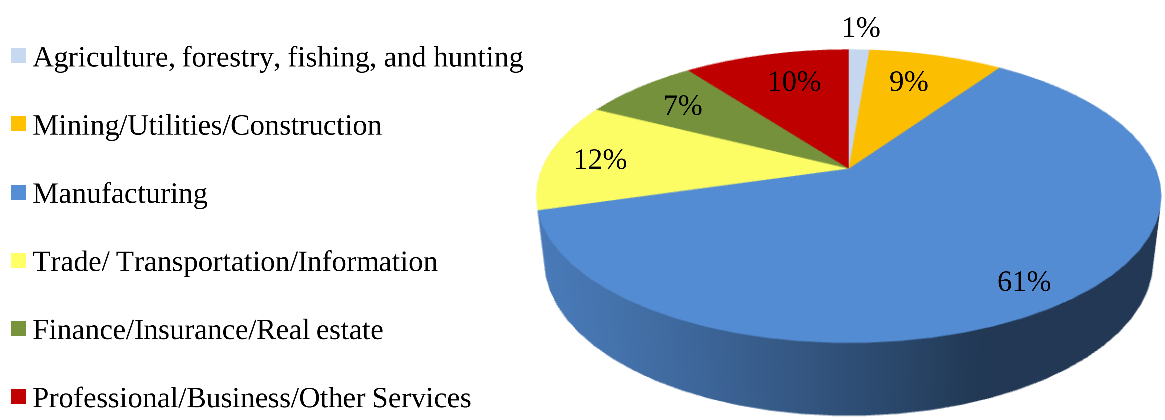
Table 3. Labor Productivity Growth and the Contribution of Non-labor Inputs and Multifactor Productivity, U.S. Private Business Sector 1997-2006
(average annual growth rates)

Output per unit of labor (includes imports)	2.56%
Multifactor Productivity (includes imports)	1.31%
Contribution of capital intensity	0.88%
Contribution of imported intermediates	0.37%
Contribution of imported materials	0.27%
Contribution of imported services	0.08%
Contribution of imported energy	0.01%
Output per unit of labor (without imports)	2.39%

We don't believe that it would be a good idea to alter the labor productivity model to incorporate imported intermediates, as then the trend could be considered "biased" to the extent that output would reflect the growth in imported intermediates, while the labor input would not include the corresponding hours worked overseas. However, the role of imported intermediates can be meaningfully assessed in the multifactor productivity model. From the exercise above (see Table 2), we find that including imported intermediates in a sector output concept and as a factor input in production, multifactor productivity would grow 0.1 – 0.2 percent per year slower than the BLS published series.

Looking at the imported intermediate data by industry, we see that the manufacturing sector consumes over 60 percent of all imported intermediate used by private industries (Figure 3). Therefore, it is worth taking a closer look at the manufacturing sector. Interestingly, 20 percent of the 61 percent of imported intermediates used by manufacturing is consumed by the petroleum and coal products industry.

Figure 3: Percent of Imported Intermediate Inputs Used by Private Industries, 2006



Source: Bureau of Economic Analysis

Productivity in the U.S. Manufacturing Sector

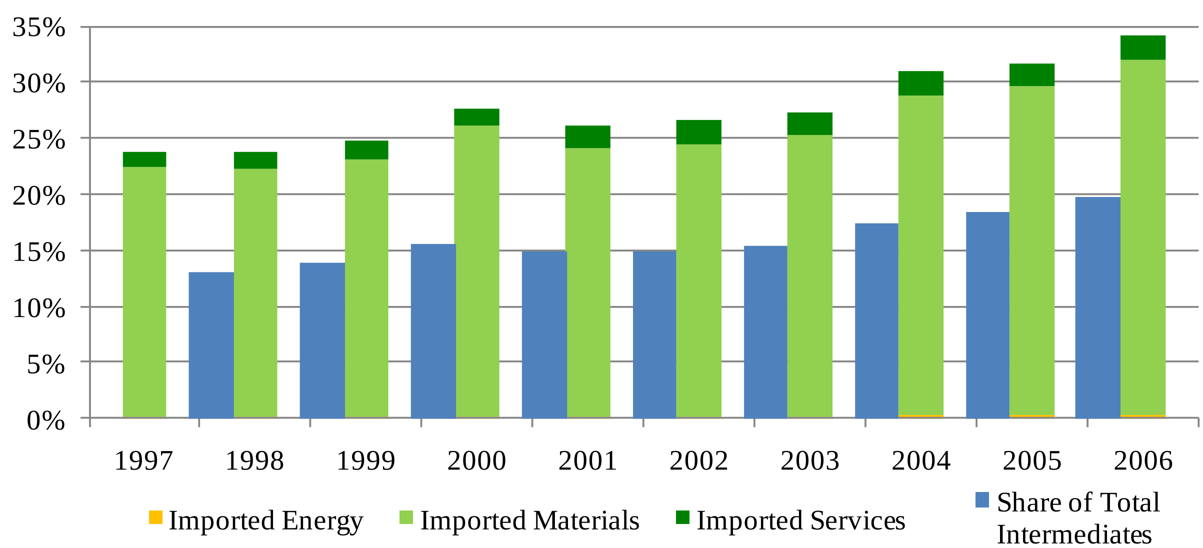
As mentioned earlier, BLS productivity measures for the manufacturing sector are constructed using a sectoral output concept. Therefore, imported intermediates are within the productivity model framework. For the multifactor productivity measures, imported intermediate inputs are a component of measured output and intermediate inputs. To identify the impact of imported intermediates on manufacturing productivity, we do not need to adjust the measures to include imports, but rather separate the intermediates into domestic and imported components. This demarcation is achieved using the BEA estimates of imported intermediates, which were provided to BLS at the industry level of detail.

Figure 4 shows imported intermediates share of "sectoral" intermediate inputs (total intermediates less domestically manufactured inputs), as well as the imports share of total intermediates. The "sectoral" intermediate inputs for the BLS manufacturing sector are less than the total intermediates in the BEA Annual I/O accounts because intermediates that are purchased from other firms within the U.S. manufacturing sector have been removed. Therefore, the imports share of "sectoral" intermediates is greater than the imports share of total intermediate inputs. The "sectoral" intermediate inputs for the manufacturing sector are 57 percent of the BEA total intermediates.

As we observed for the private business sector, imported materials account for the majority of imported intermediate inputs. The share of intermediate inputs that is accounted for by imports is significantly larger in manufacturing than for all private industries and has been growing at a faster rate; 24 percent of "sectoral" intermediates were imported in 1997; this grew to almost 35 percent in 2006. Notice in Figure 4 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.[18] Also, note that service inputs are being imported by the manufacturing sector. Imported services' share of "sectoral" intermediates in the manufacturing sector has grown from 1.3 percent in 1997 to 2.1 percent in 2006, while imported energy's share has grown from 0.1 percent in 1997 to 0.3 percent in 2006.

Figure 4. Imports Share of Sectoral Intermediate Inputs, by type of input, U.S. Manufacturing, 1997-2006

(imports share of total intermediates also shown)



Source: Bureau of Labor Statistics and Bureau of Economic Analysis

[18] 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 as compared to average growth of prices in the manufacturing sector as a whole of 4 percent.

Table 4 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 are declining and imported intermediates are growing faster than capital and domestic non-manufactured intermediate inputs. Prior to the 2001 recession, there is strong growth in capital services, imported intermediates and domestic nonmanufactured intermediates. However, note that domestic intermediates are impacted by the recession sooner than the imported intermediates. Also notice that the imported intermediates are able to rebound after the recession, while domestic nonmanufactured inputs show negative growth through 2004. Over the entire 1997-2006 period, labor and domestic nonmanufactured intermediates inputs are declining, while capital services and imported intermediates show growth.

Table 4. Manufacturing Sector Multifactor Productivity and Components, 1997-2006

	Sectoral Output	Labor	Capital	Domestic Intermediates	Imported Intermediates	MFP
Annual growth						
1998	5.2%	-0.2%	5.0%	2.3%	9.6%	2.30%
1999	3.8%	-0.7%	4.1%	4.2%	7.1%	0.80%
2000	2.7%	-1.3%	3.1%	-4.1%	5.5%	3.50%
2001	-5.1%	-6.5%	1.5%	-3.0%	-4.9%	-1.30%
2002	-0.7%	-7.1%	0.6%	-4.4%	-2.1%	3.70%
2003	1.0%	-4.9%	0.0%	-1.3%	2.6%	2.80%
2004	1.7%	-0.5%	-0.6%	-5.2%	8.7%	2.60%
2005	3.7%	-1.1%	0.0%	7.7%	4.9%	0.40%
2006	1.8%	0.6%	0.5%	-2.0%	4.3%	1.60%
Annual average growth						
1997-2006	1.53%	-2.44%	1.57%	-0.74%	3.88%	1.79%

*Combined intermediates constructed as a weighted aggregate of energy, materials, and purchased services.

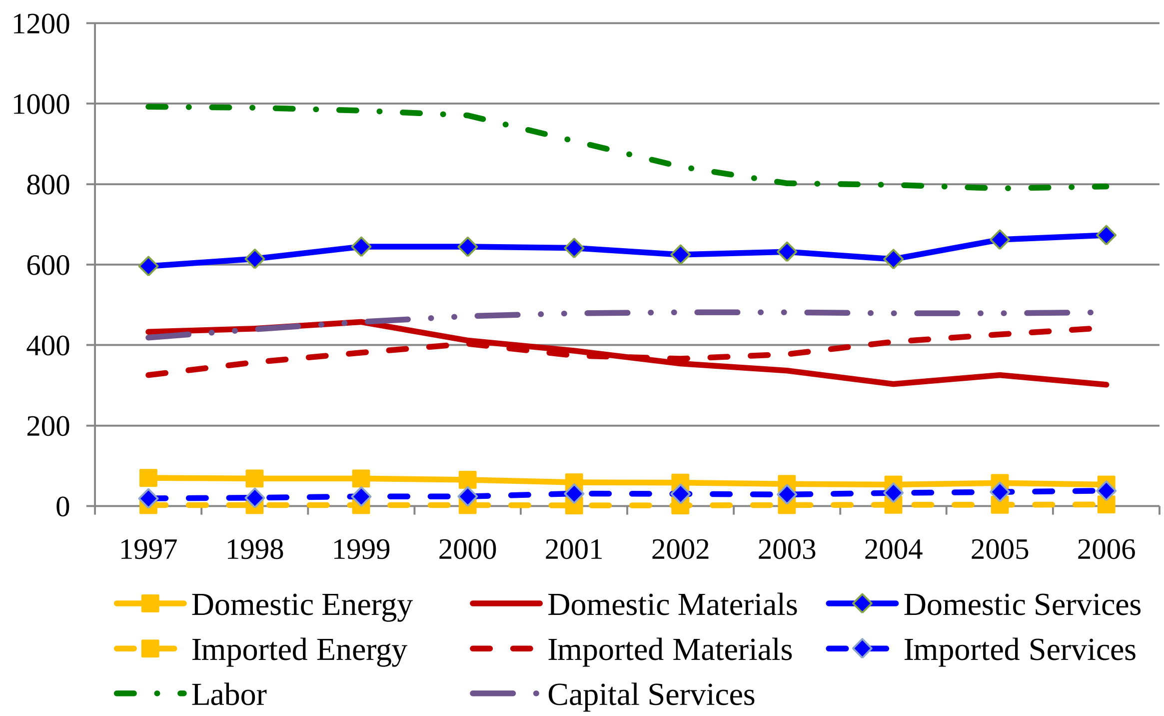
Table 5 compares the growth of domestic nonmanufactured intermediate inputs and imported intermediates by type of input. In general, we note that imported intermediates are showing stronger growth than domestically produced inputs. It is interesting to note that domestic material inputs (excluding materials purchased from other manufacturing industries) are declining in most years, while imported materials have been growing.

Table 5. Comparison of Imported and Domestic Intermediate Inputs by Type of Input, U.S. Manufacturing Sector, 1997-2006

	Total Intermediates		ENERGY		MATERIALS		SERVICES	
	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
Annual growth								
1998	2.25%	9.59%	-2.49%	-7.80%	1.94%	9.73%	3.02%	8.48%
1999	4.21%	7.12%	0.09%	0.39%	3.79%	6.57%	4.93%	15.76%
2000	-4.10%	5.52%	-5.04%	-11.12%	-10.12%	5.85%	-0.06%	1.54%
2001	-3.02%	-4.86%	-9.47%	-6.99%	-6.13%	-7.29%	-0.48%	28.48%
2002	-4.44%	-2.11%	-1.51%	-1.17%	-8.39%	-2.14%	-2.53%	-1.82%
2003	-1.25%	2.64%	-6.08%	12.96%	-4.87%	3.17%	1.14%	-4.19%
2004	-5.23%	8.71%	-2.15%	35.05%	-9.97%	8.12%	-2.89%	13.88%
2005	7.74%	4.93%	8.05%	25.06%	7.44%	4.63%	7.87%	6.38%
2006	-2.02%	4.25%	-6.81%	10.69%	-7.40%	3.91%	1.67%	8.20%
Average annual growth								
1997-2006	-0.74%	3.88%	-2.94%	5.34%	-3.93%	3.49%	1.36%	8.13%

*Combined intermediates constructed as a weighted aggregate of energy, materials, and purchased services

Figure 5: Input Costs for the Manufacturing Sector, by type 1998-2006
Constant dollar, billions



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

Figure 5 presents the trends in constant-dollar factor input costs for the U.S. manufacturing sector. Notice that labor represents the highest cost and was constant prior to the 2001 recession, when it declined with falling employment in manufacturing. Energy and imported services represent a very small portion of the overall factor costs in manufacturing and have been relatively constant over the 1997-2006 period. Interestingly the cost of imported materials has been increasing over the period, while the cost of domestic nonmanufactured materials has been declining. The factor costs of capital services and purchased domestic services have increased somewhat.

We next estimate the effects of imported intermediate inputs on labor productivity by using the Solow multifactor productivity model.

Substitution of Imported Intermediates for U.S. Labor

The model used by BLS to measure multifactor productivity for the U.S. manufacturing sector can be written as:

$$d\ln A_G = d\ln Y_G - w_L\, d\ln L - w_K\, d\ln K - w_E\, d\ln E - w_M\, d\ln M - w_S\, d\ln S \tag{10}$$

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 ($lnA_{(G,t)} - lnA_{(G,t-1)}$) , and the weights for labor , capital, energy, materials and purchased business services, w_i, are the averages of each factor's cost share relative to nominal output, Y^N_G in two successive years:

$$w_{i=L,K,E,M,S} = 1/2 * \left(\frac{C_{i,t}}{Y^N_{G,t}} + \frac{C_{i,t-1}}{Y^N_{G,t-1}} \right) \tag{11}$$

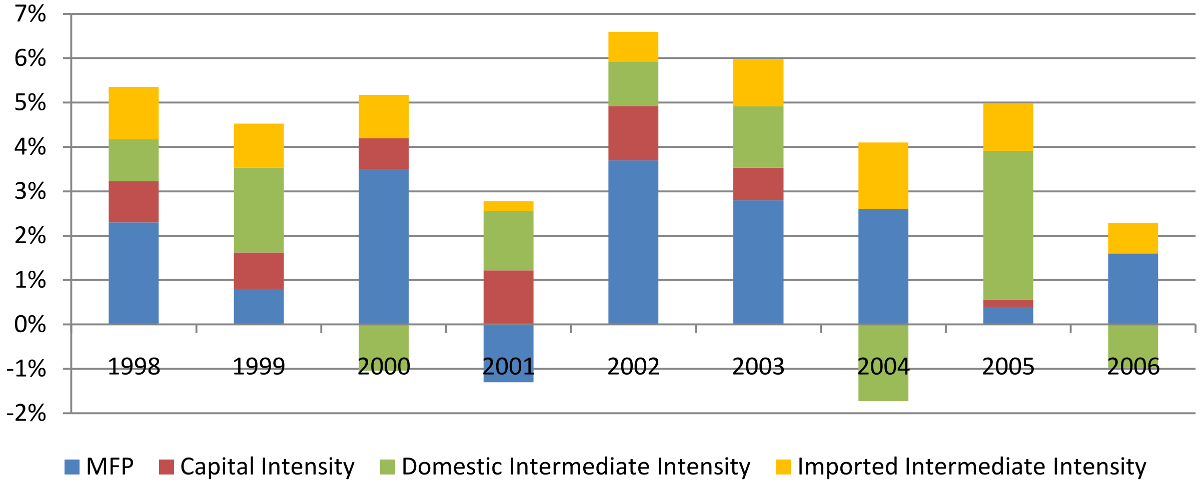
The growth in imported intermediate inputs, combined with growth in capital inputs, domestic intermediate inputs and technical change, directly influence labor productivity. Thus, labor productivity can be written as the sum the intensity of each of the other input factors (increases in the factor's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

$$d\ln Y_G - d\ln L = d\ln A_G + w_K \left(d\ln K - d\ln L \right) + \sum_j \left(w_{Dj} \left(d\ln DI_j - d\ln L \right) \right) + \sum_j \left(w_{Ij} \left(d\ln II_j - d\ln L \right) \right) \tag{12}$$

w_{Dj} denotes the weights on domestic intermediates $j = E,M,S$ and w_{Ij} denotes the weights on imported intermediates $j = E,M,S.$

Figure 6. Labor Productivity Growth by Contributing Input Factors, Manufacturing Sector, 1998-2006

(annual growth rates)



Sources: Bureau of Labor Statistics (using BEA unpublished import data)

Figure 6 shows the contributions of non-labor factor inputs to year-to-year growth of manufacturing sector labor productivity, while Table 6 presents the contributions of non-labor factor inputs on the average annual growth over the entire period from 1997-2006. From Figure 6, notice that in most years, multifactor productivity contributes the most to labor productivity growth. Also notice that growth in capital services contributes to labor productivity growth prior to 2004, but very little thereafter. Imported intermediate inputs are making a relatively constant contribution to labor productivity growth in all years, with the exception of 2001. Over the period 1997-2006, multifactor productivity accounts for 45 percent of productivity growth and imported intermediate inputs account for 23 percent.

Table 6. Contributions to Labor Productivity in the U.S. Manufacturing Sector 1997-2006

(average annual growth)

Output per unit of labor	3.96%
Multifactor Productivity	1.79%
Contribution of capital intensity	0.64%
Contribution of domestic intermediates	0.65%
Contribution of imported intermediates	0.92%
Contribution of imported materials	0.80%
Contribution of imported services	0.10%
Contribution of imported energy	0.01%

Influence of Import Prices

To assess the impact of possible bias in the price change of imports on productivity, we will consider the difference between the growth of the BLS productivity measure, $d\ln A_{BLS}$, and the growth of a productivity measure that is constructed with more precise price indexes for imports, $d\ln A_{price*}$. Prices of imports enter the BLS private business sector productivity model when imports are removed from final demand in the construction of real GDP (which is further reduced to arrive at private business sector output, Y_{BLS}). To assess the impact of possible import price bias, we will assume that domestic inputs and all other components of output are measured precisely. Therefore, the possible bias in productivity growth equates to a difference in the growth of alternative output measures:

$$d\ln A_{BLS} - d\ln A_{\text{Price*}} = d\ln Y_{BLS} - d\ln Y_{\text{Price*}} \tag{13}$$

By assuming that all domestic components of output are measured precisely, the difference in the growth of measured output and an output measure that is constructed using alternate import prices becomes the difference in the growth of measured imports, I_{BEA}, and the alternate, $I_{\text{Price*}}$, that is measured with alternative import prices. The growth of the differences in import measures must be weighted by imports' share, s_I, of output. Because the shares are calculated using nominal data, there is no difference in the weights. The difference in the growth of measured productivity relative to a productivity measures constructed with alternative prices of imports becomes:

$$d\ln A_{BLS} - d\ln A_{Price*} = -s_I \left(d\ln I_{BEA} - d\ln I_{Price*} \right) \tag{14}$$

where:

$$s_I = 1/2 * \left(\frac{I_t^N}{Y_{BLS,t}^N} + \frac{I_{t-1}^N}{Y_{BLS,t-1}^N} \right) \tag{15}$$

Real growth in imports can be calculated as the difference between nominal growth and price growth. As there will be no difference in nominal growth between the two concepts, the difference between the growth of measured productivity and a productivity measure constructed with alternative import prices becomes the weighted difference between the measured price growth of imports, $P^I{}_{BEA}$, and an alternative measure of price growth, $P^I{}_{Price*}$:

$$d\ln A_{BLS} - d\ln A_{Price*} = s_I \left(d\ln P^I{}_{BEA} - d\ln P^I{}_{Price*} \right) \tag{16}$$

Note that the value of aggregate imports is based upon many individual commodities that may, or may not, suffer from biased import prices. An individual commodity's impact on aggregate productivity growth will be determined by the bias in that commodity's price, P^I_j, growth, weighted by the imported commodity's share of output , g_j:

$$g^I_j \;=\; 1/2 * \left(\frac{I^N_{j,t}}{Y^N_{BLS,t}} + \frac{I^N_{j,t-1}}{Y^N_{BLS,t-1}} \right) \tag{17}$$

An individual commodity's impact on productivity growth can be estimated as:

$$g^I_j \left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i} \right) \tag{18}$$

The size of the possible bias in aggregate productivity growth is:

$$\sum_j g^I_j \left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i} \right) \tag{19}$$

When we modified the BLS private sector multifactor productivity model to include intermediate inputs in the model, we reduce the influence of possible price bias on the output component; however we introduce the possible price bias on the input side of the model. Again we will consider the impact of import prices on productivity as the difference between the growth of the modified productivity measure, $d\ln A_S$, and the growth of a productivity measure that is constructed with more precise price indexes for imports, $d\ln A_{price*}$. Recalling the modified MFP equation (5), the difference between the growth of modified productivity and a productivity measure constructed with alternative import prices is the difference in output growth and the weighted difference the growth of imported intermediate inputs with existing import price indexes, II_{BEA}, and an alternative measure of price growth, II_{Price*}:

$$d\ln A_S - d\ln A_{Price*} = \left(d\ln Y_S - d\ln Y_{Price*} \right) - w_{II} \left(d\ln II_{BEA} - d\ln II_{Price*} \right) \tag{20}$$

In the modified MFP model, only imports used as intermediate inputs in production are added back into the model. Assuming they can be added back in the same manner as they were originally removed, the growth of real output can only be biased to the extent that price measures for imports that are destined for final demand are biased. The possible impact on productivity growth is estimated as the weighted difference between the measured price growth of imports, P^I_{BEA}, and an alternative measure of price growth, P^I_{Price*} over final demand products and intermediate inputs :

$$\sum_i^{final\_demand} w^I_j \left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i} \right) + \sum_j^{intermediates} w^I_j \left(d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i} \right) \tag{21}$$

Because the weights on the final demand components and the intermediate inputs are both that commodity's share of nominal output, the equation reduces to:

$$\sum_{i}^{I} w_j^I \left[d\ln P^I_{BEA,i} - d\ln P^I_{Price*,i} \right] \tag{22}$$

Where

$$w_j = 1/2 * \left(\frac{I^N_{j,t}}{Y^N_{S,t}} + \frac{I^N_{j,t-1}}{Y^N_{S,t-1}} \right) \tag{23}$$

By construction w_j will be less than g_j for all commodities; recall that $Y_S = Y_{BLS} + II$. Therefore, the impact of import prices on multifactor productivity will be smaller under the modified MFP framework, than in the BLS published MFP model.

Table 7: Imported Intermediate Inputs Share of Private Business Sector Output, 1997-2006

	1998	1999	2000	2001	2002	2003	2004	2005	2006
BLS Output Share, s^I	8.05%	8.07%	8.76%	8.84%	8.25%	8.25%	8.98%	10.03%	10.77%
Sectoral Output Share, w^{II}	7.45%	7.47%	8.05%	8.12%	7.62%	7.62%	8.23%	9.11%	9.72%

Because import prices are not used to construct real output measures for the BLS manufacturing productivity statistics, any possible price mis-measurement of imports will not affect labor productivity statistics for the manufacturing sector. However, prices of imports enter the BLS manufacturing sector multifactor productivity model when imports are included in the construction of purchased intermediate inputs. To assess the impact of possible import price bias, we will assume that output and all domestic inputs are measured precisely. Therefore, the possible bias in productivity growth equates to a difference in the weighted growth of imported intermediate inputs:

$$d\ln A_S - d\ln A_{Price*} = -w_i \left(d\ln II_{BEA} - d\ln II_{Price*} \right) \tag{23}$$

$$w_{i=IE,IM,IS} = 1/2*\left(\frac{I_{i,t}}{Y^N_{G,t}} + \frac{I_{i,t-1}}{Y^N_{G,t-1}}\right) \tag{24}$$

Real growth in imports can be calculated as the difference between nominal growth and price growth. As there will be no difference in nominal growth between the two concepts, the difference between the growth of measured productivity and a productivity measure constructed with alternative import prices becomes the weighted difference between the measured price growth of imports, $P^I{}_{BEA}$, and an alternative measure of price growth, $P^I{}_{Price*}$:

$$\sum_i^I w_j^I \left[d\, ln P^I{}_{BEA,i} - d\, ln P^I{}_{Price*,i} \right] \tag{25}$$

Table 8: Imported Intermediate Factor Cost Shares, Manufacturing Sector, 1997-2006

	1998	1999	2000	2001	2002	2003	2004	2005	2006
BLS Output Share, w^I	12.24%	12.39%	13.53%	13.97%	13.57%	13.86%	15.24%	16.94%	18.33%

Conclusions

In this paper we develop 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 multifactor productivity (MFP) measures is expanded to treat imported intermediate inputs as an input, rather than as a subtraction from output. Once the imported intermediate inputs are inside the framework, we use the Solow MFP equation 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 have increased as a share of total intermediates used by private industries from 8 percent in 1997 to 10 percent in 2006. By including imported intermediates in the MFP model, we find that private business sector multifactor productivity would grow 0.1-0.2 percent per year slower than the BLS published series. Also, we estimate that the growth in imported intermediate inputs contributed 14 percent to the average annual growth of labor productivity for the private business sector from 1997-2006.

We don't believe that it would be a good idea to alter the labor productivity model to incorporate imported intermediates, as then the trend could be considered "biased" to the extent that output would reflect the growth in imported intermediates, while the labor input would not include the corresponding hours worked overseas. However, the role of imported intermediates can be meaningfully assessed in the multifactor productivity model. From the exercise above (see Table

2), we find that including imported intermediates in a sector output concept and as a factor input in production, multifactor productivity would grow 0.1 – 0.2 percent per year slower than the BLS published series.

Because over 60 percent of imported intermediate inputs purchased by private industries are used by the manufacturing sector, we also evaluate the role of imported intermediates in the U.S. manufacturing sector. The BLS methods for constructing manufacturing multifactor productivity include intermediates in the model framework. Therefore, we isolate the imported components to assess their impact on labor productivity. The data reveal that over the 1997-2006 period, imported intermediate inputs have grown as a share of total intermediate inputs. We find that labor inputs and domestic nonmanufactured inputs are declining over the entire period, while capital services and imported intermediates show growth. In addition, we estimate that growth in imported intermediate inputs contributed 23 percent to the average annual growth in labor productivity in the manufacturing sector.

Finally, we show that any mis-measurement of import prices will impact BLS productivity measures. However, the impact will be weighted by the share of imports relative to aggregate output, which range from 8 percent to 12 percent for the private business sector and 12 percent to 18 percent for the manufacturing sector.