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Lucy P. Eldridge and Susan G. Powers
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Firms produce goods and services by combining inputs of labor, capital, energy, materials, and purchased services. How efficiently these inputs are converted into outputs is captured in measures of productivity. However, there are different ways to measure output, and each has advantages and disadvantages for evaluating productivity. The three output concepts that are commonly used are: value-added, sectoral output, and gross output. These output concepts vary by whether the goods and services counted are limited to those produced for final consumption by consumers, or whether they include goods and services purchased by firms as inputs for further production. The choice of which output concept to use depends on the question of interest, as well as the availability and timeliness of data.

In this paper, we discuss these alternative concepts of output and show how they are related. We then discuss the implications of using the different output concepts for measured productivity growth. To illustrate the differences, we construct and evaluate productivity measures based on alternative output concepts for the US manufacturing sector and selected industries within manufacturing. Finally, we explore whether industry contributions are impacted when total factor productivity (TFP) is measured using three alternative output concepts. We use a U.S. Bureau of Labor Statistics (BLS) experimental production account for the U.S. manufacturing sector to investigate how output choice impacts analysis of industry contributions to manufacturing sector TFP.

Defining Productivity and Output

Productivity growth relates the growth in output to the growth in the inputs used in the production process. Labor productivity (LP) growth compares the growth in output to the growth in labor input and captures gains in output that are not a result of additional hours worked. Labor productivity growth can occur due to changes in capital investment, purchased materials and services, economies of scale, worker skills and technologies used in production.

Labor productivity is often used to evaluate labors' marginal product and is compared to trends in compensation.[1] Labor productivity growth is commonly expressed as:

(1) $$LP\ growth = Output\ growth - Labor\ growth$$

Total factor productivity (TFP), also referred to as multifactor productivity (MFP), compares output to a combination of multiple inputs used in production. Inputs in production can include capital (machinery and equipment, computers, structures, intellectual property products, inventories, and land), labor, energy, materials and purchased services. Because TFP measures the growth in output that is not a result of using additional inputs, TFP is often considered an indicator of technological progress. TFP measures reflect the effects of technical change, increases in general knowledge (for example, new scientific findings), adoption of better management techniques, and improved organizational structure.[2] Total factor productivity is commonly expressed as the difference between the growth rate of output and the weighted aggregate of the growth rates of each input in the production process:

(2) $$TFP\ growth = Output\ growth - \sum_i s_i\ \ Input\ growth_i$$

where s_i is the cost share weight for each input i. This model was developed by Robert Solow in 1957 and assumes constant returns to scale, implying that the value of output equals the total cost of all measured inputs and cost shares sum to one. [3]

Productivity estimates can be computed using any one of three output concepts: gross output, sectoral output, or value-added output. The choice of which output concept affects which inputs are explicitly included in the calculation of TFP. Given the relationship among outputs, inputs, and productivity, it is clear that how we define output will facilitate the examination of different analytical questions.

Output Definitions

The broadest measure of output is gross output. Gross output is the total value of goods and services produced by all firms in an industry or sector, regardless of whether they are sold directly to consumers or sold to other firms to become an input for further production. In this case, an output is counted when it is sold and then counted again in the value of the product it was used to produce. Thus, a measure of gross output for an economy will count the value of an output multiple times if that item is used in production by other firms. It is important to be aware of this double counting.

By contrast, value-added output is a more narrowly defined concept of output that removes the value of all purchased intermediate inputs from the value of gross output. As such, value-added output reflects only the additional value of transforming intermediate inputs into outputs. Value-added output for the aggregate economy equals the sum of value-added by each firm and can also be measured as the value of goods and services that are sold to final consumers.

Sectoral output, which lies between gross output and value-added output, is equal to gross output less only those intermediate inputs produced within that industry or sector, i.e., intrasectoral transactions. Intermediate inputs used in production that are purchased from outside the industry are not removed. Thus, sectoral output represents the value of output leaving the sector or industry.[4] By excluding transactions within an industry or sector, sectoral output measures output as if the industry or sector were vertically integrated.[5]

These three measures of output have a direct mathematical relationship, as illustrated in Figure 1. Sectoral output equals value-added output plus the intermediate inputs of energy, materials, and services purchased from **outside** the industry or sector. Gross output equals sectoral output plus the remaining intermediate inputs purchased from **within** the industry or sector. Using nominal data, gross output will be greater than sectoral output, which is greater than value-added output. However, the relationship between real trends of these three measures will depend on trends in intermediate inputs, as well as price change.

Figure 1. Integrated Output Measures

Labor and Capital Input	*is equal to:* **Value-Added Output**
plus Energy, Material and Service Inputs purchased from **Outside**	*is equal to:* **Sectoral Output**
plus Energy, Material and Service Inputs purchased from **Within**	*is equal to:* **Gross Output**

If we are measuring the total economy, the number of inputs coming from outside the economy declines and sectoral output and value-added output measures converge. The difference between value-added output and sectoral output at the economy level will depend mostly on the size of imported intermediate inputs. However, if we are measuring the output of a very detailed industry, we expect most of the inputs to be coming from outside of the industry. Thus, for detailed industries gross output and sectoral output will be closely aligned.

Value-Added Output and Productivity

Value-added output can be measured directly using data on consumption and therefore is timelier than data that require information on purchased inputs. With less demanding data requirements, the value-added output concept is the most common output measure employed for measuring productivity and can be produced at a higher frequency than productivity statistics based on other output concepts.[6] Value-added labor productivity growth (LP_{VA}) is calculated as the percent change in the ratio of value-added to hours worked and can be approximated as the growth in value-added output less the growth in hours worked:

(3) LP_{VA} *growth = Value-added Output growth – Hours Worked growth*

Value-added labor productivity more closely reflects an industry's ability to translate labor hours into final income. Labor productivity - output per hour worked - constructed using value-added output is often used as an indicator of changes in the standard of living.[7] However value-added output, by subtracting out intermediate inputs, is sensitive to biases in intermediate input prices (both import prices and within-industry transaction pricing). This simple and easy-to-calculate productivity measure does not tell the whole story. To account for the importance of capital in production, a value-added TFP growth measure (TFP_{VA}) is calculated as the percent change in the ratio of value-added output to a weighted sum of labor and capital inputs and is approximated as the growth in value-added output less the share weighted sum of growth in labor and capital:[8]

(4) TFP_{VA} *growth = Value-added Output growth* - $(s_K^{VA}\dot{K}/K + s_L^{VA}\dot{L}/L)$

where *K* is capital input, *L* is labor input, and s_K^{VA} and s_L^{VA} are cost share weights for capital and labor; the dot notation on the inputs denotes growth. Notice that energy, materials, and services are absent from this model because they are not a component of value-added output; all intermediate inputs of energy, materials and services have been removed from the measure of output. Given the assumption of constant returns to scale, the value of output will equate to the summed costs of capital and labor and the cost shares will sum to one.

Sectoral Output and Productivity

Sectoral output equals gross output less intrasectoral transactions—that is, purchases of intermediate inputs that were produced by other firms in the industry or sector. Sectoral output is a particularly useful output concept because it describes output in relation to capital, labor, and intermediate inputs purchased from firms outside an industry, rather than only capital and labor inputs. In addition, by removing the value of intrasectoral transactions, sectoral output avoids double-counting inputs purchased and used for production within the same industry or sector. Total factor (TFP_{SO}) and labor productivity (LP_{SO}) based on sectoral output are expressed as:

(5) TFP_{SO} *growth = Sectoral Output growth* –

$$(s_K^{SO}\dot{K}/K + s_L^{SO}\dot{L}/L + s_E^{SO}\dot{E}/E' + s_M^{SO}\dot{M}/M' + s_S^{SO}\dot{S}/S')$$

(6) LP_{SO} *growth = Sectoral Output growth - Hours worked growth*

where E', M', and S' are energy, materials and purchased services inputs, respectively, adjusted to remove intrasectoral transactions of energy, materials, and purchased services inputs; s_K^{SO}, s_L^{SO}, s_E^{SO}, s_M^{SO}, and s_S^{SO} are cost share weights for capital , labor and the adjusted intermediate inputs – energy, materials and purchased services; again, the dot notation on the inputs denotes growth. These cost share weights will sum to one and the weights on capital and labor in the sectoral output model of TFP will be smaller than those in the value-added model.

For both value-added and sectoral output concepts, changes in labor productivity can be due to technological progress, increased capital intensity, greater economies of scale, improved management techniques, and changes in the skills of the labor force. The key difference between the two concepts is that sectoral output-based labor productivity includes the effects of substituting other inputs (EMS) for labor, whereas value-added labor productivity does not.[9] Sectoral-output-based labor productivity will therefore grow with increased outsourcing of labor and purchases of intermediate inputs because the reduction of labor will not be off-set by a reduction in output. In the value-added model, outsourcing of labor has a smaller effect on labor productivity because the substitution of purchased services for labor reduces both output and labor input. [10] This, in part, explains why different output concepts are useful for answering different questions.[11] Value-added labor productivity more closely reflects an industry's or sector's ability to translate labor hours into final income, while sectoral-output-based labor productivity measures the efficiency with which an industry transforms labor hours into output.[12]

Gross Output and Productivity

Total factor productivity measures using a gross output concept relate output growth to the growth in all inputs of production including capital (K), labor (L), and all intermediate inputs of energy (E), materials (M), and purchased services (S). TFP measures based on gross output provide a way to observe shifts among all inputs in production, by presenting a complete accounting of inputs used in production regardless of where they are produced. Thus, including all intermediate inputs in the production model provides a way to shed light on shifts between primary inputs and purchased intermediate inputs – from within and outside the industry – that accompany efficiency gains. [13] Because gross output includes the purchase of output for further production within an industry, both output and input values are increased by the same amount – the value of outputs purchased for use as inputs within the industry. This double counting can obscure the relationship between output and inputs and the resulting measurement of productivity for the aggregate economy.[14] Gross output is more appropriate when measuring industries that use negligible amounts of inputs from within the same industry.

Total factor productivity (TFP_{GO}) and labor productivity (LP_{GO}) based on gross output are commonly expressed as:

$$(7) \qquad TFP_{GO}\ growth = Gross\ Output\ growth - (s_K^{GO}\dot{K}/K + s_L^{GO}\dot{L}/L + s_E^{GO}\dot{E}/E + s_M^{GO}\dot{M}/M + s_S^{GO}\dot{S}/S)$$

$$(8) \qquad LP_{GO}\ growth = Gross\ Output\ growth - Hours\ worked\ growth$$

where s_K^{GO}, s_L^{GO}, s_E^{GO}, s_M^{GO}, and s_S^{GO} are cost share weights for capital, labor, energy, materials and purchased services which sum to one; the dot notation on the inputs denotes growth.[15] Given the assumption of constant returns to scale, the value of gross output will equate to the summed costs of all inputs - capital, labor, energy, materials and purchased services.

Relationships Among Productivity Measures

Because there are direct relationships among the three output measures, there are also direct relationships among the productivity measures constructed using these three output measures. These relationships are well known, but it is useful to provide a brief summary.[16]

Total Factor Productivity Relationships

From our output definitions above, we know that gross output is equal to value-added output plus intermediate inputs. It follows that the relationship between gross and value-added TFP measures is a function of the ratio of intermediate inputs to gross output. This relationship can be described as follows:[17]

$$(9) \qquad TFP_{GO}\ growth = \left(\frac{Value{-}Added\ Output}{Gross\ Output}\right) \times TFP_{VA}\ growth$$

$$= \left(1 - \frac{Intermediate\ Inputs}{Gross\ Output}\right) \times TFP_{VA}\ growth$$

Clearly, gross TFP will have a proportionally smaller change than value-added TFP because nominal value-added output is less than nominal gross output. The difference between the TFP growth rates will increase as intermediate inputs increase (for example, due to an increase in outsourcing) relative to gross output.[18]

Similarly, gross output TFP can also be defined relative to sectoral output TFP. We know gross output is equal to sectoral output plus those intermediate inputs purchased from within the respective industry or sector, i.e., intrasectoral transactions. Thus, the difference between the rate of growth of sectoral TFP and the rate of growth of gross output TFP depends on intrasectoral inputs relative to gross output:[19]

$$(10) \quad TFP_{GO} \textit{ growth} = \left(\frac{Sectoral\ Output}{Gross\ Output}\right) \times TFP_{SO} \textit{ growth}$$

$$= \left(1 - \frac{Intrasectoral\ Inputs}{Gross\ Output}\right) \times TFP_{SO} \textit{ growth}$$

For narrowly defined industries with few intrasectoral transactions, sectoral TFP growth will be close to gross TFP growth. As we move from detailed to more aggregated industries or sectors, more inputs will be considered intrasectoral and the share of intrasectoral inputs to gross output will increase. As a result, gross output TFP growth will diverge proportionately further from sectoral output TFP growth. For example, if firms within an industry become less vertically integrated over time, they will rely on more inputs from outside their firm but from within their industry. Thus, purchases of intrasectoral inputs will increase and the difference between sectoral TFP and gross TFP will also increase.

Finally, sectoral output can be expressed as value-added plus intermediate inputs purchased from **outside** the industry or sector. Thus, by combining equations (9) and (10) and rearranging terms, the relationship between value-added TFP growth and sectoral TFP growth can be expressed as:[20]

$$(11) \quad TFP_{SO} \textit{ growth} = \left(\frac{Value-Added\ Output}{Sectoral\ Output}\right) \times TFP_{VA} \textit{ growth}$$

$$= \left(\frac{\left(1-\frac{Intermediate\ Inputs}{Gross\ Output}\right)}{\left(1-\frac{Intrasectoral\ Inputs}{Gross\ Output}\right)}\right) \times TFP_{VA} \textit{ growth}$$

From (11), we see that measures of sectoral TFP growth will exhibit a proportionally smaller change than value-added TFP growth. This relationship is a function of the relative shares of intrasectoral transactions in gross output compared with the share of total intermediate inputs in gross output. As we move from detailed industries to more-aggregate levels of the economy, intrasectoral transactions increase while purchases of intermediate inputs coming from outside the sector fall. For the most aggregate economic sectors, value-added TFP growth approximates sectoral TFP growth.[21]

Conversely, as the share of intermediate inputs from outside the sector grows, the difference between growth of value-added TFP and growth of sectoral TFP will also increase. When outsourcing increases, for instance, total intermediate inputs increase while intrasectoral transactions do not, and value-added TFP will grow faster than sectoral TFP. As a result, there is greater volatility in value-added TFP compared to sectoral TFP measures in response to changes in the degree of outsourcing and consumption of intermediate inputs.

In summary, the growth in the three related TFP series maintain a predictable ordering, such that, given the absolute value of each growth rate:

$$| \, TFP_{GO} \text{ growth} \, | < | \, TFP_{SO} \text{ growth} \, | < | \, TFP_{VA} \text{ growth} \, |$$

Labor productivity relationships

As with TFP, the relationships among the three labor productivity measures are directly linked to the growth in intermediate inputs, as described by equations 12, 13, and 14.

(12) LP_{VA} *growth =* LP_{GO} *growth – growth in all intermediate inputs*

(13) LP_{SO} *growth =* LP_{GO} *growth − growth in intrasectoral inputs*

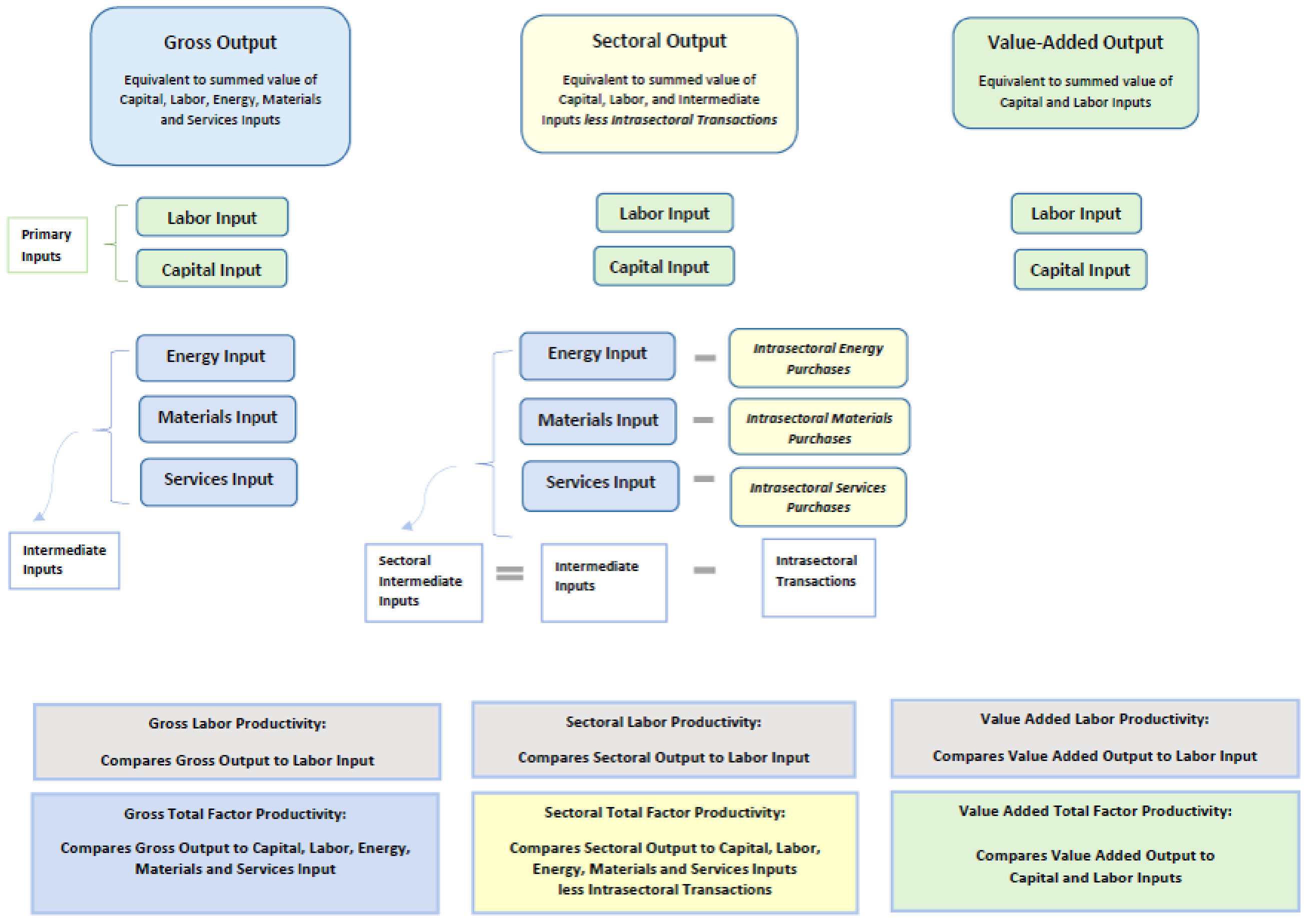
(14) LP_{VA} *growth =* LP_{SO} *growth – growth in intermediate inputs from outside the sector*

Unlike the TFP measures, however, the order of the three alternative labor productivity measures is not predictable. This can be explained by reviewing the differences in the output measures used to estimate each of these labor productivity measures. Value-added labor productivity compares growth in real value earned by capital and labor inputs to growth in labor input; sectoral labor productivity compares growth in real value earned by capital, labor, and intermediate inputs from outside the sector to growth in labor input; and gross labor productivity compares growth in capital, labor and intermediate inputs purchased both outside and within a sector to growth in labor input.

The order of the three alternative labor productivity measures, then, depends on the relative growth rates of capital, labor, and intermediate inputs purchases from within and from outside a sector. A decline in capital and labor input growth that is offset by larger increases in intermediate input purchases, whether from within or outside a sector, will result in value-added labor productivity growing more slowly than sectoral and gross labor productivity. And, regardless of capital and labor input growth, the relationship between sectoral and gross labor productivity will vary depending on the relative growth rates of intermediate input purchased from within versus outside a sector.

Figure 2 below summarizes the relationships among the various elements of the integrated productivity growth model.

Figure 2. Elements of the Integrated Productivity Growth Model



BLS Output and Productivity Model Choice

To estimate measures of productivity, it is important to have measures of both output and inputs that are consistently defined and independently measured. The output measure used will depend on several factors, including data availability and analytical purpose. In addition, the output measure selected from the growth accounting model's integrated system of outputs and inputs must be appropriate both for the level of economic aggregation under examination and the analytical purpose of the application. In this section, we discuss some of the output characteristics BLS considers before selecting the most appropriate output concept for use in developing productivity measures for specific purposes.

Aggregate Productivity Measures

The BLS uses value-added output for its business sector productivity measures, including the quarterly labor productivity measure, which is a Principal Federal Economic Indicator (PFEI). Value-added output is appropriate for highly aggregated sectors because most inputs are purchased from within the sector.[22] And because value-added output is measured using data on consumption (final demand of goods and services), the data are timely and easily obtained. U.S. value-added output data (GDP) are available from the U.S. Bureau of Economic Analysis (BEA) shortly after the reference quarter for use in constructing BLS quarterly labor productivity measures. Because of the less demanding data requirements, value-added is the most commonly used output concept and is particularly useful for making international comparisons. BLS also publishes estimates of TFP growth for business sectors using value-added output.[23] With labor and total factor productivity measures based on the same measure of value-added output, it is possible to decompose the labor productivity measures into contributions coming from capital intensity, labor composition and TFP.

However, value-added productivity measures do not provide a way to explain shifts between primary and imported inputs or other purchases from outside the business sector, as does the sectoral model. Presenting the trends in offshoring, as well as purchases of inputs from the government and nonprofit sectors can provide useful information about economic trends and would provide a bridge between the value-added and sectoral productivity series.[24]

Industry Productivity Measures

For industry level analysis, including the manufacturing sector and 3- and 4-digit NAICS manufacturing industries, the BLS uses sectoral output to estimate labor productivity and TFP growth. [25] The sectoral output concept best represents the value of output leaving a particular industry. Compared to a value-added approach, sectoral output TFP provides a more complete picture of the sources of growth by showing the contributions of energy, materials and purchased services inputs, in addition to capital and labor.[26] In addition, as intermediate inputs become a more important part in the production process, the productivity measures using the sectoral output will reflect the growth that results when intermediate inputs are substituted for labor.[27] Again, when both productivity measures use the same output concept, it is possible to relate labor and total factor productivity.[28]

The BEA/BLS integrated industry production account uses a gross output approach to measure industry productivity because it provides a complete accounting of inputs used in production regardless of where they are produced. Including all intermediate inputs in the production model provides a way to shed light on shifts between primary inputs and purchased intermediate inputs from outside and within the industry.

Although gross and sectoral output measures both include intermediate inputs, sectoral output is less sensitive to shifts in industry structure due to mergers and split offs than gross output. For example, suppose a single plant restructures into two plants such that all of the output of plant A is consumed by plant B. In this case, industry gross output (and inputs) increases by the output of plant A, whereas sectoral output for the industry (correctly) does not change. This is because any outputs produced for consumption within a single plant are not reported to the

U.S. Census Bureau as outputs or inputs.[29] However, after the restructuring into two separate plants, the output that is produced by one plant and consumed by the other is now explicitly reported as output in both plants, as well as reporting the input produced. Because labor productivity measures do not account for purchased materials and services as inputs, this double counting is particularly problematic. Therefore, it is not advised to measure labor productivity using gross output.

Comparing Productivity Measures in U.S. Manufacturing

BLS publishes labor and total factor productivity measures for industries and subsectors of the U.S. business sector.[30] We illustrate the impact of using different output measures on related productivity measures by constructing value-added and gross output measures for the manufacturing sector and nineteen roughly 3-digit NAICS manufacturing industries.[31] The methodology used to construct these measures is consistent with the sectoral output methodology used for official BLS productivity measures. [32]

Data

Table 1 illustrates the data sources used in constructing the various measures for the manufacturing sector and for the underlying manufacturing industries. BLS published measures of labor and total factor productivity for the manufacturing sector and manufacturing industries use the sectoral output model. In addition, the BLS measures exclude the output of households and nonprofit institutions to remove known sources of bias; thus, our value-added and gross output models also remove these components.[33] Output measures for all three models are based on value of shipments data from the Census Bureau, as well as data on inputs used in production (BEA energy, materials, and services). Data on intangible outputs are obtained from BEA.

Note that all three approaches use the same estimates of labor and capital services. The labor input for labor productivity measures is the hours worked by all persons produced by the BLS Productivity Program. By using hours worked as the labor input measure, labor productivity can be decomposed into its component sources of growth, including TFP, capital per unit of labor input or capital intensity, and the effect of labor composition.[34] For our TFP estimates, we use labor input measures defined as hours worked adjusted for differences in age, education, and gender, and based on the same methodology as the BLS published indexes of labor input.[35] Capital input is measured as the flow of capital services from physical capital stock and intellectual property assets.[36] The capital input measures we use to construct our manufacturing sector and industry TFP measures are consistent with BLS published data but have been adjusted to allow for consistency among the three output concept models.[37]

For the TFP models, we use consistent measures of total intermediates and intrasectoral transactions in the gross output and sectoral output approaches; there are no intermediate inputs in the value-added model. Additional information on the data and methods used to construct the value-added and gross models is available in the Appendix.[38]

Table 1. Data Sources by Type of Measure

Industry Aggregate	Value-Added	Sectoral Output	Gross Output
Manufacturing Sector	<u>Total Factor Productivity</u> Output – BLS estimate of value-added output for the manufacturing sector, constructed as a chained superlative index (Tornqvist) of three-digit NAICS industry value-added outputs. Capital and Labor – BLS <u>Labor Productivity</u> Value-added output estimate and BLS hours of all persons	<u>Total Factor Productivity</u> Output – BLS estimate of sectoral output for the manufacturing sector, constructed as a chained superlative index (Tornqvist) of three-digit NAICS industry outputs adjusted to remove manufacturing sector intrasectoral transactions. Capital and Labor – BLS Energy, Materials, and Services– BLS <u>Labor Productivity</u> Sectoral output estimate and BLS hours of all persons	<u>Total Factor Productivity</u> Output – BLS estimate of gross output for the manufacturing sector, constructed using a chained superlative index (Tornqvist) of three-digit NAICS industry gross outputs. Capital and Labor – BLS Energy, Materials, and Services – BLS <u>Labor Productivity</u> Gross output estimate and BLS hours of all persons
NIPA Manufacturing Industries	<u>Total Factor Productivity</u> Output – BLS estimates of value-added output for detailed manufacturing industries, constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau and U.S. Bureau of Economic Analysis data on intermediate inputs. 1 Capital and Labor – BLS <u>Labor Productivity</u> Value-added output estimate and BLS hours of all persons	<u>Total Factor Productivity</u> Output - BLS estimates of sectoral output measures for detailed manufacturing industries, constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau. 1 Capital and Labor – BLS Energy, Materials, and Services– BLS <u>Labor Productivity</u> Sectoral output estimate and BLS hours of all persons	<u>Total Factor Productivity</u> Output – BLS estimates of gross output for detailed manufacturing industries, constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau.1 Capital and Labor – BLS Energy, Materials, and Services – BLS <u>Labor Productivity</u> Gross output estimate and BLS hours of all persons

1 Output in NAICS 323 is adjusted to remove the output value of households and nonprofit entities, for each type of output measure.

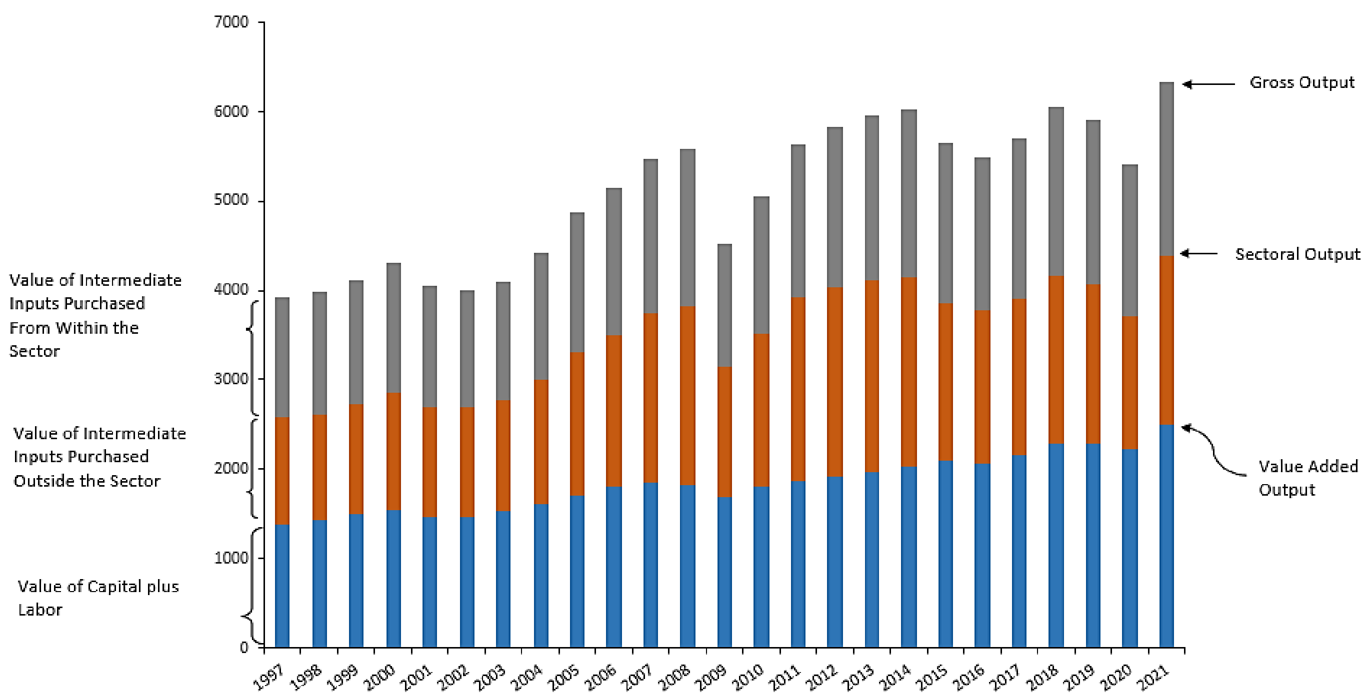
Empirical Results

We estimate the relationships between output, labor productivity, and total factor productivity for the manufacturing sector and 19 manufacturing industries using the three output measures.

<u>Manufacturing Sector: Output Measures</u>

Figure 3 illustrates the nominal output and input relationships for the manufacturing sector.

Figure 3. Output and Input Relationships in the Manufacturing Sector
Billions of Current Dollars



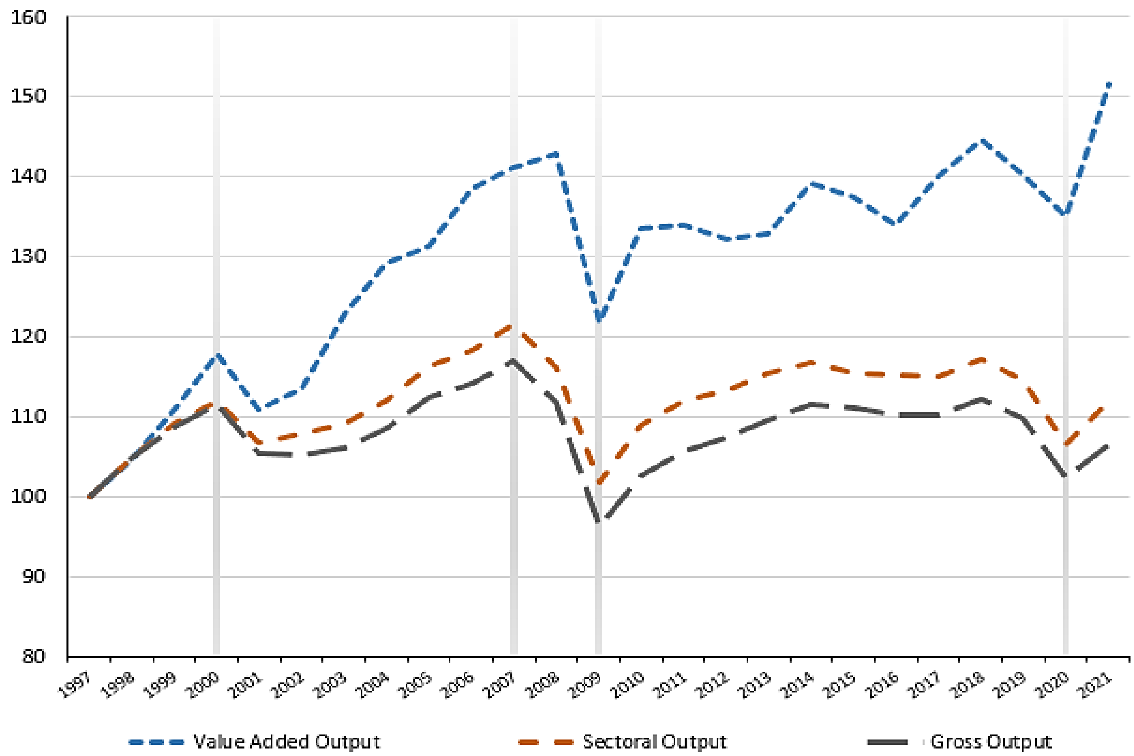
Source: BLS Unpublished Manufacturing Production Account

As shown in Figure 3, the current dollar data have a predictable relationship: value-added output is less than sectoral output and sectoral output is less than gross output. However, this is not necessarily the case for the growth rates of the three real output measures.[39] Differences in growth rates for the three measures depend on growth rates of intermediate inputs, as well as price change for output and intermediate inputs.

Figure 4 presents trends in the three measures of real output for the manufacturing sector for the 1997 to 2021 period. From Figure 4, we see that real gross output for the manufacturing sector decreased at a 0.22 percent annual rate over the 2000-2021 period compared to a 1.20 percent increase for value-added output, while remaining unchanged for sectoral output. In general, sectoral output and gross output behave similarly, while value-added output shows a very different trend. Although current dollar gross output is larger than sectoral output and value-added output, real gross output has been growing at the slowest rate over the 2000-2021 period.

Table 2 highlights the role that changes in intermediate inputs purchased within an industry versus from outside an industry may play in relative growth trends of the alternative output measures. Our data contain 2 complete business cycles, 2000-2007 and 2007-2019, and two of the U.S.'s most severe recessions, 2007-2009 and 2019-2020. The somewhat slower long-run growth of real gross output compared to real sectoral output in the manufacturing sector from 2000-2021 reflects a decrease in real intermediate input purchases from within the manufacturing sector of 0.67 percent per year.[40]

Figure 4. Value-Added, Sectoral, and Gross Output Measures
Manufacturing Sector, 1997-2021
Index, 1997=100



Source: BLS Unpublished Manufacturing Production Account

Table 2. Growth in Output and Intermediate Inputs for the Manufacturing Sector, Selected Periods
(Annual Percent Change)

Time Period	Real Value-Added Output	Real Sectoral Output	Real Gross Output	Real Intermediates Purchased Within the Industry	Real Intermediates Purchased Outside the Industry
2000-2021	1.20	0.00	-0.22	-0.67	-1.48
2000-2007	2.60	1.18	0.69	-0.30	-0.33
2007-2019	-0.06	-0.49	-0.52	-0.59	-1.30
2019-2021*	4.00	-1.15	-1.54	-2.41	-6.43

* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

From Figure 4, we also see real value-added output growing faster than sectoral output. This is due to a decline in the real value of intermediate inputs purchased from outside the sector, including purchases from service industries, the household and government sectors, or imported intermediates. Looking at the sub-period from 2000-2007, we see real imported and out-of-sector purchases of intermediate inputs were falling at an annual rate of 0.33.[41] Thus from 2000-2007, real value-added output grew faster than sectoral output at a rate of 2.60 compared to 1.18. In the more recent period from 2007-2019 this difference in growth rates narrowed, with real sectoral output declining at a rate of 0.49 and value-added decreasing at a rate of 0.06 percent. Real imported and out-of-sector purchases of intermediate inputs declined by 1.30 percent in this period.[42]

Figure 4 also captures the impact of the Great Recession that began in the 4th quarter of 2007, lasted through the 2nd quarter of 2009, and resulted in a decline in all measures of manufacturing sector output. As shown in Table 3, real value-added output growth fell by 7.15 percent per year from 2007 to 2009, while growth in real sectoral and gross outputs for the manufacturing sector fell 8.54 and 9.30 percent, respectively. The 2007-2009 decline in real sectoral output reflects the 7.15 percent drop in real value-added and a 10.19 percent drop in real intermediate inputs purchased outside the manufacturing sector. Gross output for the manufacturing sector fell by 9.30 percent over the 2007 to 2009 period, reflecting the drop in real value-added and a 10.59 percent decline in total real gross intermediate input purchases.

During the more recent 2019-2020 recession coinciding with the Covid pandemic, we see a smaller 3.73 annual percent decline in value-added output. During this initial pandemic impact, sectoral and gross output experienced more rapid declines of 7.02 and 6.79, respectively. The decline in sectoral output reflects the fall in value-added output and an 11.49 percent drop in real intermediate input purchases outside of the manufacturing sector. Slower gross output in manufacturing reflects an 8.90 percent decrease in total real gross intermediate input purchases as well as the accompanying decline in value-added output. Moving forward from this initial pandemic period, the path to recovery from this 2019-2020 pandemic shock is yet to be determined.

Table 3. Growth in Output and Intermediate Inputs for the Manufacturing Sector, Recessionary Periods
(Annual Percent Change)

Recession Period	Real Value-Added Output	Real Sectoral Output	Real Gross Output	Real Intermediates Purchased Within the Industry	Real Intermediates Purchased Outside the Industry
2007-2009	-7.15	-8.54	-9.30	-10.96	-10.19
2019-2020	-3.73	-7.02	-6.79	-6.31	-11.49

Source: BLS Unpublished Manufacturing Production Account

Manufacturing Sector: Productivity

We now compare growth in productivity using the three output measures for the Manufacturing Sector. In table 4, trends in labor productivity, output, and hours worked under each measurement framework are presented for the 2000-2021 period in the manufacturing sector.[43]

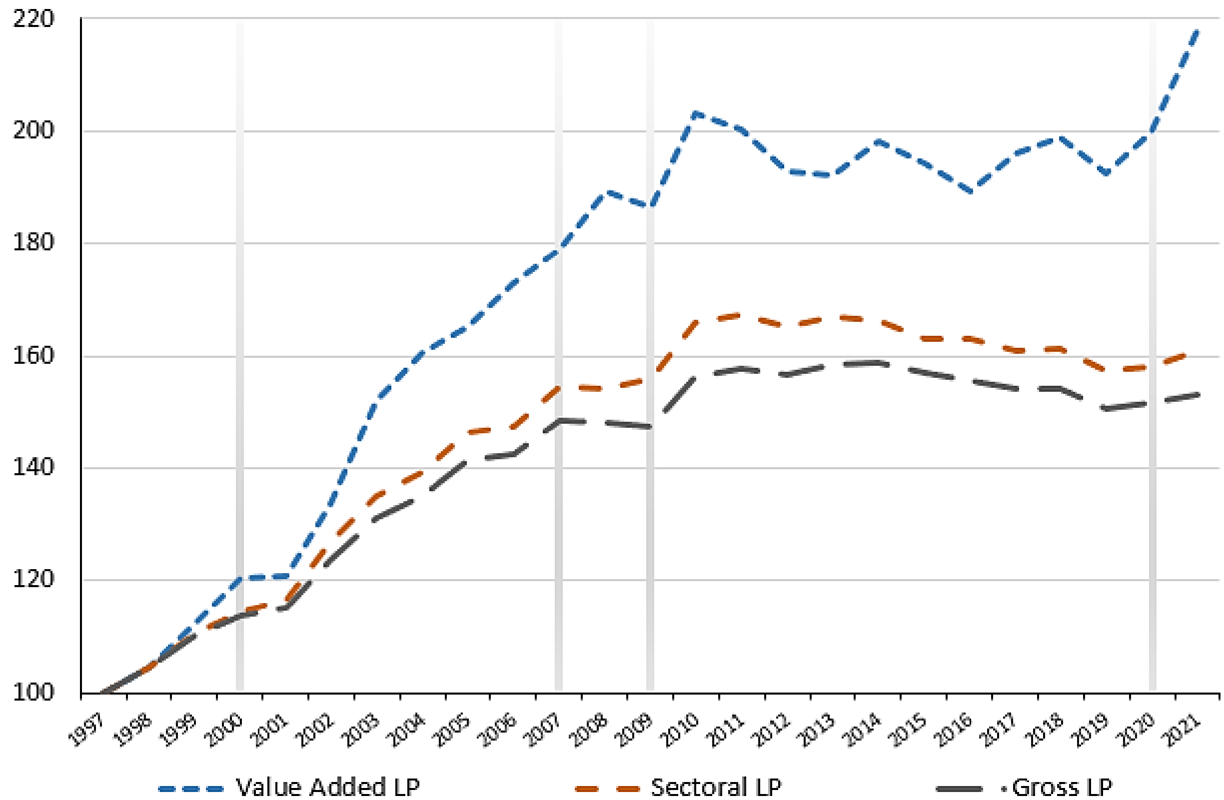
Table 4. Labor Productivity and Component Trends for the Manufacturing Sector, by Output Measure, 2000-2021
(Annual Percent Change)

Measure	Value-Added	Sectoral	Gross
Labor Productivity	2.86	1.64	1.42
Output	1.20	0.00	-0.22
Hours Worked	-1.61	-1.61	-1.61

Source: BLS Unpublished Manufacturing Production Account

Because we use the same labor input measure - hours worked - for each of the three labor productivity measures, differences in labor productivity are driven solely by the differences in output growth. From 2000-2021, hours worked declined 1.61 percent per year, resulting in labor productivity growing faster than output over this period. As with the three output measures, we observe labor productivity growing the fastest for the value-added model and the slowest for the gross output model. Figure 5 compares trends in labor productivity based on the three output measures.

Figure 5. Labor Productivity by Output Measure
Manufacturing Sector, 1997-2021
Index, 1997=100



Source: BLS Unpublished Manufacturing Production Account

From Table 5, we notice that labor productivity measured using value-added output grows at a faster 5.84 percent annual rate during the 2000-2007 period, decelerating to 2.04 percent growth during the 2007-2009 Great Recession, and recovering at a 0.31 rate over the 2009-2019 expansionary period. By comparison, the sectoral labor productivity measure exhibits a slower 4.37 percent rate over the 2000-2007 cycle, a more extreme deceleration to 0.51 in the 2007-2009 cycle, and a slower 0.09 rate of recovery from 2009-2019. Gross output labor productivity has the slowest growth prior to the Great Recession with a 3.87 percent rate, and declining growth during the Great Recession years of 0.32, followed by a slightly faster 0.23 rate of recovery post 2009 than found using the sectoral labor productivity measure. Labor productivity measured using gross output reflects variation in the value of both within and outside the sector purchases of intermediate inputs over the business cycle periods, whereas sectoral labor productivity reflects only variation in outside of sector purchases of intermediate inputs. In the 2019-2020 downturn triggered by the Covid pandemic, value-added labor productivity increased sharply at a 3.99 percent annual growth rate. This reflects a 3.73 percent decline in real value-added output growth and a 7.42 percent decline in hours worked. Sectoral and gross labor productivity increased slightly with 0.44 and 0.68 percent growth, reflecting decreases in sectoral and gross output growth of 7.02 and 6.79 percent as well as the 7.42 percent decline in hours worked.

Table 5. Labor Productivity by Output Measure
Manufacturing Sector, Selected Periods
(Annual Percent Change)

Time Period	Value-Added	Sectoral	Gross
2000-2021	2.86	1.64	1.42
2000-2007	5.84	4.37	3.87
2000-2001	0.48	1.88	1.29
2001-2007	6.76	4.79	4.30
2007-2019	0.60	0.16	0.13
2007-2009	2.04	0.51	-0.32
2009-2019	0.31	0.09	0.23
2019-2021*	6.41	1.14	0.74
2019-2020	3.99	0.44	0.68
2020-2021	8.89	1.84	0.79

***** Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

For the total factor productivity (TFP) comparisons, the differences among the TFP growth rates is driven by both the different growth rates of the alternative output measures and by differences in the change over time in intermediate inputs of energy, materials, and services. In the TFP model, trends in labor and capital are the same for all three models. Table 6 shows trends in TFP, real output, and inputs under each measurement framework, for the 2000-2021 period in the manufacturing sector.

Table 6. Total Factor Productivity and Component Trends for the Manufacturing Sector by Output Measure, 2000-2021
(Annual Percent Change)

Measure	Value-Added	Sectoral	Gross
TFP	1.03	0.59	0.41
Output	1.20	0.00	-0.22
Combined Inputs[1]	0.17	-0.59	-0.62
Capital	1.64	1.64	1.64
Labor	-1.01	-1.01	-1.01
Energy, Materials and Purchased Services	*not applicable*	-1.48 [2]	-1.09 [3]

[1] Note that labor input is a combination of hours worked and a labor composition adjustment reflecting the effect of shifts in the age, education, and gender composition of the work force on the efficiency of the hours worked.
[2] This trend reflects purchases of intermediate inputs from outside the manufacturing sector, including imported intermediates. Sectoral energy, materials, and services growth rates for 2000-2021 are -5.68, -1.33, and -1.06, respectively.
[3] Gross energy, materials, and services growth rates over the 2000-2021 period are -5.64, -0.92, and -1.09.

Source: BLS Unpublished Manufacturing Production Account

Value-added TFP, comparing value-added output to capital and labor inputs only, has the fastest growth rate at a 1.03 percent annual rate over the 2000-2021 period. Sectoral TFP grows at a 0.59 percent rate, resulting from a 0.00 percent growth in output and a 0.59 percent decline in combined inputs, with energy, materials and services purchased from outside the manufacturing sector declining at a 1.48 percent rate. Thus, the slower growth of sectoral output relative to value-added output is primarily responsible for the difference in TFP growth. These outside-the-sector intermediate inputs include purchases from all other sectors, including agriculture; mining, oil and gas; utilities; construction; trade; transportation and warehousing;

finance; and service sector industries, as well as imported intermediates and purchases from the household and government sectors.

Growth in the gross output based TFP measure over the 2000-2021 period, at 0.41 percent per year, is slower than the 0.59 percent rate measured using sectoral output. This reflects the combination of slower growth in gross output accompanied by a similarly decreasing growth rate of combined capital, labor, and intermediate inputs used to calculate gross TFP. Total energy, materials and services purchased by the manufacturing sector decline at a slightly slower 1.09 percent rate than those intermediates purchased solely from outside the sector. This difference in energy, materials, and services growth was driven by the material inputs produced and consumed within the manufacturing sector that are included in the gross output model and excluded from the sectoral output model. Note that the nominal value of intrasectoral intermediate inputs declined slightly from 53 percent of total intermediates in 2000 to 51 percent in 2021.

Figure 6 compares trends in indexes of TFP based on the three output measures, using a 1997 base year. From this figure, the decline in TFP during business cycle periods is particularly evident. As seen in Table 7, value-added TFP declines more steeply than sectoral and gross TFP during both the 2007-2009 Great Recession and the recent pandemic downturn beginning in 2019. The faster slowdown in value-added TFP from 2019-2020 reflects a steep decline in real value-added output growth of 3.73 percent accompanied by a lesser decline in combined capital and labor input growth of 2.15 percent. By comparison, larger decreases in real sectoral and gross output growth of 7.02 and 6.79 percent are offset by decreases in combined capital, labor, and intermediate input growth of 6.18 and 6.27 percent, respectively, in this 2019-2020 period. The larger 6.27 percent decline in combined capital, labor, and gross intermediate inputs reflects the inclusion of within sector intermediate input purchases that fell by 6.31 percent compared to a decline of 11.49 percent in outside the sector intermediate inputs, for 2019-2020.

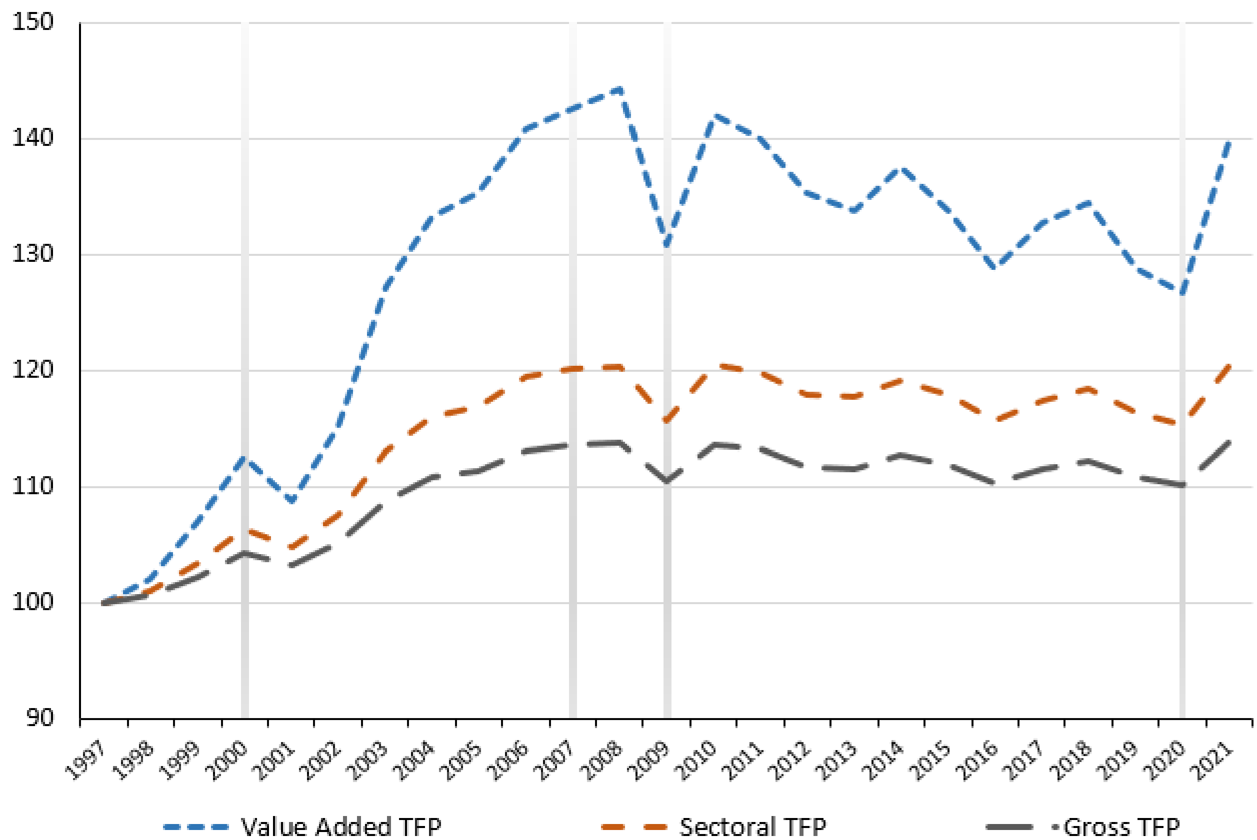
Table 7. Total Factor Productivity by Output Measure
Manufacturing Sector, Selected Periods
(Annual Percent Change)

Time Period	Value-Added	Sectoral	Gross
2000-2021	1.03	0.59	0.41
2000-2007	3.43	1.75	1.21
2000-2001	-3.36	-1.58	-1.03
2001-2007	4.01	2.05	1.41
2007-2019	-0.84	-0.27	-0.20
2007-2009	-4.19	-1.91	-1.31
2009-2019	-0.15	0.07	0.02
2019-2021*	0.55	1.70	1.30
2019-2020	-1.62	-0.89	-0.56
2020-2021	10.15	4.35	3.19

***** Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

Looking at the annual trends, we notice that movements in gross output TFP and sectoral output TFP are similar, as is also found in their measures of output. Recall that the difference between sectoral output and gross output is the intermediate inputs consumed from within the industry.

Figure 6. Total Factor Productivity by Output Measure
Manufacturing Sector, 1997-2021
Index, 1997=100

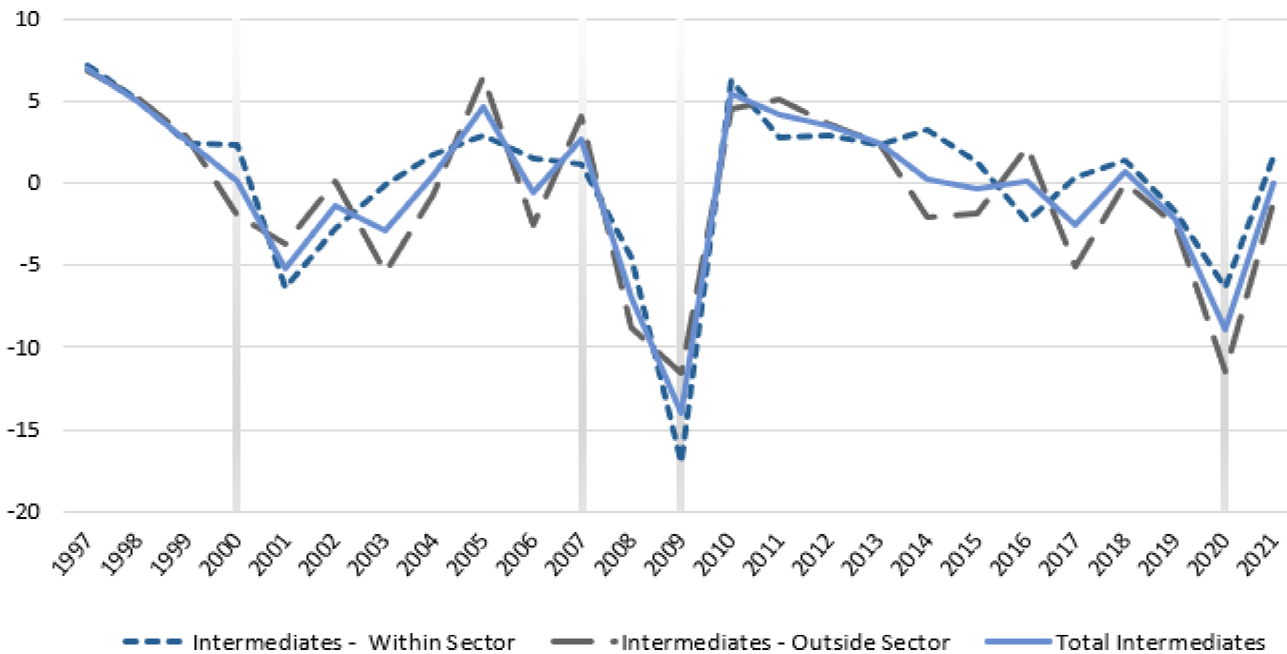


Source: BLS Unpublished Manufacturing Production Account

Figure 7 below presents the trends in total, within-industry, and outside the industry real intermediate inputs for the manufacturing sector, from 1997-2021. Focusing first on within-industry intermediate inputs, we see that intrasectoral intermediate inputs exhibit cyclical movements that are similar to those found in the output measures. Use of intrasectoral intermediate inputs in manufacturing dips during the 2000-2002 period, followed by a large decline during the Great Recession years, 2007-2009, a shallow decline from 2015-2017, and a steep downturn beginning in 2018. However, growth rates for real intermediate inputs purchased outside the manufacturing sector exhibit some additional year to year variation compared to within-industry intermediate inputs. In general, the trends in growth rate movements of outside the sector and within sector intermediates are similar.

Total intermediates, reflecting intermediate inputs purchased from within and outside the sector, has somewhat dampened growth rate movements compared to both within and outside the sector intermediate inputs. The gross TFP model reflects the growth rate movements of total intermediate inputs, i.e., intermediate inputs purchased within the manufacturing sector as well as intermediates purchased outside the sector. Because of this similar pattern of movements in within and outside the industry intermediate input use, trends in sectoral and gross TFP are also similar.

Figure 7. Real Intermediate Inputs: Total, Within-Sector, and Outside-the-Sector Manufacturing Sector, 1997-2021
(Annual Percent Change)



Source: BLS Unpublished Manufacturing Production Account

Manufacturing Industries: Output

We now turn to the 19 manufacturing industries and explore variations in output, primary inputs (capital and labor), and use of intermediate inputs by industry. Table 8 presents the 2021 shares of intermediate inputs relative to gross output, as well as intermediate inputs from within (intrasectoral transactions) and from outside each industry. We see that in 2021 total intermediate input as a share of gross output varies greatly across industries. A low share indicates that production in an industry is more labor or capital intensive, such as in the Computer and Electronic Products industry where intermediate inputs were only 17 percent of gross output. Generally, manufacturing industries consumed intermediate inputs that were valued at over 50 percent of the value of gross output. Petroleum and Coal Products had the highest share of intermediate inputs at 79 percent. Other industries that used large quantities of intermediate inputs include Motor Vehicles, Bodies and Trailers, and Parts, Food and Beverage and Tobacco Products; Primary Metals, and Paper Products.

Table 8. Total, Within-Industry, and Outside-Industry Intermediate Input Purchases relative to Gross Output, by Manufacturing Industry, 2000-2021

NAICS CODE	INDUSTRY	*Share Values, 2021*			*Annual Percent Change in Shares, 2000-2021*		
		Total Intermediate Inputs relative to Gross Output	Within-Industry Intermediate Inputs relative to Gross Output	Outside-Industry Intermediate Inputs relative to Gross Output	Total Intermediate Inputs relative to Gross Output	Within-Industry Intermediate Inputs relative to Gross Output	Outside-Industry Intermediate Inputs relative to Gross Output
MFG	Manufacturing Sector	0.61	0.31	0.30	-0.27	-0.45	-0.08
321	Wood products	0.59	0.15	0.44	-0.87	-0.17	-1.08
327	Nonmetallic mineral products	0.52	0.10	0.42	-0.41	-0.01	-0.50
331	Primary metals	0.71	0.18	0.52	0.04	0.44	-0.09
332	Fabricated metal products	0.58	0.08	0.50	0.25	-0.50	0.39
333	Machinery	0.58	0.10	0.47	-0.33	0.17	-0.44
334	Computer and electronic products	0.17	0.07	0.10	-5.76	-3.83	-6.74
335	Electrical equipment, appliances, and components	0.53	0.08	0.45	-0.89	-0.22	-0.99
3361-3363	Motor vehicles, bodies and trailers, and parts	0.78	0.17	0.61	0.43	-0.69	0.81
3364-3369	Other transportation equipment	0.49	0.12	0.37	-0.65	0.95	-1.06
337	Furniture and related products	0.60	0.06	0.54	0.30	-0.07	0.34
339	Miscellaneous manufacturing	0.45	0.12	0.33	-0.93	1.15	-1.48
311, 312	Food and beverage and tobacco products	0.71	0.17	0.53	-0.12	0.90	-0.41
313, 314	Textile mills and textile product mills	0.66	0.16	0.49	-0.11	-0.74	0.12
315, 316	Apparel and leather and allied products	0.61	0.11	0.50	-0.71	-0.52	-0.75
322	Paper products	0.68	0.23	0.44	0.40	0.68	0.26
323	Printing and related support activities	0.52	0.04	0.48	-0.64	-1.16	-0.59
324	Petroleum and coal products	0.79	0.10	0.68	0.08	2.11	-0.17
325	Chemical products	0.48	0.13	0.35	-0.94	-1.49	-0.72
326	Plastics and rubber products	0.65	0.09	0.57	0.13	1.32	-0.03

Source: BLS Unpublished Manufacturing Production Account

Although the majority of these inputs are purchased from outside their own industry, thirteen of the nineteen manufacturing industries use at least 10 percent of intermediate inputs produced by other firms within their industry. The Paper Products, Food and Beverage and Tobacco Products, and Motor Vehicles industries use the largest shares of within-industry intermediate inputs (intrasectoral transactions) while the Printing and Related Support Activities industry uses the fewest. The relationship between the share of intermediate inputs in output and the share of intrasectoral transactions in output depends on the level of vertical integration within an industry. By construction, the closer the intrasectoral transactions share of gross output is to zero, then the closer the sectoral output measure will be to gross output.

Table 8 also illustrates how these shares have been changing over time. Notice that the total intermediate inputs share of gross output in the Computer and Electronic Products industry in 2021 has decreased substantially over the 2000 to 2021 period, declining at an annual rate of 5.76 percent per year. This industry experienced the largest decline in the share of intermediate purchases in the manufacturing sector. Intrasectoral inputs share of gross output in the Computer and Electronics Products industry has been declining on average 3.83 percent per year from 2000-2021, while the share of inputs from outside the industry has been declining 6.74 percent per year. By comparison, in the Motor Vehicles industry, total intermediate inputs have been growing the fastest at 0.43 percent per year. Intermediate inputs consumed from outside the industry have been increasing by 0.81 percent per year, while the share of intermediate inputs consumed from within the industry has decreased by 0.69 percent annually. The Petroleum and Coal Products industry experienced the largest average annual increase in within-industry intermediate inputs of 2.11 percent, while inputs from outside the industry were declining. In the Plastics and Rubber Products industry we observe intermediate inputs from within the industry growing by an average of 1.32 percent per year over the 2000-2021 period, while inputs from outside the industry are declining at a 0.03 percent rate.

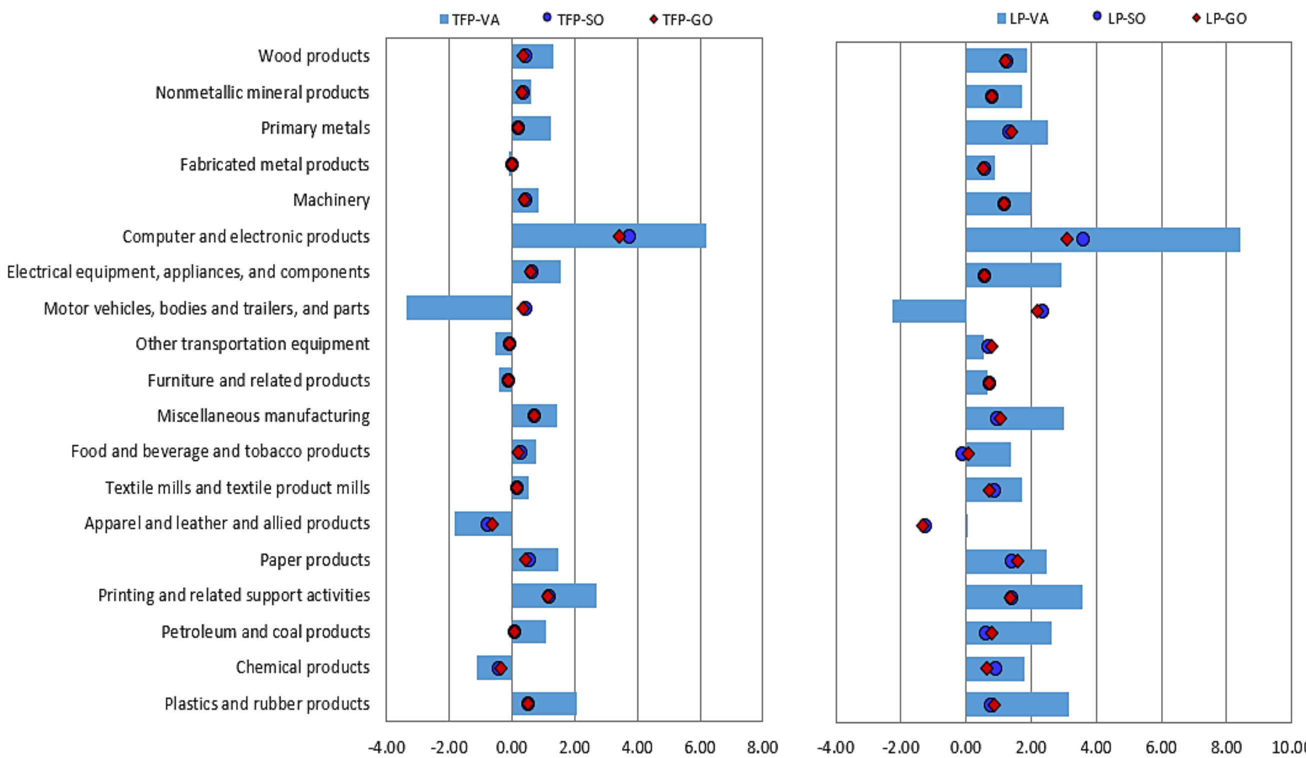
Manufacturing Industries: Productivity

Figure 8 presents labor and total factor productivity growth rates over the 2000-2021 period for the 19 manufacturing industries using value-added, sectoral, and gross output measures.[44] Because all three approaches use the same measure of hours worked growth, the differences in labor productivity growth mimic the differences in output growth across the three concepts.

As noted earlier, labor productivity based on gross output is complicated by double counting output but only counting the hours worked once, causing these measures to be upward biased and as a result, must be interpreted with caution. Fortunately, intrasectoral intermediate inputs are relatively small in manufacturing, limiting the extent of double counting in gross output. For this reason, Figure 8 reveals rather similar growth in labor productivity based on gross and sectoral outputs in each of the nineteen manufacturing industries.

We note that in most industries value-added TFP and labor productivity are growing faster than sectoral and gross output productivity measures. Recall from equation (5) that outsourcing will result in a faster increase in TFP measured using a value-added approach relative to TFP measured using sectoral or gross output. Sectoral and gross output TFP will be impacted by both the decrease in labor input and the increase in intermediate inputs, resulting in less volatile TFP measures than under a value-added approach. Finally, Figure 8 shows the relative difference in TFP and LP growth over 2000-2021 by output measure, for each industry.

Figure 8. Productivity by Output Measure, 2000-2021
Manufacturing Industries
(Annual Percent Change)



Source: BLS Unpublished Manufacturing Production Account

Table 9 presents manufacturing industry TFP growth rates by output measure for the 2000-2007, 2007-2019, and 2019-2021 business cycles. At the industry level, sectoral and gross TFP measures tend to be similar because they differ only by the intermediate inputs produced and consumed within the industry. TFP based on the value-added model removes all intermediate inputs from the model, and as a result, value-added TFP may differ widely from sectoral and gross TFP. For the Manufacturing Sector, all three models show positive growth in TFP for the 2000-2007 and 2019-2021 business cycles followed by negative TFP growth in 2007-2009. However, this pattern is not present for all industries. For example, the Petroleum industry has slower or negative TFP growth in the 2000-2007 and 2019-2021 business cycles than in the 2007-2019 period.

Table 9. Total Factor Productivity Growth by Output Measure, Selected Business Cycles

Annual Percent Change

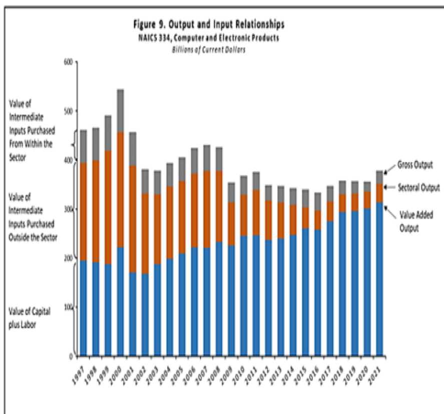
NAICS Industry		TFP - Value-Added Output			TFP - Sectoral Output			TFP - Gross Output		
		2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*
31-33	Manufacturing Sector	3.43	-0.84	4.10	1.75	-0.27	1.70	1.21	-0.20	1.30
321	Wood products	2.51	-0.10	5.93	0.89	0.07	1.11	0.74	0.05	1.00
327	Nonmetallic mineral products	0.04	0.44	3.87	0.13	0.25	1.83	0.08	0.22	1.67
331	Primary metals	1.33	1.83	-2.53	0.63	0.53	-3.06	0.49	0.45	-2.48
332	Fabricated metal products	1.44	-1.79	5.04	0.66	-0.67	1.80	0.57	-0.62	1.59
333	Machinery	3.78	-1.21	3.11	1.60	-0.44	1.82	1.42	-0.39	1.57
334	Computer and electronic products	12.14	3.49	2.46	6.50	2.41	2.30	5.81	2.24	2.16
335	Electrical equipment, appliances, and components	4.46	-0.27	2.67	1.71	-0.12	1.40	1.64	-0.10	1.20
3361-3363	Motor vehicles, bodies and trailers, and parts	5.91	-7.88	-6.52	1.92	-0.34	-0.03	1.54	-0.29	-0.06
3364-3369	Other transportation equipment	2.36	-1.44	-5.05	1.31	-0.50	-2.48	1.17	-0.47	-2.19
337	Furniture and related products	-0.03	-0.06	-3.92	-0.10	0.03	-1.00	0.01	-0.04	-1.09
339	Miscellaneous manufacturing	3.37	0.44	0.82	1.59	0.13	1.12	1.46	0.24	0.79
311-312	Food and beverage and tobacco products	2.49	-2.08	12.58	0.71	-0.48	3.23	0.60	-0.45	2.71
313-314	Textile mills and textile product mills	2.16	-0.35	0.34	0.56	-0.14	0.62	0.61	-0.14	0.48
315-316	Apparel and leather and allied products	3.03	-0.71	-22.54	-1.24	0.68	-7.71	0.44	0.06	-8.06
322	Paper products	2.25	0.13	7.21	0.87	0.04	2.38	0.72	0.04	1.87
323	Printing and related support activities	6.09	1.06	0.84	2.66	0.53	0.10	2.57	0.52	0.05
324	Petroleum and coal products	0.64	1.38	0.94	-0.08	0.18	-0.12	0.00	0.19	-0.15
325	Chemical products	1.92	-4.43	9.02	0.87	-1.85	3.64	0.76	-1.62	3.30
326	Plastics and rubber products	2.12	-0.49	18.76	0.61	-0.06	3.88	0.63	-0.07	3.58

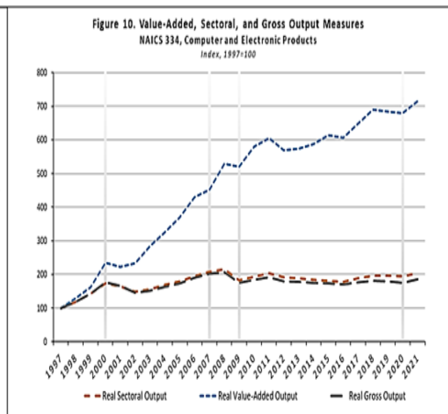
* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

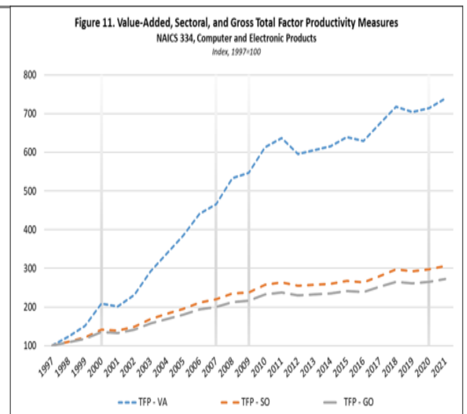
Manufacturing Industries: Examples

The figures below illustrate the output and input relationships from 1997 to 2021 for three selected industries. Computer and Electronic Products (NAICS 334) experienced a decline in both within-industry and out-of-industry intermediate input purchases, while Motor Vehicles, Bodies and Trailers, and Parts (NAICS 3361-3363) experienced substantially faster growth in out-of-industry intermediate input purchases than in within-industry intermediates; and Plastics and Rubber Products (NAICS 326) experienced faster growth in within-industry intermediate input purchases compared to outside-the industry intermediates.

Figure 9 presents nominal output in the Computer and Electronic Products industry using the three output concepts. In this industry, nominal capital and labor inputs are increasing while nominal values of *both within-industry and outside-of-industry intermediate inputs are declining over time*. These capital, labor, and intermediate input growth patterns over time are reflected in our three output measures. From our nominal data, we see that nominal value-added output (value of capital plus labor) increased at an annual rate of 1.6 percent, while nominal sectoral and gross output both declined at 1.2 and 1.7 percent respectively from 2000 to 2021. The current dollar value of intermediate inputs purchased outside the sector declined steadily at a rate of 5.6 percent from 2000 to 2007 and then rather dramatically at an 11.5 percent rate from 2007 to 2019 before returning to a positive 1.8 percent rate from 2019 to 2021. Nominal purchases of intermediate inputs from within the industry (intrasectoral transactions) also declined from 2000 to 2007 at a 6.7 percent rate. From 2007-2019, within-industry intermediate input purchases declined at a slower 6.1 percent rate before growing at 3.0 percent from 2019-2021.







Annual Percent Change	NOMINAL					REAL					Total Factor Productivity		
	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	TFP_{VA}	TFP_{SO}	TFP_{GO}
2000-2021	1.6	-1.2	-1.7	-5.5	-8.3	5.4	0.8	0.3	-3.6	-8.2	6.2	3.7	3.4
2000-2007	-0.1	-2.7	-3.3	-6.7	-5.6	9.8	2.6	2.0	-1.7	-5.0	12.1	6.5	5.8
2007-2019	2.5	-1.1	-1.6	-6.1	-11.5	3.5	-0.5	-1.0	-5.6	-10.9	3.5	2.4	2.2
2019-2021	3.0	2.9	2.9	3.0	1.8	2.2	1.9	1.9	2.0	-2.0	2.5	2.3	2.2

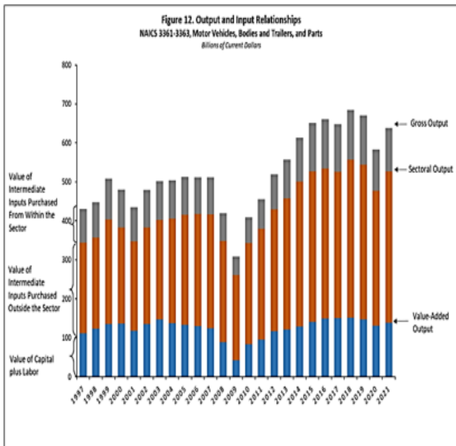
Figure 10 displays the related real value-added, sectoral, and gross output measures for Computer and Electronic Products. Real gross output for the Computer and Electronic Products industry increased at a 0.3 percent rate over the 2000-2021 period, compared with a 5.4 percent increase for real value-added output and a 0.8 percent increase for real sectoral output in this industry. This slower growth in real gross output compared to real sectoral output reflects both a 3.6 percent decline in real intermediate input purchases from within this industry and a much larger 8.2 percent decline in growth of real intermediate input purchases outside the Computer and Electronic Products industry. The current value of within-industry intermediates fell at a rate of 5.5 percent annually, while the price of within-industry intermediate inputs declined at a slower 2.0 percent rate. The faster growth in real value-added output compared to sectoral output can be explained in the same way, by examining growth in intermediate inputs. Recall that sectoral output differs from value-added output by the amount of intermediate inputs purchased from outside the industry.

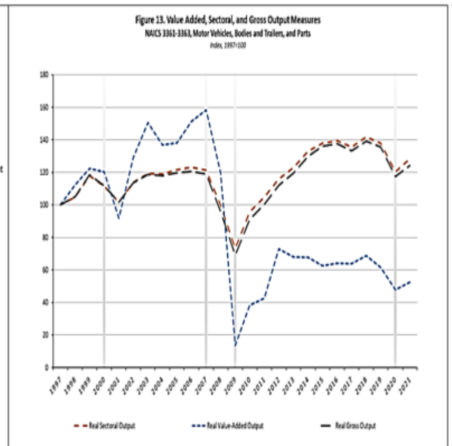
During the 2000-2021 period, real imported and out-of-industry purchases of intermediate inputs declined at a rate of 8.2 percent. This reflects an 8.3 percent decline in the nominal value of intermediate inputs from outside this industry and a 0.2 percent decline in the prices of these inputs. Because real intermediate input purchases from outside the industry fell significantly from 2000-2021, the growth rate of real sectoral output is less than that of value-added output. From 2000-2007, real sectoral output was outpaced by nearly four times faster real value-added output growth; real value-added output grew at a 9.8 rate, compared to 2.6 for real sectoral output during this period. Again, this can be explained by examining industry purchases of intermediate inputs by source. Real imported and outside the industry purchases of intermediate inputs declined at a 5.0 percent annual rate. This decline reflects nominal outside-the industry intermediates declining at a 5.6 percent rate while their prices declined at a 0.6 rate. From 2007-2019, real value-added output growth declined to 3.5, while real sectoral output growth also fell to 0.5. In this case, real imported and out-of-sector purchases of intermediate inputs declined at an annual rate of 10.9, with nominal out-of-sector intermediate input growth falling at an 11.5 percent rate and prices falling at a rate of 0.6 over the 2007-

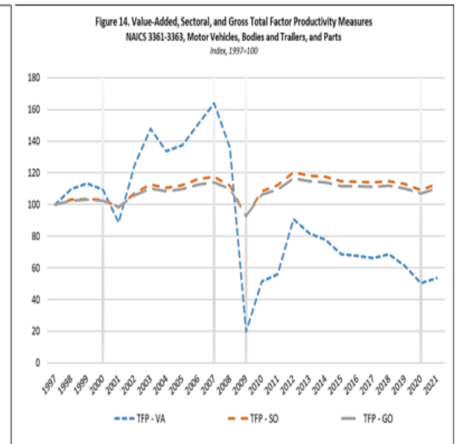
2019 period. The 2019-2021 period, encompassing the Covid pandemic and related massive federal economic support for industry production, saw slow but positive real output growth of 2.2, 1.9, and 1.9 for value-added, sectoral, and gross output measures, respectively. Nominal purchases of intermediate inputs similarly grew positively, at a 3.0 percent rate for within-industry intermediate inputs and a slower 1.8 percent rate for intermediates purchased outside the Computer industry. Within-industry intermediate input prices increased at a 1.0 percent rate, resulting in positive real within-industry intermediate input growth of 2.0, while outside-the-industry intermediates experienced a larger 3.9 percent rate of price increase resulting in real outside the industry intermediate inputs declining at a 2.0 percent rate. This larger increase in price for intermediate inputs acquired outside the Computer industry reflects the effects of global production and shipping difficulties occurring during the initial pandemic years.

Figure 11 displays the different trends in total factor productivity measures in the Computer and Electronics industry, derived using the alternative output measures, for the 1997-2021 period. TFP based on value-added output has a higher positive trend of 6.2 percent in the 2000-2021 period, compared to the slower TFP growth rates of 3.7 and 3.4 percent when measured using the sectoral and gross output models, respectively. Real value-added output increases at a 5.4 percent rate and is offset by declining combined capital and labor input growth of 0.7 percent in this period. This compares to the sectoral and gross TFP measures where real output growth of 0.8 and 0.3 percent is offset by a drop in combined capital, labor, and intermediate input growth of 2.9 and 3.0 percent, respectively. In the gross model, total input growth is slower than in the sectoral model, reflecting the inclusion of intermediate inputs purchased within the industry that fell at a 3.6 percent rate.

In our second industry example, Motor Vehicles, Bodies and Trailers, and Parts, we see that the pattern of use of capital, labor, and intermediate inputs in the Motor Vehicles industry over time differs markedly from the use of these inputs in the Computer and Electronic Products industry. In the Motor Vehicles industry, *purchases of intermediate inputs from outside the industry increased* in nominal value by 2.2 percent during the 2000-2021 period. Figures 12 and 13 portray the relationships between within and outside the industry intermediate input growth and output measures for the Motor Vehicle industry. The share of current dollar intermediate inputs purchased outside the industry, relative to current dollar gross output, increased steadily in the Motor Vehicles industry, from 51 percent of gross output in 2000 to 61 percent by 2021. By comparison, in Computer and Electronic Products, the share of intermediate inputs purchased from outside the industry relative to gross output declined substantially from 43 percent in 2000 to 10 percent by 2021. Changes in nominal purchases of intermediate inputs from within the industry (intrasectoral transactions) were more similar between the two industries. Within-industry intermediate input purchases comprised 20 percent of gross output for the Motor Vehicle industry in 2000, falling to a low of 15 percent in 2009 before increasing again to 17 percent, and in the Computer industry, intermediate inputs purchased within the industry initially comprised 16 percent of current dollar industry gross output and fell to 7 percent of gross output by 2021. Nominal value-added output (value of capital plus labor) in Motor Vehicles is a much smaller share of nominal gross output than in Computer and Electronic Products. In the Motor Vehicles industry, nominal value-added as a share of nominal gross output is 28 percent in 2000, reaching a high of 29 percent in 2003. Following the Great Recession of 2007-2009, this share dropped to a low of 14 percent in 2009, before recovering to 22 percent in 2021. By comparison, value-added as a share of gross output in the Computer industry climbed relatively steadily from 41 percent to 83 percent by 2021.





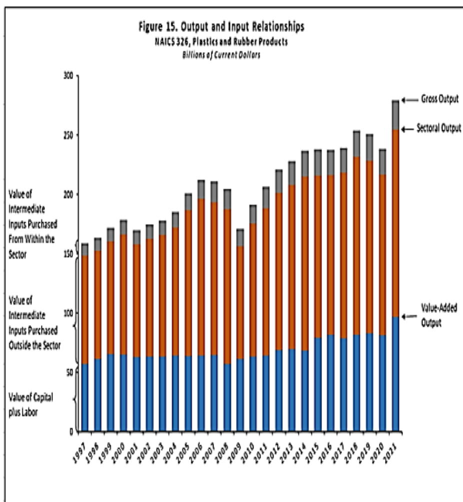


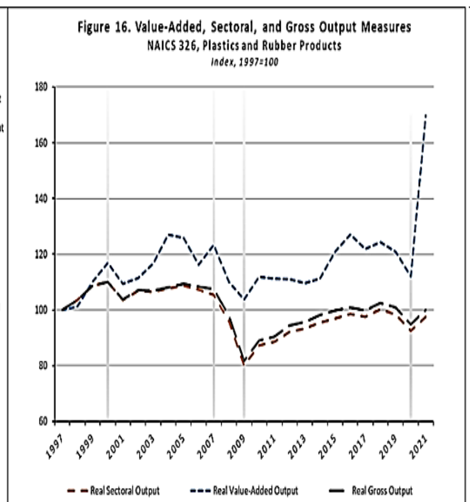
Annual Percent Change	NOMINAL					REAL					Total Factor Productivity		
	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	TFP_{VA}	TFP_{SO}	TFP_{GO}
2000-2021	0.1	1.5	1.4	0.7	2.2	-3.9	0.7	0.5	-0.2	0.5	-3.4	0.4	0.3
2000-2007	-1.4	1.2	0.9	-0.4	2.5	4.0	1.2	0.9	-0.4	-0.1	5.9	1.9	1.5
2007-2019	1.4	-1.7	2.3	2.4	2.6	-7.6	1.1	1.1	1.2	1.6	-7.9	-0.3	-0.3
2019-2021	-3.1	-1.7	-2.4	-5.8	-1.2	-7.7	-3.6	-4.3	-7.7	-4.4	-6.5	0.0	-0.1

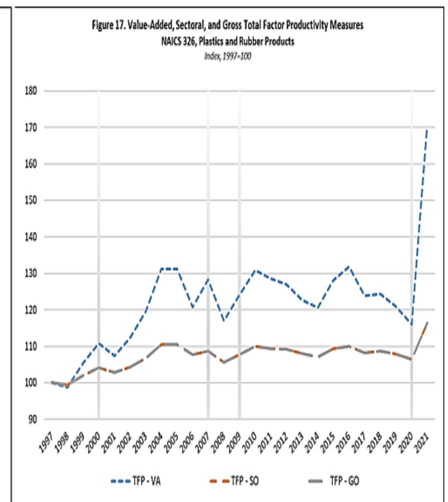
Figure 13 displays real value-added, sectoral, and gross output measures for the Motor Vehicle industry from 1997 to 2021. While real gross output for Motor Vehicles increased at a 0.5 percent annual rate from 2000-2021, value-added output decreased at a rate of 3.9 and sectoral output grew at a 0.7 percent rate. The faster growth in gross and sectoral output growth rates than in value-added output during this period reflects the positive growth rate for real intermediate inputs purchased from outside the Motor Vehicles industry. We see that real intermediate inputs purchased within the industry declined at a 0.2 percent rate, as a result of a 0.7 percent growth in current dollar within-industry intermediate inputs and a larger 0.9 percent price increase during this period. At the same time, purchases of real intermediate inputs outside the industry grew at a 0.5 percent rate. This 0.5 percent rate reflects a 2.2 percent increase in the current value of outside the industry intermediate inputs and a 1.7 percent increase in outside the industry intermediate input prices. Looking at output measures and sources of intermediate inputs in business cycle subperiods, however, reveals a different pattern. From 2000-2007, purchases of real intermediates from within and outside the industry declined, resulting in value-added output growth exceeding both gross and sectoral output growth. Real imported and outside of the industry purchases of intermediate inputs fell at a rate of 0.1, while nominal intermediates increased at a rate of 2.5 and their prices grew at a rate of 2.6 percent. Real sectoral output growth of 1.2 percent exceeded real gross output growth of 0.9. This reflects a 0.4 percent decline in nominal purchases of within-industry intermediates and a slight decline of 0.01 percent in growth of within-industry intermediate prices. In the more recent 2007-2019 period, including both the Great Recession years and the recovery years following this recession, purchases of within and outside the sector intermediate inputs again showed positive growth as a result of strong growth in nominal intermediate input purchases and somewhat slower growth in prices. Both sectoral and gross output measures grew faster than value-added output as a result. Nominal purchases of intermediate inputs from outside the industry increased at a 2.6 percent rate while prices of these inputs increased at a 0.9 percent rate. The nominal value of intermediate inputs purchased from within the industry grew at a 2.4 percent rate and within-industry intermediate input prices increased at a slower 1.2 percent pace. During the 2019-2021 period, real value-added output declined by 7.7 percent. Nominal purchases of both within and outside the industry intermediate inputs declined by 5.8 and 1.2 percent respectively. Within-industry intermediate input prices experienced a 2.0 percent growth rate while outside the industry intermediate input prices increased at a rapid rate of 3.4. As a result, real within and outside the industry intermediate input growth similarly declined by 7.7 and 4.4 percent per year.

Figure 14 displays total factor productivity trends for the Motor Vehicle industry over the 1997-2021 period. TFP based on value-added output grew at a steady annual 5.9 percent trend from 2000 until the beginning of the Great Recession in 2007, when it plummeted as real value-added output in the industry declined sharply, reaching a low point in 2009 before beginning to recover at 8.6 percent per year from 2009 to 2021. This dramatic decline in TFP based on value-added output during the 2007-2009 recession reflects the movements of capital and labor inputs only, with capital input declining at a 2.3 percent rate and labor growth falling at an historic 18.6 percent rate in this period. With a 3.4 percent declining rate for the 2000-2021 period, TFP based on value-added output has a slower trend growth rate than either the sectoral or gross output based TFP measures from 2007 to 2019. Over the entire 2000-2021 period, real value-added output decreases at a 3.9 percent rate and is offset by declining combined capital and labor input growth of 0.5 percent. This compares to growth in sectoral and gross TFP measures of 0.4 and 0.3 percent, respectively. Real sectoral output growth of 0.7 percent is offset by combined capital, labor, and intermediate input growth at a 0.2 percent rate while real gross output growth of 0.5 percent is similarly offset by increasing combined input growth of 0.2 percent.

Our final industry example is Plastics and Rubber Products. In this industry, we see that *purchases of intermediate inputs produced within the industry have increased substantially* over time relative to purchases of intermediates from outside the industry. As shown in Figure 15 below, nominal value-added output is a relatively stable share of current dollar gross output from 1997-2021. Nominal value-added output increased at an average annual rate of 1.9 percent from 2000-2021, while nominal sectoral and gross output both increased by 2.1 and 2.2 percent, respectively. The current dollar value of intermediate inputs purchased outside this industry grew at a 2.1 percent rate while the value of intermediate inputs purchased from within this industry increased at a 3.5 percent rate.







Annual Percent Change	NOMINAL					REAL					Total Factor Productivity		
	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	Value-Added Output	Sectoral Output	Gross Output	Intermediates Purchased Within the Industry	Intermediates Purchased Outside the Industry	TFP_{VA}	TFP_{SO}	TFP_{GO}
2000-2021	1.9	2.1	2.2	3.5	2.1	1.8	-0.6	-0.5	0.9	-1.5	2.1	0.5	0.5
2000-2007	-0.1	2.2	2.4	5.8	3.5	0.8	-0.6	-0.3	3.0	-1.1	2.1	0.6	0.6
2007-2019	2.1	1.4	1.4	1.8	1.0	-0.2	-0.6	-0.5	-0.2	-0.9	-0.5	-0.1	-0.1
2019-2021	8.0	5.6	5.6	5.7	4.1	18.5	-0.4	-0.4	-0.3	-6.4	18.8	3.9	3.6

Figure 16 presents real value-added, sectoral, and gross output measures for the Plastics and Rubber Products industry. Over the 2000-2021 period, real value-added output increased by 1.8 percent per year, while real sectoral and gross output declined by 0.6 and 0.5 percent, respectively. Because gross output includes the value of intermediate inputs purchased within the industry, real gross output reflects the additional growth of real intrasectoral transactions. Real within-industry intermediate inputs increased at a 0.9 percent rate, reflecting growth of 3.5 percent points in nominal within-industry intermediate input purchases and a slower 2.6 percent increase in within-industry intermediate input prices. Real value-added output grew faster than real sectoral output in this period, due to a 1.5 percent decline in purchases of intermediate inputs from outside the Plastics and Rubber Products industry. While nominal purchases of intermediate inputs purchased outside this industry increased by 2.1 percent, prices of out-of-industry intermediate inputs increased faster, by 3.7 percent.

Looking at changes within business cycle periods, we see that real sectoral output declined at a 0.6 rate while real value-added output grew by 0.8 percent from 2000-2007. Real imported and out-of-industry purchases of intermediate inputs declined by 1.1 percent, while nominal intermediates increased at a 3.5 percent rate and prices for out-of-industry intermediates increased by 4.6 percent. Real gross output declined from 2000-2007 by a relatively smaller 0.3 percent, reflecting growth in within-industry real intermediate inputs of 3.0 percent. This growth in within-industry real intermediate inputs resulted from a 5.8 percent increase in nominal purchases of intermediate inputs accompanied by a 2.8 percent increase in the prices of these intermediate inputs. In the latest business cycle period, 2007-2019, real value-added output decreased at a 0.2 percent rate while real gross and sectoral output declined by 0.5 and 0.6 percent, respectively. Real imported and out-of-industry purchases of intermediate inputs declined by 0.9 percent, reflecting nominal growth of 1.0 percent and price growth of 2.0 percent. Real within sector purchases of intermediate inputs declined by 0.2 percent due to an increase in nominal within-industry intermediate input purchases of 1.8 percent and an increase in prices of 2.0 percent. Real value-added output during the 2019-2021 period accelerates at an 18.5 percent annual rate, while both real sectoral and gross output growth decline at 0.4

percent rates. The decline in sectoral output reflects a large decline in outside the industry intermediate input growth of 6.4, resulting from a 4.1 percent increase in nominal purchases of intermediate inputs from outside the industry accompanied by an 11.3 percent growth in prices of these inputs. Within-industry intermediate inputs declined slightly at a 0.3 percent rate, reflecting a 5.7 percent increase in purchases of intermediate inputs within industries and a slightly faster 6.0 percent increase in the price of these inputs.

Figure 17 presents TFP measures for the Plastics and Rubber Products industry by output measure. From 2000-2021, value-added TFP increased at a 2.1 percent rate while sectoral and gross TFP both have slower trends of 0.5 percent. The 0.6 percent decline in real sectoral output is offset by a decline in combined capital, labor, and sectoral intermediate input growth of 1.1 percent from 2000-2021. Similarly, falling real gross output growth of 0.5 and decreasing combined capital, labor, and gross intermediate input growth of 1.0 percent results in a gross TFP growth of 0.5 percent. The similarity between sectoral and gross TFP results from the offsetting effect of sectoral and gross intermediate inputs relative to trends in real sectoral and gross output. Sectoral intermediate input declines at a 1.5 percent rate, while gross intermediate input declines at a 1.3 growth rate. Because both within and outside the industry intermediate inputs are included in gross intermediates, and real within-industry intermediates increased at a 0.9 percent rate while real outside the industry intermediates declined at a 1.5 percent rate, we see a more moderate decline in gross intermediate inputs and a similar gross TFP value.

Industry Contributions to Manufacturing Sector Performance

The manufacturing sector is an important part of the U.S. economy. Yet looking at the manufacturing sector as a whole can mask the varied performance of the many diverse industries that make up this goods-producing sector. An industry's performance along with its relative size will determine how the performance of an individual industry contributes to manufacturing sector performance. Evaluating industry contributions to manufacturing sector performance reveals which industries are creating a drag on the sector, and which are enhancing it. For example, in the manufacturing sector, TFP grew at an annual rate of 0.60 percent per year from 2000-2021.[45] Yet across industries within manufacturing, TFP growth ranged from an increasing rate of 3.87 percent in the Computer and Electronic Products industry to a declining rate of 0.47 percent in the Chemical Products industry.

In this section, we first present industry contributions to manufacturing sector performance using the BLS published TFP and related data. We include a discussion of changes in industry average shares, or relative size, and industry TFP growth. We also discuss the considerable variation in TFP across industries and industry contributions to manufacturing TFP across business cycles. Next, we investigate how industry contributions are impacted when TFP is measured using three alternative output concepts.

BLS Industry Contribution Measures

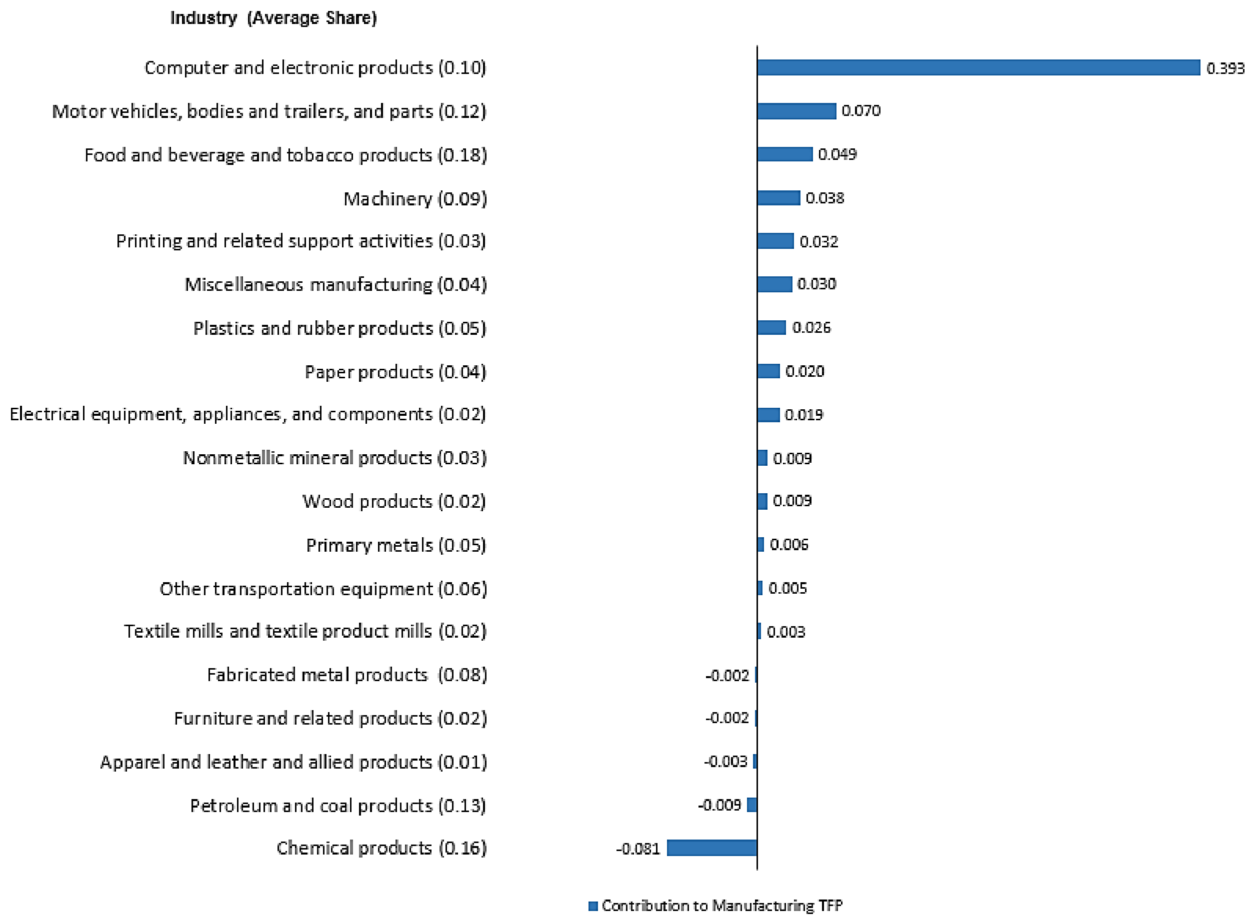
To determine how industries contribute to manufacturing sector productivity, we weight the TFP growth rates for each industry by the value of that specific industry's share of sector output. The weights for each industry are the industry's current dollar sectoral output share of the aggregate manufacturing sector's sectoral output.[46] The industry weights reflect not only the contributions of the primary inputs – capital and labor – to production but also the contributions of the intermediate inputs – energy, materials, and purchased services. These industry weights will sum to a value greater than one since the numerator – the value of sectoral output in each industry – will include intermediate inputs purchased from outside the industry, while the denominator includes only the value of intermediate inputs purchased outside the aggregate manufacturing sector. TFP growth in any one industry will tend to augment productivity growth in other industries that use other manufactured goods in their production processes.[47]

Figure 18 shows the relative contribution of each industry to manufacturing sector TFP growth from 2000-2021 using BLS published data. The Computer and Electronic Products industry leads both in TFP growth and contribution to manufacturing sector TFP for this period. This result reflects not only the highest manufacturing industry TFP growth but a relatively large average industry share of 0.10 for the 2000-2021 period. By contrast, the Printing and Related Support Activities industry had a relatively strong TFP growth rate of 1.17 percent per year yet contributed only 0.032 percentage points to growth in manufacturing sector TFP due to a small 0.03 industry share. The Motor Vehicles industry and the Paper Products industry experienced similar TFP growth rates of 0.53 and 0.52 percent respectively but made contributions of 0.070 and 0.020 percentage points to manufacturing sector TFP growth over the 2000-2021 period. This is because the Motor Vehicles industry's share of sector output (0.12) is three times larger than the Paper Products industry's share (0.04).

Figure 18. Industry Contributions to Manufacturing Sector Total Factor Productivity Growth

Manufacturing Industries, 2000-2021

Annual Percent Change



Source: BLS Published Data

Table 10 presents each industry's contribution to manufacturing sector TFP growth, industry average share, and industry TFP growth for 2000-2021. Combining industry TFP measures with information on the industry's share of manufacturing sector final demand enables those industries driving or detracting from sector level TFP growth to be identified in any given period.

Table 10. Industry Contributions to Manufacturing Sector Total Factor Productivity Growth and Related Components, 2000-2021

NAICS Industry		Industry Contribution to Manufacturing TFP Growth *Annual Percent Change*	Industry Share *Average*	Industry TFP *Annual Percent Change*
31-33	Manufacturing Sector			0.60
321	Wood products	0.009	0.02	0.39
327	Nonmetallic mineral products	0.009	0.03	0.37
331	Primary metals	0.006	0.05	0.15
332	Fabricated metal products	-0.002	0.08	0.00
333	Machinery	0.038	0.09	0.48
334	Computer and electronic products	0.393	0.10	3.87
335	Electrical equipment, appliances, and components	0.019	0.02	0.63
3361-3363	Motor vehicles, bodies and trailers, and parts	0.070	0.12	0.53
3364-3369	Other transportation equipment	0.005	0.06	0.12
337	Furniture and related products	-0.002	0.02	-0.08
339	Miscellaneous manufacturing	0.030	0.04	0.72
311-312	Food and beverage and tobacco products	0.049	0.18	0.24
313-314	Textile mills and textile product mills	0.003	0.01	0.20
315-316	Apparel and leather and allied products	-0.003	0.01	-0.37
322	Paper products	0.020	0.04	0.52
323	Printing and related support activities	0.032	0.03	1.17
324	Petroleum and coal products	-0.009	0.13	0.07
325	Chemical products	-0.081	0.16	-0.47
326	Plastics and rubber products	0.026	0.05	0.44

* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Published Data

Industry Contributions Across Business Cycles

Looking at changes in industry contributions, industry shares, and TFP growth across business cycles provides insights into how the manufacturing sector has evolved over the past 20 years. The 2000-2021 period includes three business cycles: 2000-2007, 2007-2019, and 2019-2021.[48] Table 11 presents each industry's contribution to manufacturing sector TFP growth, industry average share, and industry TFP growth, across the last 3 business cycles.[49]

Table 11. Industry Contributions to Manufacturing Sector Total Factor Productivity Growth and Related Components, Selected Business Cycles

NAICS Industry		Industry Contribution to Manufacturing TFP Growth *Annual Percent Change*			Industry Share *Average*			Industry TFP *Annual Percent Change*		
		2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*
31-33	Manufacturing Sector							1.74	-0.18	1.32
321	Wood products	0.024	0.000	0.010	0.03	0.02	0.03	0.90	0.13	0.20
327	Nonmetallic mineral products	0.004	0.006	0.051	0.03	0.03	0.03	0.13	0.30	1.62
331	Primary metals	0.027	0.029	-0.205	0.05	0.05	0.05	0.66	0.54	-3.90
332	Fabricated metal products	0.051	-0.053	0.126	0.08	0.08	0.09	0.64	-0.62	1.46
333	Machinery	0.129	-0.037	0.171	0.09	0.09	0.09	1.53	-0.38	2.00
334	Computer and electronic products	0.738	0.217	0.240	0.13	0.09	0.08	6.59	2.48	2.84
335	Electrical equipment, appliances, and components	0.046	-0.001	0.046	0.03	0.02	0.03	1.60	-0.07	1.43
3361-3363	Motor vehicles, bodies and trailers, and parts	0.253	-0.032	0.037	0.13	0.11	0.13	1.92	-0.24	0.40
3364-3369	Other transportation equipment	0.079	-0.019	-0.110	0.06	0.07	0.06	1.40	-0.29	-1.85
337	Furniture and related products	0.000	-0.001	-0.011	0.02	0.02	0.02	-0.07	-0.01	-0.56
339	Miscellaneous manufacturing	0.061	0.008	0.056	0.04	0.04	0.04	1.48	0.13	1.57
311-312	Food and beverage and tobacco products	0.118	-0.084	0.607	0.17	0.19	0.20	0.69	-0.45	2.92
313-314	Textile mills and textile product mills	0.010	-0.001	0.008	0.02	0.01	0.01	0.56	-0.12	0.84
315-316	Apparel and leather and allied products	-0.011	0.003	-0.014	0.01	0.00	0.00	-1.42	0.84	-3.84
322	Paper products	0.036	0.001	0.078	0.04	0.04	0.04	0.87	0.05	2.15
323	Printing and related support activities	0.078	0.012	-0.004	0.03	0.02	0.02	2.59	0.57	-0.17
324	Petroleum and coal products	-0.111	0.053	-0.020	0.10	0.16	0.12	-0.12	0.21	-0.16
325	Chemical products	0.144	-0.289	0.384	0.15	0.17	0.17	0.89	-1.69	2.22
326	Plastics and rubber products	0.033	-0.001	0.166	0.06	0.05	0.06	0.55	-0.02	2.88

* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Published Data

Industry contributions over the three business cycles are more varied and reflect changes in individual industry TFP growth rates and shifts in industry shares. The Computer industry, with the highest TFP growth of any manufacturing industry during the 2000-2007 and 2007-2019 business cycles, is the largest contributor to manufacturing sector growth in these periods. However, this industry's average share of sector output is only fourth highest in 2000-2007 and sixth highest in 2007-2019. During the 2019-2021 period, encompassing the Covid pandemic years, the Food and Chemical industries' contributions to manufacturing final demand exceed those of the Computer industry, resulting primarily from large increases in TFP growth in both industries, compared to the previous cycle. Previously, the Food and Chemical industries ranked as the third and fifth highest contributors to manufacturing TFP in the 2000-2007 cycle and the eighteenth and nineteenth highest, respectively, during the 2007-2019 cycle. With shares consistently among the top three industries since 2000, this variation in industry contribution by the Food and Chemical industries is driven by fluctuation in these industries' TFP growth across business cycles.

Table 12 highlights the top five contributing industries for each of the three business cycles. The Computer and Electronic Products industry was by far the largest contributor to manufacturing sector TFP growth in the 2000-2007 cycle. Its contribution was nearly three times as large as the second highest contributing industry during this period, Motor Vehicles. Although TFP growth in the Computer industry falls by half in the 2007-2019 period, this industry continues as the top contributor with a smaller yet still strong industry average share. The Petroleum and Coal products industry moves from least contributing industry over the 2000-2007 period to second highest contributor in the 2007-2019 period, reflecting a jump in output share from 0.10 during 2000-2007 to 0.16 in the 2007-2019 cycle, and a corresponding increase in TFP growth from a declining rate of 0.12 percent per year to an increasing rate of 0.21 percent. This reflects the historic increase in U.S. oil and gas production from 2010 to 2020, as a result of the "shale boom" and increased fracking.[50] The dynamics of the 2019-2021 post pandemic recovery period led to a redistribution of the top contributing industries. The Food and Beverage and Tobacco Products industry becomes the top contributor in this period, with the strongest industry share of 0.20 and highest industry TFP growth of 2.92 percent annual growth. The Chemical Products industry moves to the second highest contributing industry position, with its typically high industry share and rapid TFP growth of 2.22 percent. The Computer industry, while still a large contributor to sector level TFP during the 2019-2021 period, falls to third highest. The Plastics and Rubber Products industry moves to fifth highest contributing industry reflecting its position as the industry with the second fastest TFP growth in this period.

Table 12. Top Five Contributors to Manufacturing Sector TFP Growth and Related Contribution Components in Selected Business Cycles

NAICS Industry		Industry Contribution to Manufacturing TFP Growth *Annual Percent Change*	Industry Share *Average*	Industry TFP *Annual Percent Change*
2000-2007				
334	Computer and electronic products	0.738	0.13	6.59
3361-3363	Motor vehicles, bodies and trailers, and parts	0.253	0.13	1.92
325	Chemical products	0.144	0.15	0.89
333	Machinery	0.129	0.09	1.53
311-312	Food and beverage and tobacco products	0.118	0.17	0.69
2007-2019				
334	Computer and electronic products	0.217	0.09	2.48
324	Petroleum and coal products	0.053	0.16	0.21
331	Primary metals	0.029	0.05	0.54
323	Printing and related support activities	0.012	0.02	0.57
339	Miscellaneous manufacturing	0.008	0.04	0.13
2019-2021*				
311-312	Food and beverage and tobacco products	0.607	0.20	2.92
325	Chemical products	0.384	0.17	2.22
334	Computer and electronic products	0.240	0.08	2.84
333	Machinery	0.171	0.09	2.00
326	Plastics and rubber products	0.166	0.06	2.88

*Note that 2019-2021 is an incomplete business cycle.
Source: BLS Published Data

Different Output Concepts and Industry Contributions

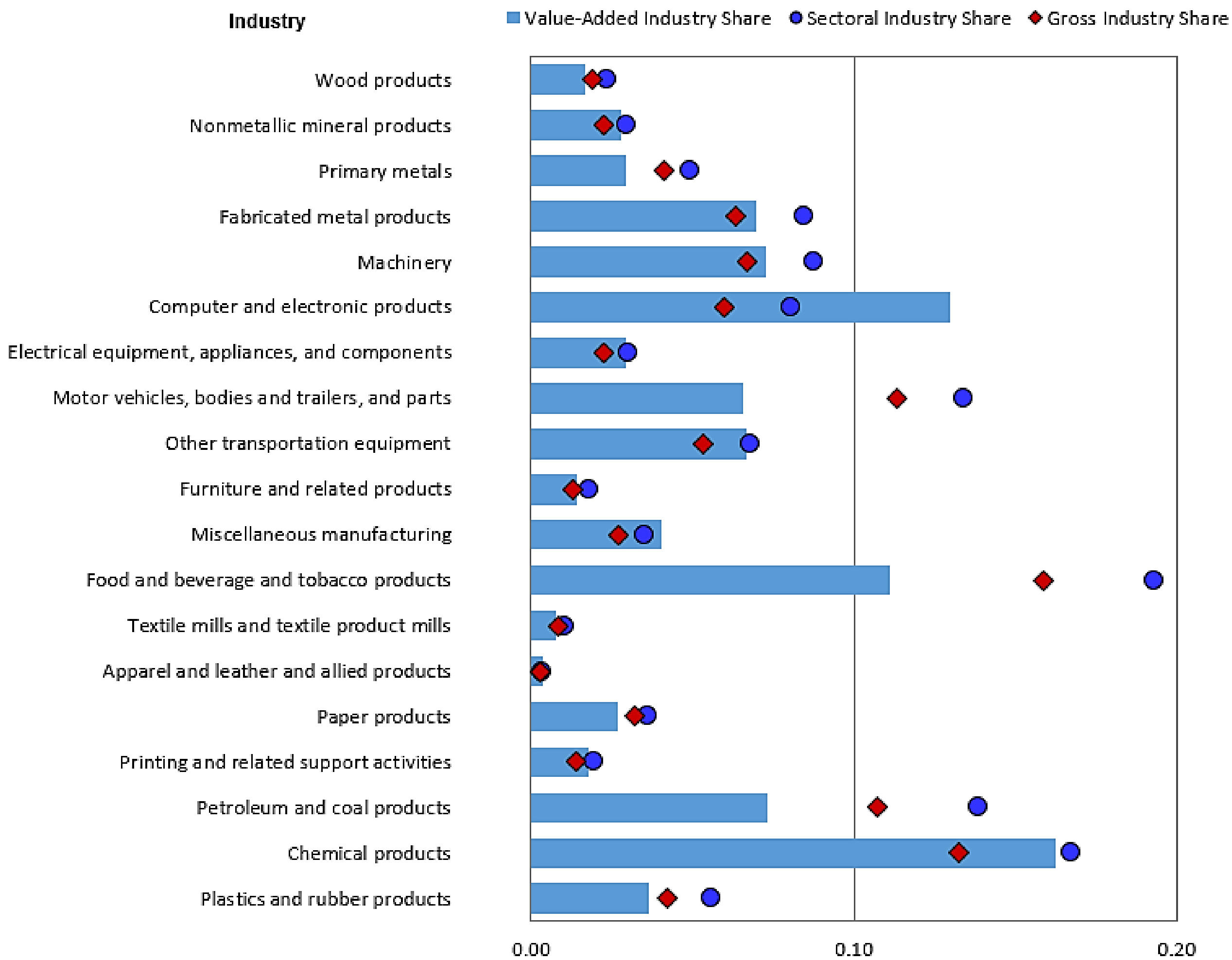
As discussed above, choice of output measure has implications for the measurement and interpretation of productivity. Here we compare industry contributions to manufacturing sector TFP using experimental value-added, sectoral, and gross output measures developed using our research production account for the manufacturing sector and industries.[51] Recall that the BLS TFP data for manufacturing rely on a sectoral output definition. In this section, we analyze differences among industry contributions based on alternative output concepts and discuss the underlying causes of differences in these measures.

To estimate how an industry i contributes to manufacturing sector (MN) TFP, we construct weights for each industry as the industry's current dollar output share of the manufacturing sector based on the output concept used. For example, when using the value-added framework to estimate industry contributions to sector (MN) TFP, we construct industry weights as the industry's current dollar value-added output share of value-added for the manufacturing sector VA_i/VA_{MN}.[52] In the gross output framework, weights for each industry are the industry's current dollar gross output share of manufacturing sector gross output, GO_i/GO_{MN}.[53] The gross output model double counts the value of intermediate inputs produced and sold within an industry, both when sold to another producer for use in production and in the value of the producer's final product. For this reason, the gross output model is seldom recommended for industry contribution analysis. In the value-added and gross output models, industry weights will sum to one. Within the sectoral framework, weights for each industry are the industry's current dollar sectoral output share of sectoral output for the manufacturing sector $SO_i/SO_{MN.}$ As noted above in our BLS published measures, the industry weights in the sectoral output model will sum to a value greater than one because total factor productivity growth in any one industry will tend to augment productivity growth in other industries.[54]

Figure 19 compares industry shares using the three different output concepts, for the year 2019. Note that because sectoral output shares will sum to a value greater than one, sectoral output shares tend to be larger than industry shares using the other two output concepts, for most industries. This is true throughout the 2000-2021 period. In addition, gross output for the manufacturing sector double counts the value of intermediate inputs and is quite large, resulting in gross output industry shares that are uniformly and substantially less than sectoral output shares.[55] As evident in Figure 19, sectoral output shares are higher than value-added shares for sixteen of the nineteen industries in 2019. For example, the sectoral output share in Food and Beverage is much greater than the value-added output share in 2019. This can be explained by noting that Food and Beverage has the highest share of sectoral intermediate inputs among all manufacturing industries, at 30 percent, but only the third highest share of capital costs, at 12 percent, and second highest share of labor costs, at 11 percent, among manufacturing industries in 2019. By comparison, the value-added share for the Computer industry is larger than the sectoral output share in 2019. In this year, the Computer industry has the third lowest share of sectoral intermediate inputs among manufacturing industries and the first and second highest shares of labor and capital costs, respectively, among manufacturing industries. Also note that as the relative use of capital, labor, and sectoral intermediate inputs in an industry changes over time, the relationship between sectoral and value-added output shares in an industry may vary. In the Computer industry, for instance, sectoral shares initially exceed value-added shares over the 1988-2003 period. Then, as a result of a continuous, dramatic decline in outside-the-sector intermediate input purchases accompanied by more moderate variation in capital and labor costs, value-added shares become larger than sectoral shares over the 2004-2021 period. Gross output shares similarly may be larger or smaller than value-added output shares, depending on the relative shares of primary and intermediate inputs among the manufacturing industries. For 2019, gross output shares are larger than value-added output shares in eight industries and smaller in eleven industries.

Figure 19. Industry Shares of Manufacturing Sector Output, by Output Type

Manufacturing Industries, 2019



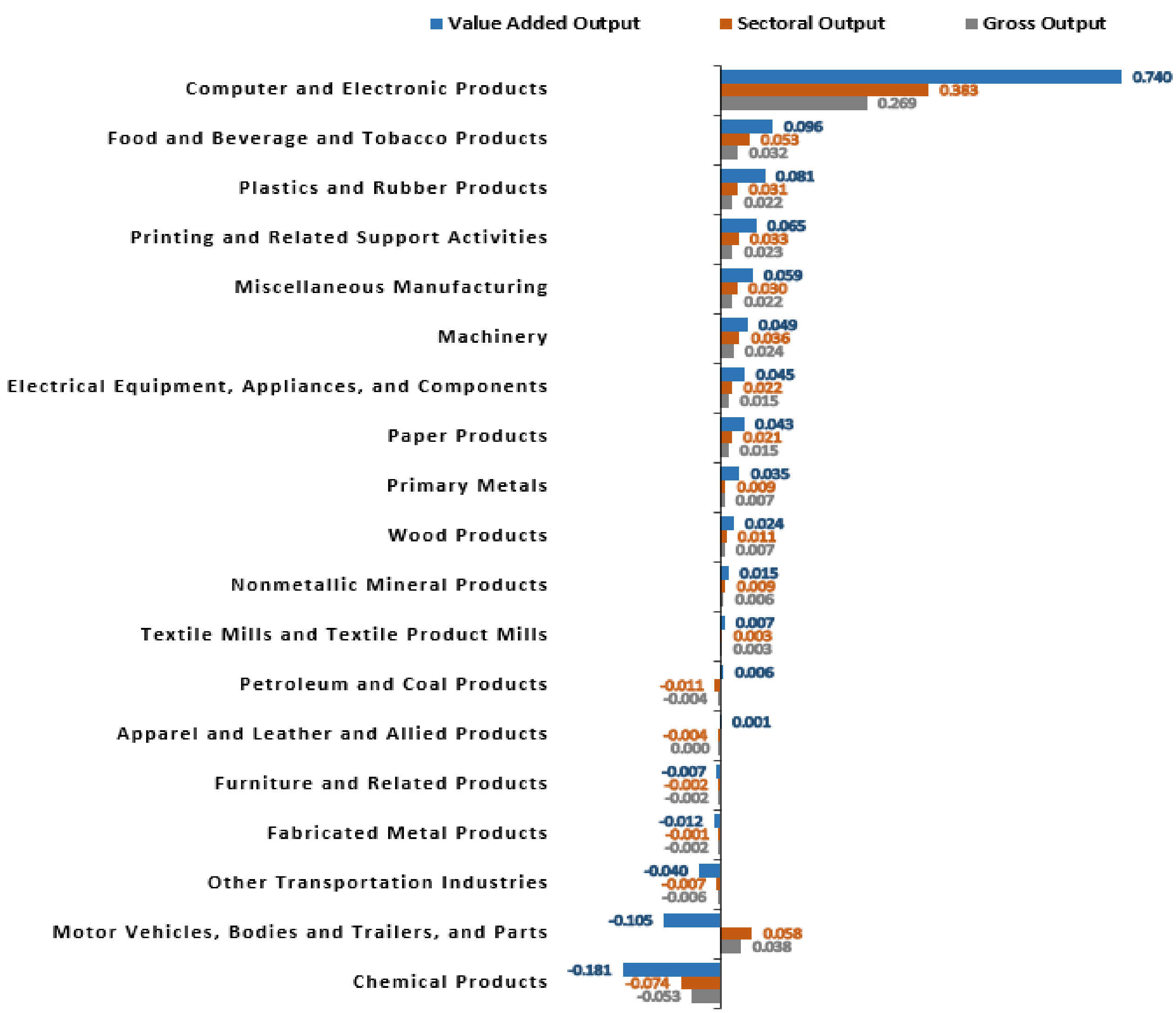
Source: BLS Unpublished Manufacturing Production Account

Impact of Output Concepts 2000-2021

We estimate the contribution of individual industries to overall manufacturing sector TFP growth using each of the output concepts: value-added, sectoral, and gross output. Figure 20 summarizes the relative contribution of each industry to manufacturing sector TFP growth for the 2000-2021 period as measured using each output concept. In general, in this longer time period, the rankings of industry contributions are similar.

Figure 20. Industry Contributions to Manufacturing TFP Growth, by Type of Output, 2000-2021

Annual Percent Change



Source: BLS Unpublished Manufacturing Production Account

However, for a few industries, the choice of output measure still has a large impact on the estimated contribution to manufacturing sector TFP growth. Table 13 compares manufacturing industry contributions, shares, and TFP across the three alternative output measures. Under the value-added output framework, the Motor Vehicles, Bodies and Trailers, and Parts industry is a drag on manufacturing sector TFP with a negative industry contribution of 0.105. Conversely, using either the sectoral or gross output frameworks moves the Motor Vehicle industry from eighteenth to second highest contributing industry with positive contributions of 0.058 and 0.038 respectively. Thus, the impact of including intermediate input purchases on industry contribution measures is especially evident for the Motor Vehicle industry. This movement reflects both higher average industry share values and small but positive growth in TFP when intermediate inputs are included, to some degree, in the output measure. This industry was the second largest user of intermediate inputs, the third largest user of within sector intermediate inputs, and the second largest user of outside the sector intermediate inputs in 2021.

As illustrated in Figure 20, under the value-added output framework, Food and Beverage and Tobacco Products is the second most important contributing industry to TFP growth with a contribution of 0.096. When using sectoral output to measure TFP, the industry falls to the third most important contributing industry and the industry contribution to overall Manufacturing sector TFP declines to 0.053. This reflects the inclusion of intermediate inputs that are purchased from outside the industry in the calculation. Under the gross output model, that adds intermediate inputs produced within and outside the Food industry, the industry remains the third highest contributing industry with a smaller positive contribution of 0.032 to manufacturing sector TFP growth.

Similarly, Plastics and Rubber Products is the third highest contributing industry to manufacturing sector TFP growth, with a contribution of 0.081, under the value-added model. When intermediate inputs are considered by using either sectoral or gross output to measure TFP, this industry's rank changes to seventh highest contributing industry, with corresponding contributions of 0.031 and 0.022.

Table 13. Manufacturing Industry Total Factor Productivity Growth and Related Contribution Components, 2000-2021

NAICS Industry		Value-Added Output			Sectoral Output			Gross Output		
		Industry Contribution *Annual Percent Change*	Industry Share *Average*	Industry TFP *Annual Percent Change*	Industry Contribution *Annual Percent Change*	Industry Share *Average*	Industry TFP *Annual Percent Change*	Industry Contribution *Annual Percent Change*	Industry Share *Average*	Industry TFP *Annual Percent Change*
31-33	Manufacturing Sector	0.920		1.03	0.599		0.59	0.415		0.41
321	Wood products	0.024	0.02	1.33	0.011	0.02	0.44	0.007	0.02	0.37
327	Nonmetallic mineral products	0.015	0.03	0.63	0.009	0.03	0.36	0.006	0.02	0.31
331	Primary metals	0.035	0.03	1.24	0.009	0.05	0.21	0.007	0.04	0.18
332	Fabricated metal products	-0.012	0.07	-0.09	-0.001	0.08	0.01	-0.002	0.06	-0.02
333	Machinery	0.049	0.07	0.84	0.036	0.09	0.45	0.024	0.07	0.40
334	Computer and electronic products	0.740	0.13	6.20	0.383	0.10	3.74	0.269	0.08	3.41
335	Electrical equipment, appliances, and components	0.045	0.03	1.56	0.022	0.03	0.63	0.015	0.02	0.60
3361-3363	Motor vehicles, bodies and trailers, and parts	-0.105	0.07	-3.36	0.058	0.12	0.44	0.038	0.10	0.34
3364-3369	Other transportation equipment	-0.040	0.06	-0.54	-0.007	0.06	-0.09	-0.006	0.05	-0.09
337	Furniture and related products	-0.007	0.02	-0.43	-0.002	0.02	-0.11	-0.002	0.01	-0.12
339	Miscellaneous manufacturing	0.059	0.04	1.44	0.030	0.04	0.71	0.022	0.03	0.70
311-312	Food and beverage and tobacco products	0.096	0.11	0.75	0.053	0.18	0.26	0.032	0.15	0.19
313-314	Textile mills and textile product mills	0.007	0.01	0.55	0.003	0.01	0.16	0.003	0.01	0.17
315-316	Apparel and leather and allied products	0.001	0.01	-1.83	-0.004	0.01	-0.79	0.000	0.01	-0.62
322	Paper products	0.043	0.03	1.49	0.021	0.04	0.54	0.015	0.03	0.44
323	Printing and related support activities	0.065	0.02	2.69	0.033	0.03	1.20	0.023	0.02	1.15
324	Petroleum and coal products	0.006	0.07	1.09	-0.011	0.13	0.06	-0.004	0.10	0.09
325	Chemical products	-0.181	0.16	-1.13	-0.074	0.16	-0.43	-0.053	0.13	-0.37
326	Plastics and rubber products	0.081	0.04	2.08	0.031	0.05	0.53	0.022	0.04	0.51

Source: BLS Unpublished Manufacturing Production Account

The degree to which industry contributions to manufacturing sector TFP vary by the choice of output concept is somewhat muted over an extended period of time such as 2000-2021. This reflects the averaging of cyclical changes over a longer time period. We next examine the effect of output choice on variation in TFP, industry shares and industry contributions across business cycles.

Impact of Output Concepts across Business Cycles

As noted in our earlier discussion of BLS published measures, contributions to manufacturing sector productivity by individual industries may exhibit variation over shorter time periods that is otherwise averaged out over the longer trend period. This variation reflects specific industry dynamics that impact industry TFP growth and the relative size of the industry in the manufacturing sector. To determine the effect of output choice on shorter term variation in industry contributions, we examine measures of industry contributions based on value-added, sectoral, and gross output over selected business cycle periods.

The degree of variation in any given industry's contribution to manufacturing sector productivity growth is driven by industry TFP growth and industry share. Table 9 above presents TFP growth by output measure for each of the 19 manufacturing industries across three business cycle periods. As discussed above, for any given industry, TFP growth measured using gross and sectoral output tends to be similar while TFP growth measured using value-added output differs more widely.

Industry shares under the value-added, sectoral, and gross output measurement frameworks, respectively, are presented in Table 14 for these three business cycle periods.[56] Industry shares change over time as the value of the industry's output relative to sector increases or decreases. For example, sectoral and gross output shares for the Computer industry averaged 0.13 and 0.10 respectively in the 2000-2007 business cycle, before declining relatively quickly to 0.08 and 0.06 in the more recent business cycles. Using the value-added model, the share of the Computer industry was relatively stable over time. Similarly with the Petroleum industry there is greater share volatility across business cycles using the sectoral and gross output models than with the value-added model.

Table 14. Industry Shares by Output Measure, Selected Business Cycles

Share Averages for Selected Periods

NAICS Industry		Value-Added Output Industry Shares			Sectoral Output Industry Shares			Gross Output Industry Shares		
		2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*
321	Wood products	0.02	0.01	0.02	0.03	0.02	0.03	0.02	0.02	0.02
327	Nonmetallic mineral products	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
331	Primary metals	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.04	0.04
332	Fabricated metal products	0.07	0.07	0.07	0.08	0.08	0.09	0.06	0.06	0.06
333	Machinery	0.07	0.07	0.07	0.09	0.09	0.09	0.07	0.07	0.07
334	Computer and electronic products	0.12	0.13	0.13	0.13	0.09	0.08	0.10	0.07	0.06
335	Electrical equipment, appliances, and components	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.02
3361-3363	Motor vehicles, bodies and trailers, and parts	0.08	0.06	0.06	0.13	0.11	0.13	0.11	0.10	0.11
3364-3369	Other transportation equipment	0.05	0.07	0.06	0.06	0.07	0.06	0.04	0.05	0.05
337	Furniture and related products	0.02	0.01	0.01	0.03	0.02	0.02	0.02	0.01	0.01
339	Miscellaneous manufacturing	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
311-312	Food and beverage and tobacco products	0.10	0.11	0.12	0.17	0.19	0.20	0.14	0.15	0.17
313-314	Textile mills and textile product mills	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
315-316	Apparel and leather and allied products	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
322	Paper products	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03
323	Printing and related support activities	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.01
324	Petroleum and coal products	0.06	0.07	0.05	0.10	0.16	0.12	0.07	0.12	0.09
325	Chemical products	0.14	0.16	0.17	0.15	0.17	0.17	0.12	0.14	0.14
326	Plastics and rubber products	0.04	0.04	0.04	0.06	0.05	0.06	0.04	0.04	0.04

* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

Table 15 and Figure 21 compare industry contributions to manufacturing sector TFP across business cycles using the three output concepts. The data in Figure 21 are ranked using the 2000-2007 contribution values from the value-added model.

Table 15. Industry Contributions to Manufacturing Sector Total Factor Productivity Growth by Output Measure, Selected Business Cycles

Annual Percent Change

NAICS Industry		Value-Added Output Industry Contributions			Sectoral Output Industry Contributions			Gross Output Industry Contributions		
		2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*	2000-2007	2007-2019	2019-2021*
321	Wood products	0.044	-0.008	0.146	0.024	-0.001	0.037	0.016	-0.001	0.027
327	Nonmetallic mineral products	0.001	0.007	0.112	0.004	0.004	0.057	0.001	0.003	0.040
331	Primary metals	0.033	0.059	-0.099	0.026	0.028	-0.162	0.016	0.020	-0.110
332	Fabricated metal products	0.098	-0.135	0.341	0.052	-0.058	0.155	0.034	-0.040	0.103
333	Machinery	0.256	-0.100	0.221	0.135	-0.042	0.155	0.090	-0.028	0.103
334	Computer and electronic products	1.377	0.439	0.320	0.728	0.214	0.195	0.506	0.154	0.134
335	Electrical equipment, appliances, and components	0.128	-0.009	0.075	0.059	-0.004	0.045	0.041	-0.003	0.029
3361-3363	Motor vehicles, bodies and trailers, and parts	0.470	-0.384	-0.435	0.253	-0.042	-0.017	0.170	-0.029	-0.017
3364-3369	Other transportation equipment	0.131	-0.098	-0.292	0.074	-0.033	-0.138	0.050	-0.024	-0.095
337	Furniture and related products	0.000	-0.002	-0.059	-0.001	-0.001	-0.019	0.001	-0.001	-0.015
339	Miscellaneous manufacturing	0.129	0.023	0.030	0.065	0.009	0.040	0.044	0.010	0.022
311-312	Food and beverage and tobacco products	0.253	-0.227	1.505	0.122	-0.090	0.670	0.081	-0.070	0.471
313-314	Textile mills and textile product mills	0.025	-0.003	0.002	0.010	-0.001	0.006	0.009	-0.001	0.004
315-316	Apparel and leather and allied products	0.038	-0.007	-0.082	-0.008	0.002	-0.028	0.007	-0.001	-0.023
322	Paper products	0.070	0.002	0.193	0.036	0.001	0.087	0.025	0.001	0.061
323	Printing and related support activities	0.156	0.021	0.011	0.079	0.011	0.001	0.054	0.008	0.000
324	Petroleum and coal products	-0.207	0.130	0.006	-0.108	0.047	-0.016	-0.074	0.038	-0.014
325	Chemical products	0.282	-0.733	1.539	0.142	-0.316	0.627	0.101	-0.227	0.451
326	Plastics and rubber products	0.087	-0.017	0.648	0.036	-0.004	0.222	0.027	-0.003	0.155

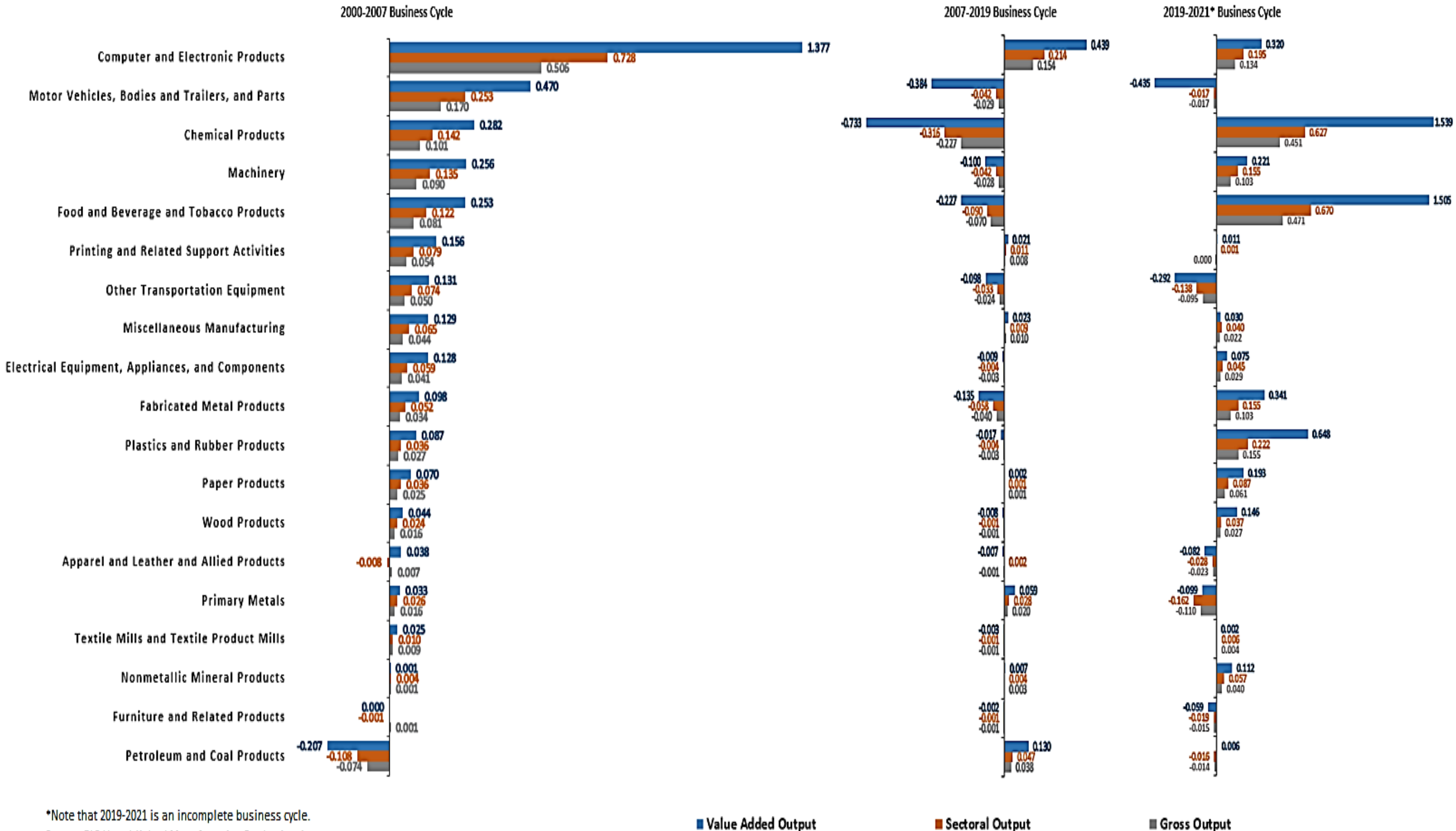
* Note that 2019-2021 is an incomplete business cycle.
Source: BLS Unpublished Manufacturing Production Account

In the 2000-2007 business cycle, the Computer industry is the highest contributor to manufacturing sector TFP growth while Motor Vehicles is the second highest contributor, in all three output models. The Computer industry retains its position as the greatest contributor to manufacturing sector TFP growth in the following business cycle period, 2007-2019. However, the contribution of the Motor Vehicle industry falls to among the lowest four contributing industries and the Petroleum and Coal industry rises from least contributing industry in the 2000-2007 cycle to second highest contributor, in all three models, during the 2007-2019 period. Industry TFP growth in all output models is typically slower in the 2007-2019 cycle that included the Great Recession than in the 2000-2007 period. Numerous industries that previously contributed positively to manufacturing TFP growth instead have a negative or diminishing effect in this second business cycle period, including the Chemical industry and the Food industry. In the still incomplete 2019-2021 business cycle, the choice of output model has a larger impact on industry contribution than in the prior two cycles. Under the value-added output model, the Chemical Products industry now ranks as the greatest contributor to manufacturing sector TFP, with the Food industry as the second highest contributor. These two rankings, while very close, are reversed under the sectoral and gross output models. In addition, this period sees much more variation in ranking among the top twelve industries.

The values of industry contributions to manufacturing sector TFP growth derived from the value-added model are markedly different from industry contributions derived from the sectoral and gross output models in several industries. This pattern reflects the variation in TFP growth for each output model, across industries, as well as differences in industry shares among the value-added, sectoral, and gross output models.

Figure 21. Comparison of Industry Contributions to Manufacturing Sector Total Factor Productivity by Type of Output, Selected Business Cycles

Annual Percent Change



*Note that 2019-2021 is an incomplete business cycle.

Source: BLS Unpublished Manufacturing Production Account

Summary

When analyzing productivity growth for an industry or sector of the economy it is important to understand how the choice of output concept will impact measured performance. In this paper, we have presented an integrated system of output, input and productivity measures as characterized by the Solow growth accounting model. We have demonstrated how the three output concepts – gross output, sectoral output, and value-added output – are interrelated and have summarized the strengths and weaknesses among their related productivity measures. Further, we have provided empirical comparisons of total factor and labor productivity measures using alternative output definitions at the manufacturing sector and industry levels. This analysis highlights the bias that may occur in productivity measurement when ignoring the treatment of within-industry transactions. We also demonstrate that shifts in outsourcing will make the choice of output concept even more important. BLS measures of productivity for the manufacturing sector and industries use the sectoral output concept. This output concept captures the output that is leaving the sector or industry but is not impacted by changes in firm structures within an industry. In addition, this model converges toward the value-added model for the most aggregate sectors and approaches gross output for the most detailed industries. Yet, we note that productivity measures constructed with value-added and gross output measures may be useful depending on the data user's analytical purpose. By constructing an integrated set of productivity measures, based on related output measures and using a consistent framework of outputs and inputs, we hope to provide data users with the broadest and most useful suite of measures for productivity analysis.

In order to understand the performance of the U.S. manufacturing sector it is important to look beyond sector level data and explore the performance of individual industries. Using BLS published data, we have shown that any one industry's influence on sector level performance is a function of both its size in the sector and the TFP growth of that individual industry. Both the industry share of output and industry TFP growth will vary during different time periods, reflecting the underlying dynamics of production in any given industry. For example, over the entire period from 2000-2021 the Computer and Electronic Products industry contributed over half of the growth in manufacturing sector TFP. However, in the most recent 2019-2021 period, the Food, Beverage, and Tobacco Products industry is contributing the most.

By tracing the contribution of industries to manufacturing sector TFP over three different business cycles, the rise and fall of industries' importance to overall manufacturing sector performance is made explicit and linked to technological innovations, changing economic needs, and global economic patterns. The dramatic increase in U.S. oil and natural gas production as a result of the development of revolutionary hydraulic fracturing and horizontal drilling techniques increased the average industry share of manufacturing output produced by the Petroleum industry by 60 percent, from 0.10 in 2000-2007 to 0.16 in the 2007-2019 period. Combined with increased, positive TFP growth of 0.21 percent per year in the 2007-2019 period, the Petroleum industry contributed 0.053 percentage points to manufacturing sector TFP growth. This compares to the industry's previous impact as a drag on manufacturing sector TFP growth with a negative industry contribution of -0.111 percentage points in the 2000-2007 period. Similarly, innovations in the Chemical and Food industries resulted in large increases in TFP growth in the most recent 2019-2021 period compared to the 2007-2019 period, repositioning these industries as the top two contributing industries to manufacturing sector TFP growth in 2019-2021 versus the two lowest industries with negative contributions to overall sector TFP in the 2007-2019 period. This dramatic shift in the ranking of these two industries has occurred despite a slight increase in the Food industry's average share, (0.19 to 0.20) and a larger decrease in the Petroleum industry's average share (0.16 to 0 .12) from 2007-2019 to the most recent period.

Our comparison of industry contributions to manufacturing sector TFP growth using three different output concepts – value-added, sectoral, and gross – demonstrates that choice of output measure directly impacts productivity analysis both through implicit differences in the resulting empirical measures of TFP and the estimation of industry contribution to TFP growth in any given sector.

Choice of output measure first impacts the measurement of TFP growth and second, impacts the estimate of an industry's contribution to aggregate TFP growth via both the industry's output share weighting scheme and TFP growth. Whereas a TFP measure based on value-added output reflects only the effect of primary inputs – capital and labor – on production of output, TFP measures based on sectoral and gross output reflect either the effect of intermediate inputs purchased outside an industry or intermediate inputs purchased both outside and within an industry on output production. Each of the respective TFP measures – value-added, sectoral, and gross – are subject to different interpretations as a result of the inherent constraints embedded in the related growth accounting model. Additionally, the selection of the output concept has implications for the value of the industry's share of sector output. Even over a longer term such as 2000-2021, the impact of output model choice had a notable effect, with the Motor Vehicles industry moving from second lowest and negative contributor to manufacturing TFP growth under a value-added model to second highest contributing industry under either a sectoral or gross output model. When examined across shorter business cycle periods, the use of alternative output measures results in more pronounced variability in industry ranking by contribution to sector TFPs.

By expanding on the differences among the three output measures and how these differences impact the related TFP, industry share weights, and industry contribution measures, we have shown that careful deliberation is warranted before selecting a value-added, sectoral, or gross output framework for TFP and contribution analysis. Use of a sectoral output framework avoids the double counting issues that render the gross output framework difficult to interpret and of little analytical value, while reflecting the effect on productivity of capital, labor, and intermediate inputs purchased outside a given industry. While the value-added output framework also avoids the double counting inherent in the gross output model, using value-added output captures only the increase in TFP that results from the use of capital and labor inputs in production. Industry shares in the value-added framework reflect only differences in the use of capital and labor inputs by industry while sectoral shares reflect changes in the relative use of capital, labor, and intermediate inputs. For these considerable reasons, BLS has selected the sectoral output framework as the most informative and least compromised output framework for productivity analysis for the manufacturing sector and industries.

[1] See, for example, Michael Brill, Corey Holman, Chris Morris, Ronjoy Raichoudhary, and Noah Yosif, "Understanding the labor productivity and compensation gap," *Beyond the Numbers*, June, vol. 6, no. 6, June 2017, https://www.bls.gov/opub/btn/volume-6/pdf/understanding-the-labor-productivity-and-compensation-gap.pdf; and Susan Fleck, John Glaser, and Shawn Sprague, "The compensation–productivity gap: a visual essay," *Monthly Labor Review*, January 2011, https://www.bls.gov/opub/mlr/2011/01/art3full.pdf.

[2] "Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth," (Paris: Organisation for Economic Co-operation and Development, 2001), p. 11, https://www.oecd.org/sdd/productivity-stats/2352458.pdf

[3] Robert M. Solow, "Technical Change and the Aggregate Production Function," The Review of Economics and Statistics, vol. 39, no. 3, August 1957, pp. 312-20. Note that Solow's growth model assumes Hicks-neutral technical change and constant returns to scale.

[4] For further discussion, see William Gullickson, "Measurement of Productivity Growth in U.S. Manufacturing," *Monthly Labor Review*, July 1995, p. 14, https://www.bls.gov/opub/mlr/1995/07/art2full.pdf.

[5] Ibid., p. 18.

[6] Internationally, value-added labor productivity is by far the most frequently computed productivity statistic. This measure is easy to calculate and accounts for all factors of production except capital and labor composition. For further discussion, see Organization for Economic Cooperation and Development, "Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth," (Paris: Organisation for Economic Co-operation and Development, 2001), p.12.

[7] See, for example, Lawrence Mishel, Elise Gould, and Josh Bivens, "Wage Stagnation in Nine Charts," (Washington, DC: Economic Policy Institute, January 6, 2015). http://www.epi.org/publication/charting-wage-stagnation/ .

[8] U.S. Bureau of Labor Statistics (BLS) industry labor productivity measures compare output to hours worked of all persons, where hours worked of all persons is the total number of hours worked by wage and salary workers, unincorporated self-employed workers, and unpaid family workers to produce output. By comparison, BLS industry total factor productivity measures compare output to growth in the combination of capital, labor, energy, materials and purchased services, with materials and in selected industries, services, inputs adjusted to remove intrasectoral transactions and where labor input is measured as a Törnqvist aggregation of the hours at work by all persons, classified by education, work experience, and gender with weights determined by their shares of labor compensation in each industry. Using these alternative labor input definitions allows labor productivity growth to be decomposed into the contribution of total factor productivity growth, the contribution resulting from capital/ labor substitution (capital deepening) and the contribution of the labor composition effect. The labor input measures used in this project are developed within the manufacturing production model to maintain consistency

across the value-added, sectoral, and gross output frameworks, using the same methodology as used to produce the BLS published labor input measures.

[9] This topic is discussed further in Edwin R. Dean, Michael J. Harper, and Mark S. Sherwood," Productivity Measurement with Changing Weight Indices of Outputs and Inputs," in *Industry Productivity: International Comparison and Measurement*, (Paris: Organization for Economic Co-operation and Development, 1996), pp. 183-215; and Gullickson (1995), especially footnote 12, p. 27.

[10] For additional discussion of this topic, see "Measuring Productivity: Measurement of Aggregate and Industry-level Productivity Growth" (Paris: Organisation for Economic Co-operation and Development, 2001), p. 28. If technical change within an industry does not affect all factors of production but operates primarily on the primary inputs, then a value-added approach is preferable.

[11] The BLS is conducting research on the feasibility of constructing new productivity measures using alternative output concepts.

[12] For a complete discussion of the advantages and disadvantages of the gross and value-added output concepts, see "Measuring Productivity: Measurement of Aggregate and Industry-level Productivity Growth" (Paris: Organisation for Economic Co-operation and Development, 2001), Chapter 3, pp. 23-33.

[13] The U.S. Bureau of Economic Analysis (BEA)/BLS integrated production accounts use a gross output approach because it provides a complete accounting of inputs used in production regardless of where they are produced. For further information on the Integrated BEA GDP-BLS Productivity Account, see [https://www.bea.gov/data/special-topics/integrated-bea-gdp-bls-productivity-account .](https://www.bea.gov/data/special-topics/integrated-bea-gdp-bls-productivity-account)

[14] William Gullickson and Michael J. Harper, "Possible Measurement Bias in Aggregate Productivity Growth", *Monthly Labor Review*, February 1999, p. 51.

[15] Gross output may also be measured as the sum of compensation of employees; taxes on production and imports, less subsidies; gross operating surplus; and the cost of intermediate inputs.

[16] For theoretical proofs, see Michael Bruno (1978), "Duality, Intermediate Inputs and Value-added," in Melvyn Fuss and Daniel McFadden (eds.), *Production Economics: A Dual Approach to Theory and Applications*, North Holland; and Bert M. Balk, 2003b, "On the relationship between gross output and value-added based productivity measures: the importance of the Domar factor," Working Paper No. 2005/05, Centre for Applied Economic Research, The University of New South Wales, Sydney.

[17] Noting that $TFP_{GO} = (\frac{Value-Added\ Output}{Gross\ Output})\ x\ TFP_{VA}$ and value-added output equals gross output less intermediate inputs (II), then $TFP_{GO} = (\frac{Gross\ Output-Intermediate\ Inputs}{Gross\ Output})\ x\ TFP_{VA}$ or TFP_{GO} = (1- II/GO) x TFP_{VA}. Alternatively, we can show that if $TFP_{VA} = (\frac{Gross\ Output}{Value-Added\ Output})\ x\ TFP_{GO}$; then $TFP_{VA} = (VA+EMS)/VA\ X\ TFP_{GO}$ *or* $TFP_{VA} = (1+II/VA)\ x\ TFP_{GO}$, where Value-Added Output (VA) = the summed value of Capital and Labor (KL); Gross Output (GO) = the summed value of Capital, Labor, Energy, Materials and Services (KLEMS), and Intermediate Inputs (II) = the summed value of Energy, Materials and Services (EMS).

[18] Given TFP_{GO} growth of 1 percent, an increase (decrease) in intermediate inputs as a result of outsourcing implies an acceleration (deceleration) in the rate of growth of TFP_{VA} relative to $TFP_{GO.}$ See, for further discussion, Trevor Cobbold, "A Comparison of Gross Output and Value-Added Methods of Productivity Estimation," Productivity Commission Research Memorandum, Canberra, 2003, p. 8.

[19] Bartelsman, Eric J., J. Joseph Beaulieu, Carol Corrado, and Paul Lengermann, "Modeling Aggregate Productivity at a Disaggregate Level: A First Look at Estimating Recent MFP Growth using a Sectoral Approach," Working Paper for the OECD workshop on productivity measurement, Madrid, Spain, October 17-19, 2005, footnote 5, p.5.

[20] Note that $TFP_{VA} = (\frac{Sectoral\ Output}{Value-Added\ Output})$ x $TFP_{SO} = TFP_{SO}$ x *(Sectoral Output/Gross Output)/(Value-added Output/Gross Output.)* Substituting the expressions (Sectoral Output/Gross Output) = $(1 - \frac{Intrasectoral\ Inputs}{Gross\ Output})$ and (Value-added Output/Gross Output) = $(1 - \frac{Intermediate\ Inputs}{Gross\ Output})$ from equations 5b and 6b, then $TFP_{VA} = TFP_{SO}$ x $(\frac{(1-\frac{Intrasectoral\ Inputs}{Gross\ Output})}{(1-\frac{Intermediate\ Inputs}{Gross\ Output})})$. Alternatively, note that $TFP_{SO} = (\frac{Gross\ Output}{Sectoral\ Output})\ x\ TFP_{GO}$; then TFP_{SO} = $(KLEMS)/(KLEMS-ITR)\ X\ TFP_{GO}$ *or* $TFP_{SO} = 1/((KLEMS-ITR)/((KLEMS))\ x\ TFP_{GO}$. This can be rearranged to show $TFP_{SO} = (1/(1-(ITR/GO)))\ x\ TFP_{GO}$, where Sectoral Output (SO) = the summed value of Capital, Labor, Energy, Materials and Services less Intrasectoral Transactions (KLEMS - ITR); Gross Output (GO) = the summed value of Capital, Labor,

Energy, Materials and Services (KLEMS), and Intermediate Inputs (II) = the summed value of Energy, Materials and Services (EMS).

[21] Alternatively, we can show that value-added TFP is related to sectoral TFP as follows: $TFP_{VA} = (TFP_{SO} \times (1 - ITR/GO) \times (1 + II/VA))$.

[22] The main exception is imported intermediate inputs.

[23] BLS measures of TFP also account for changes in the composition of the labor force by using a measure of labor input defined as hours worked adjusted for differences in age, education, and gender rather than simply hours worked.

[24] Lucy P. Eldridge and Michael J. Harper, "Effects of Imported Intermediate Inputs on Productivity," *Monthly Labor Review*, June 2010, pp. 3.

[25] *Handbook of Methods*, (U.S. Bureau of Labor Statistics, September 1983), Chapter 11, p. 2.

[26] U.S. Department of Labor, Bureau of Labor Statistics, Trends in Multifactor Productivity, 1948-81, Bulletin 2178, (Washington DC: U.S. Government Printing Office) September 1983, p. 16.

[27] "Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth," (Paris: Organisation for Economic Co-operation and Development, 2001), p. 14.

[28] *Trends in Multifactor Productivity*, 1948-81, Bulletin 2178, (U.S. Bureau of Labor Statistics, September 1983), pp. 33-34.

[29] Gullickson, "Measurement of Productivity Growth in U.S. Manufacturing," p. 18.

[30] Total factor productivity statistics are available for the U.S. business sector, the nonfarm business sector, the manufacturing sector, and 18 groups of manufacturing industries, 86 detailed manufacturing industries, railroad transportation, air transportation, and utilities. Output per hour and unit labor costs data are available for the U.S. business sector, the nonfarm business sector, and the manufacturing sector. In addition, output per hour and unit labor costs are available for over 400 selected industries in manufacturing, mining, utilities, wholesale and retail trade, and services.

[31] The nineteen manufacturing industries included in our analysis correspond to industry definitions used in the U.S. National Income and Product Accounts (NIPAs). The NIPA industry definitions, in turn, are based on the North American Industry Classification System (NAICS). Of the nineteen industries, fourteen are three-digit level NAICS industries and five are combinations of NAICS industries. These five industries include Food and Beverage and Tobacco Products (NAICS 311-312); Textile Mills and Textile Product Mills (NAICS 313-314); Apparel and Leather and Allied Products (NAICS 315-316); Motor Vehicles, Bodies and Trailers, and Parts (NAICS 3361-3363); and Other Transportation Equipment (NAICS 3364-3369).

[32] The sectoral output and related KLEMS data used in this paper is from an unpublished production account developed for the manufacturing sector. This production account includes gross, value-added, and sectoral output measures and the congruent KLEMS input measures. Sectoral output data from this account differs marginally from the published BLS sectoral output measures for manufacturing. Some minor adjustments to the published BLS sectoral output and related input data are required to maintain consistency with the related gross and value-added output measures within the manufacturing production account. Note also that this data has been adjusted to remove the output of households and nonprofit entities. Appendix Tables A-13 and A-14 compare published BLS sectoral output and capital services data with the respective research data series developed in the unpublished manufacturing sector production account.

[33] BLS total factor productivity measures for manufacturing industries are based on published BLS sectoral output measures. This paper develops sectoral output based total factor productivity measures using sectoral output measures from an unpublished manufacturing sector production account.

[34] This decomposition is based on the relationship LP growth = TFP growth + Capital/Labor growth + Labor Composition growth.

[35] BLS industry labor productivity measures compare output to hours worked of all persons, where hours worked of all persons is the total number of hours worked by wage and salary workers, unincorporated self-employed workers, and unpaid family workers to produce output. By comparison, BLS industry total factor productivity measures compare output to growth in the combination of capital, labor, energy, materials and purchased services, with materials and in selected industries, services, inputs adjusted to remove intrasectoral transactions and where labor input is measured as a Tornqvist aggregation of the hours at work by all persons, classified by education, work experience, and gender with weights determined by their shares of labor compensation in each industry.

[36] There are 90 asset types for fixed business equipment, structures, inventories, land, and intellectual property products. The aggregate capital services measures are obtained by Tornqvist aggregation of the capital stocks for each asset type within each of the nineteen manufacturing North American Industry Classification System (NAICS) industry groupings using estimated rental prices for each asset type. Each rental price reflects the nominal rate of return to all assets within the industry and rates of economic depreciation and revaluation for the specific asset; rental prices are adjusted for the effects of taxes. Data on investment for fixed assets are obtained from BEA. Data on inventories are estimated using data from BEA and additional information from the Internal Revenue Service (IRS) Corporation Income Returns. Data for land in the farm sector are obtained from the United States Department of Agriculture. Nonfarm industry detail for land is based on IRS book value data. Current-dollar value-added data, obtained from BEA, are used in estimating capital rental prices.

[37] The capital services measures for this research are developed using the value-added output model and differ very slightly from BLS published capital input measures. Appendix Table A-14 compares published BLS capital services data with the research capital data series developed in the unpublished manufacturing sector production account.

[38] Appendix tables A-1, A-2, and A-3 provide specific details regarding the underlying data sources and methods. Tables A-4, A-5, and A-6 present the annual percent change in TFP for the manufacturing sector and nineteen manufacturing industries for 1997-2021 and for selected time periods, based on the value-added, sectoral, and gross output measurement frameworks respectively. Tables A-7, A-8, and A-9 present industry shares in manufacturing output by manufacturing industry for 1997-2021 and average shares for selected time periods, based on each output measure. Tables A-10, A-11, and A-12 present the annual percent change in industry contributions for 1997-2021 and average annual growth rates for selected time periods, based on each output measure. Table A-13 compares published BLS sectoral output with the research sectoral output series developed in the unpublished manufacturing sector production account, and Table A-14 compares published BLS capital services data with the research capital data series developed in the unpublished manufacturing sector production account.

[39] In discussing economic growth and productivity, it is important to evaluate how factors influencing productivity are changing over time. Therefore, output, inputs and productivity are generally presented as growth rates, to facilitate the analysis of output and input growth.

[40] From 2000-2021, the current value of within-sector intermediates grew at a 1.4 percent annual rate, while the price of within-sector intermediate inputs increased by 2.1 percent.

[41] During the 2000-2007 period, nominal out-of-sector intermediates increased at a 5.4 percent rate and their prices grew at a rate of 5.8 percent.

[42] Over the 2007-2019 period, nominal out-of-sector intermediate inputs decreased at a 0.54 percent rate and their prices grew only 0.77 percent.

[43] For the labor productivity estimates, using hours worked as the labor input measure allows us to deconstruct labor productivity growth into the components impacting labor productivity growth, including TFP, capital per unit of labor input (capital intensity), and the labor composition effect, using the relationship $LP\ growth$ = $TFP\ growth$ *+ Capital/Labor growth + Labor Composition growth.*

[44] See Appendix Tables A-4, A-5, and A-6 for TFP annual growth rates based on the value-added, sectoral, and gross output measures, by NIPA industry.

[45] "Total Factor Productivity for Major Industries – 2021" (Washington, DC: U.S. Bureau of Labor Statistics, updated annually), https://www.bls.gov/news.release/prod5.nr0.htm

[46] BLS prioritizes using output measures that most accurately reflect movements in output for each specific industry. Manufacturing industry output measures are derived using various data sources including the Census Annual Survey of Manufactures, the Energy Information Administration, and industry trade associations. Intermediate input data is obtained from BEA. The weights for the BLS manufacturing industry contributions relate industry sectoral output to sectoral output for the aggregate manufacturing sector. Each industry's relative contribution to aggregate manufacturing sectoral output reflects the industry's sectoral TFP growth weighted by the ratio of the industry specific sectoral output to manufacturing sectoral output, in a given year.

[47] For further discussion, see Evsey D. Domar, "On the Measurement of Technological Change", *Economic Journal*, vol.71, no. 284, December 1961, pp. 709-729; and Charles R. Hulten, "Growth Accounting with Intermediate Inputs," *The Review of Economic Studies*, Vol. 45, No. 3, October 1978, pp. 511-518.

[48] The most recent business cycle is not complete, but began in 2019 with the recession that resulted from the onset of the Covid-19 pandemic.

[49] Industry contributions to TFP growth are calculated using the difference in natural logs of industry TFP in adjacent years to preserve the additive quality of the growth rates.
[50] Charles F. Mason, Lucija A. Muehlenbachs, and Sheila M. Olmstead, “The Economics of Shale Gas Development,” Resources for the Future, November 2014, revised February 2015. https://media.rff.org/documents/RFF-DP-14-42.pdf and Robert Rapier, “How the Shale Boom Turned the World Upside Down,” Forbes, April 21, 2017, https://www.forbes.com/sites/rrapier/2017/04/21/how-the-shale-boom-turned-the-world-upside-down/?sh=5ae9810977d2.
[51] See TFP comparisons in Lucy P. Eldridge and Susan G. Powers, “The Importance of Output Choice: Implications for Productivity Measurement,” *Monthly Labor Review*, August 2023.
[52] The weights used in the value-added model relate industry value-added output to aggregate manufacturing sector value-added output. In this model, the weights are similar to Domar weights, as described in the 1961 article by Evsey D. Domar, “On the Measurement of Technological Change.” This theoretical framework showed that the effective productivity growth rate for industries may be measured by weighting the multifactor productivity growth rates for each industry by the value of that specific industry’s share of final output, measured as value-added output. A particularly useful summary of the Domar method is available in William Gullickson, “Multifactor Productivity in Manufacturing,” *Monthly Labor Review*, October 1992, pp. 31-32.
[53] The industry weights in the sectoral and gross output models relate industry sectoral (gross) output to sectoral (gross) output for the manufacturing sector. While these shares differ from the standard Domar weights relating industry sectoral (gross) output to aggregate value-added output, they are useful for comparing industry contribution results across output models. These share definitions were adopted to accommodate the BLS unpublished manufacturing database, which incorporates data from multiple datasets.
[54] Gullickson and Harper (1999), p. 50.
[55] See, for example, Appendix Tables A-7, A-8, and A-9.
[56] Industry contributions to TFP growth are calculated using the difference in natural logs of industry TFP in adjacent years to preserve the additive quality of the growth rates.

APPENDIX

This appendix provides detailed information on the data and methods used to construct the output and input measures used in this research.[1] In addition, the appendix includes expanded data on total factor productivity growth rates, industry shares, and industry contributions to manufacturing sector total factor productivity growth, for each output framework, over the 1997-2021 period. Comparisons of U.S. Bureau of Labor Statistics (BLS) published sectoral output and capital input measures with experimental sectoral output and capital input measures from the unpublished manufacturing production account are also included.[2]

A. *Value-added Output Framework*

Output

Value-added output measures are constructed for the manufacturing sector and 19 National Income and Product Account (NIPA) manufacturing industries using a double deflation method.

Manufacturing sector value-added output is developed using gross output data, obtained primarily from economic censuses and annual surveys of the U.S. Bureau of the Census, and data on the gross value of intermediate inputs (energy, materials, and services) from the U.S. Bureau of Economic Analysis (BEA).[3] The value-added output measure for the manufacturing sector is constructed as a chained superlative index (Tornquist) of the 19 NIPA industry value-added outputs.

Similarly, for the 19 NIPA manufacturing industries, we construct current dollar value-added output measures using a double deflation method; gross output data primarily from economic censuses and annual surveys of the U.S. Bureau of the Census; and data on the gross value of intermediate inputs from BEA. Current dollar value-added output for one industry, NAICS 323, Printing and related support activities, is adjusted to exclude the output of households and nonprofit institutions.[4] These current dollar value-added output measures are then deflated using chain-type price indexes to obtain real value-added output by industry.

Inputs

In the value-added framework, output is defined as gross output less the value of intermediate inputs. As a result, measures of total factor productivity based on a value-added output concept relate output only to the primary inputs, capital and labor, whose value remains reflected in output. In the value-added model, total factor productivity for the manufacturing sector is estimated using unpublished manufacturing sector value-added output measures, BLS published labor input measures, and unpublished capital services measures consistent with BLS methodology.

For the manufacturing sector, unpublished capital input and published BLS labor input measures are used in estimating value-added total factor productivity. The capital input used in this research differs slightly from BLS published capital input because it is estimated based on the experimental value-added model rather than the published BLS sectoral model.

Capital input is measured as the flow of capital services from physical capital stock and intellectual property assets. There are 90 asset types for fixed business equipment, structures, inventories, land, and intellectual property products. The aggregate capital services measures are obtained by Tornquist aggregation of the capital stocks for each asset type using asset rental price weights, in each of the nineteen manufacturing NIPA industry groupings. Each rental price reflects the nominal rate of return to all assets within the industry and rates of economic depreciation and revaluation for the specific asset; rental prices are adjusted for the effects of taxes. The capital input measures developed for the manufacturing production model are consistent with BLS published data but have been adjusted to allow for consistency among the three output concept models.

BLS published labor input in the manufacturing sector is obtained by Tornquist aggregation of the hours at work by all persons, classified by education, work experience, and gender with weights determined by their shares of labor compensation. The labor input measures used in the unpublished manufacturing production account are the BLS published indexes of labor input and are consistent across the value-added, sectoral, and gross models.[5]

For the 19 NIPA manufacturing industries, we estimate total factor productivity on a value-added basis using BLS published labor input and unpublished capital services measures by NIPA industry, developed for the unpublished manufacturing production account. NIPA industry level capital measures are computed using a service flow concept for physical capital assets — equipment, structures, inventories, and land. Labor input for NIPA industries is hours at work by all persons, classified by education, work experience, and gender, with weights determined by their shares of labor compensation.

B. Sectoral Output Framework

Output

A current dollar sectoral output measure for the manufacturing sector is constructed primarily using data from the economic censuses and annual surveys of the U.S. Bureau of the Census. BLS estimates of sectoral output measures for the manufacturing sector are constructed by adjusting BLS estimates of gross output to remove manufacturing sector intrasectoral transactions. A real sectoral output measure for the manufacturing sector is obtained by deflating the current dollar sectoral output measure using a sectoral output deflator.

Similarly, unpublished sectoral output measures for the 19 NIPA manufacturing industries are constructed using economic census and annual survey data from the U.S. Bureau of the Census. To construct sectoral output measures for the 19 NIPA manufacturing industries, we omit intrasectoral transactions from the value of gross output. In constructing our estimate of the sectoral output in each manufacturing industry, the value of intermediate inputs purchased from outside the manufacturing sector industries is estimated based on BEA Input-Output Use tables. Data on imported intermediate inputs for manufacturing industries is obtained from BEA import matrices. Real sectoral output measures for the manufacturing industries are then obtained by deflating the current dollar sectoral output measures using a sectoral output deflator.

Inputs

In the sectoral output framework, the value of output is defined as gross output adjusted to remove the value of intrasectoral transactions. Sectoral output for the manufacturing sector can be defined as value-added output for the manufacturing sector plus purchases of intermediate inputs from outside the sector. Alternatively, sectoral output for an industry can be equated to the value of capital, labor, energy, materials and purchased business services inputs, where the inputs have also been adjusted to remove the value of intrasectoral transactions. Measures of total factor productivity based on the sectoral output concept relate sectoral output both to the primary inputs, capital and labor, and the intermediate inputs, energy, materials and purchased business services, with an adjustment on the input side to remove the value of intrasectoral transactions.

For the manufacturing sector, unpublished capital input consistent with BLS methodology and published BLS labor input measures are used in estimating sectoral total factor productivity. As described above, capital input is measured as the flow of capital services from physical capital stock and intellectual property assets. The labor input measures used in the unpublished manufacturing production account are the BLS published indexes of labor input and are consistent across the value-added, sectoral, and gross models.

The value of intermediate input purchases from outside the manufacturing sector is estimated using BEA Input-Output Use tables, BEA data on manufacturing sector purchases of intermediates from government and household sectors, and data on imported intermediate inputs from BEA import matrices. Finally, a total intermediate input measure for the manufacturing sector is constructed as a Tornquist index of intermediate inputs purchased from private industries outside the manufacturing sector, from government and nonprofits, and imported from outside the United States.

For the 19 NIPA manufacturing industries, unpublished capital input consistent with BLS methodology and published BLS labor input measures are used. Unpublished data on intermediate input measures (energy, materials, and services) and capital, labor, and intermediate input costs are also developed and adjusted to remove the value of intrasectoral transactions.

C. Gross Output Framework

Output

Current dollar gross output for the manufacturing sector is constructed primarily using data from the economic censuses and annual surveys of the U.S. Bureau of the Census. Real gross output for the manufacturing sector is constructed using a chained superlative index (Tornqvist) of three-digit NAICS industry outputs.

Current dollar gross output for the 19 NIPA manufacturing industries is constructed primarily using data from the economic censuses and annual surveys of the U.S. Bureau of the Census. Note that in one industry, NAICS 323, Printing and related support activities, current dollar gross output is adjusted to exclude the output of households and nonprofit institutions. Real gross output measures for the manufacturing industries are obtained by deflating the current dollar gross output measures using a gross output deflator.

Inputs

In the gross output framework, the value of all production, including the value of output sold as intrasectoral transactions, is included in the output measure. Therefore, gross output is equated to the value of capital, labor, energy, materials and purchased business services inputs. Measures of total factor productivity based on the gross output concept relate gross output both to the primary inputs, capital and labor, and the intermediate inputs, energy, materials and purchased business services.

For the manufacturing sector, unpublished capital input and published BLS labor input measures are used in estimating gross total factor productivity. Energy, materials and purchased services data for each manufacturing industry is estimated using BEA data on energy, materials, and services initially. This data is then adjusted to remove the gross output value of households and nonprofit institutions and to meet the condition that the value of gross output is equal to total input cost. A Tornquist aggregate across NIPA industries is generated for each intermediate input, using compensation data for the input to obtain share weights, in order to construct energy, materials, and purchased services quantity indexes for the manufacturing sector.

Similarly, for the 19 NIPA manufacturing industries, unpublished capital input and published BLS labor input measures are used in estimating gross total factor productivity for each industry. Energy, materials and purchased business services input and compensation data for the manufacturing industries is estimated by BLS, as described above.

[1] Data series constructed for output, inputs, and total factor productivity are available upon request of the authors.

[2] Tables A-1, A-2, and A-3 describe the methodology and data sources used for the value-added, sectoral, and gross output models. Tables A-4, A-5, and A-6 present total factor productivity measures based on each output concept. Tables A-7, A-8, and A-9 present industry shares derived using each output concept. Tables A-10, A-11,

and A-12 present industry contributions based on each output concept. Table A-13 compares BLS published sectoral output to unpublished manufacturing production account sectoral output. Table A-14 compares BLS published capital services measures to unpublished manufacturing production account capital services.

[3] Data on the gross value of intermediate inputs is constructed for use in this project. Initially, BEA gross intermediate input data is obtained. This data is then adjusted to uphold the relationship between output and input values in the gross output framework. Unpublished gross output data is constructed for this project and derived primarily from U.S. Bureau of the Census data sources.

[4] The value-added output value of nonprofit entities is estimated using either nonprofit employment ratios based on Economic Census data or nonprofit compensation ratios prepared by the U.S. Bureau of Economic Analysis and based on Economic Census data supplemented with County Business Pattern data, depending on data availability for each of the 19 National Income and Product Account (NIPA) industries.

[5] See U.S. Department of Labor, Bureau of Labor Statistics, Labor Composition and US Productivity Growth, 1948-90, Bulletin 2426, (Washington DC: U.S. Government Printing Office) December 1993 for a complete description of Tornquist aggregation of hours. https://www.bls.gov/productivity/articles-and-research/labor-composition-us-productivity-growth-1948-1990.pdf See also “Changes in the Composition of Labor for BLS Multifactor Productivity Measures,” https://www.bls.gov/productivity/technical-notes/changes-in-composition-of-labor-total-factor-productivity-2014.pdf .

Table A-1. Value Added Measurement Framework

	Source of Component		
	Output	**Capital**	**Labor**
Manufacturing Sector	Real value added output for the manufacturing sector is constructed using gross output data, obtained primarily from economic censuses and annual surveys of the U.S. Census Bureau, and U.S. Bureau of Economic Analysis (BEA) data on the gross value of intermediate inputs (energy, materials, and services). Estimates of value-added output for the manufacturing sector are constructed using a chained superlative index (Tornqvist) of the 19 National Income and Product Account (NIPA) industry output measures.	Capital service measures are constructed using BEA capital investment data and a capital measurement methodology consistent with U.S. Bureau of Labor Statistics (BLS) published data. Unpublished capital compensation for the manufacturing sector is constructed to be consistent with BLS methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in the manufacturing sector. BLS published hours worked by all persons is used to estimate labor productivity in the manufacturing sector. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology.
19 NIPA Manufacturing Industries	Real value added output for the 19 NIPA manufacturing industries is constructed using unpublished gross output data, obtained primarily from economic censuses and annual surveys of the Census Bureau, and data on the gross value of intermediate inputs (BEA energy, materials, and services) for each industry. Gross output and intermediate inputs are deflated separately using gross output and intermediate input price deflators. Real value added output for each industry is obtained as industry real gross output less the real value of intermediate inputs in that industry. Note that in one industry, NAICS 323, Printing and related support activities, value-added output is adjusted to remove the value-added output of nonprofits.	Capital service measures for each of the 19 NIPA manufacturing industries are constructed using BEA capital investment data and a capital measurement methodology consistent with BLS published data. Unpublished capital compensation for each NIPA manufacturing industry is constructed to be consistent with BLS methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in each of the 19 NIPA manufacturing industries. BLS published hours worked by all persons is used to estimate labor productivity in each NIPA manufacturing industry. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology. Labor compensation data for each NIPA manufacturing industry is unpublished data developed for the manufacturing production account.
Industry Weights	To analyze each industry's contribution to manufacturing sector total factor productivity growth as measured using value-added output, share weights for each of the 19 NIPA manufacturing industries are defined as each industry's current dollar value added output relative to manufacturing sector current dollar value added output.		

Source: Bureau of Labor Statistics

Table A-2. Sectoral Measurement Framework

	Source of Component					
	Output	**Capital**	**Labor**	**Energy**	**Materials**	**Purchased Services**
Manufacturing Sector	Current dollar sectoral output for the manufacturing sector is constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau. Real sectoral output for the manufacturing sector is constructed using a chained superlative index (Tornqvist) of the 19 National Income and Product Account (NIPA) industry output measures.	Capital service measures are constructed using U.S. Bureau of Economic Analysis (BEA) capital investment data and a capital measurement methodology consistent with BLS published data. Unpublished capital compensation for the manufacturing sector is constructed to be consistent with U.S. Bureau of Labor Statistics (BLS) methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in the manufacturing sector. BLS published hours worked by all persons is used to estimate labor productivity in the manufacturing sector. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology.	Sectoral energy input and compensation for the manufacturing sector is developed using BEA data on purchases of energy inputs. Intrasectoral purchases of energy inputs are then estimated and used in constructing measures of energy inputs purchased outside the manufacturing sector.	Sectoral materials input and compensation for the manufacturing sector is developed using BEA data on purchases of materials inputs. Intrasectoral purchases of materials inputs are then estimated and used in constructing measures of materials inputs purchased outside the manufacturing sector.	Sectoral services input and compensation for the manufacturing sector is developed fusing BEA data on purchases of services inputs. Intrasectoral purchases of services inputs are then estimated and used in constructing measures of services inputs purchased outside the manufacturing sector.
19 NIPA Manufacturing Industries	Current dollar sectoral output for each of the 19 NIPA manufacturing industries is constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau. Real sectoral output measures for the manufacturing industries are obtained by deflating the current dollar sectoral output measures using a sectoral output deflator. Note that in one industry, NAICS 323, Printing and related support activities, current dollar sectoral output is adjusted to exclude the output of households and nonprofit institutions.	Capital service measures for each NIPA manufacturing industry are constructed using BEA capital investment data and a capital measurement methodology consistent with BLS published data. Unpublished capital compensation for each NIPA manufacturing industry is constructed to be consistent with BLS methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in each of the 19 NIPA manufacturing industries. BLS published hours worked by all persons is used to estimate labor productivity in each NIPA manufacturing industry. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology. Labor compensation data for each NIPA manufacturing industry is unpublished data developed for the manufacturing production account.	Sectoral energy input and compensation for each of the 19 NIPA industries is developed using BEA data on purchases of energy inputs. Intrasectoral purchases of energy inputs are then estimated and used in constructing measures of energy inputs purchased outside each industry.	Sectoral materials input and compensation for each NIPA industry is developed using BEA data on purchases of materials inputs. Intrasectoral purchases of materials inputs are then estimated and used in constructing measures of materials inputs purchased outside each industry.	Sectoral services input and compensation for each NIPA industry is developed using BEA data on purchases of services inputs. Intrasectoral purchases of services inputs are then estimated and used in constructing measures of services inputs purchased outside each industry.
Industry Weights	To analyze each industry's contribution to manufacturing sector total factor productivity growth as measured using sectoral output, industry weights for each NIPA industry are defined as the share of each industry's current dollar sectoral output in sectoral output for the manufacturing sector.					

Source: Bureau of Labor Statistics

Table A-3. Gross Output Measurement Framework

	Source of Component					
	Output	**Capital**	**Labor**	**Energy**	**Materials**	**Purchased Services**
Manufacturing Sector	Current dollar gross output for the manufacturing sector is constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau. Real gross output for the manufacturing sector is constructed using a chained superlative index (Tornqvist) of the 19 National Income and Product Account (NIPA) industry output measures.	Capital service measures are constructed using U.S. Bureau of Economic Analysis (BEA) capital investment data and a capital measurement methodology consistent with U.S. Bureau of Labor Statistics (BLS) published data. Unpublished capital compensation for the manufacturing sector is constructed to be consistent with BLS methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in the manufacturing sector. BLS published hours worked by all persons is used to estimate labor productivity in the manufacturing sector. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology.	Gross energy input and compensation for the manufacturing sector is developed for the unpublished manufacturing production account using BEA data on purchases of energy inputs.	Gross materials input and compensation for the manufacturing sector is developed for the unpublished manufacturing production account using BEA data on purchases of materials inputs.	Gross services input and compensation for the manufacturing sector is developed for the unpublished manufacturing production account using BEA data on purchases of services inputs.
19 NIPA Manufacturing Industries	Current dollar gross output for each NIPA manufacturing industry is constructed primarily using data from the economic censuses and annual surveys of the U.S. Census Bureau. Real gross output measures for the manufacturing industries are obtained by deflating the current dollar gross output measures using a gross output deflator.	Capital service measures for each NIPA manufacturing industry are constructed using BEA capital investment data and a capital measurement methodology consistent with BLS published data. Unpublished capital compensation for each NIPA manufacturing industry is constructed to be consistent with BLS methodology.	BLS published labor input, defined as hours worked adjusted for differences in age, education, and gender, is used to estimate total factor productivity in each of the 19 NIPA manufacturing industries. BLS published hours worked by all persons is used to estimate labor productivity in each NIPA manufacturing industry. Unpublished labor compensation for the manufacturing sector is constructed to be consistent with BLS methodology. Labor compensation data for each NIPA manufacturing industry is unpublished data developed for the manufacturing production account.	Gross energy input and compensation for each NIPA industry is developed using BEA data on purchases of energy inputs.	Gross materials input and compensation for each NIPA industry is developed using BEA data on purchases of materials inputs.	Gross services input and compensation for each NIPA industry is developed using BEA data on purchases of services inputs.
Industry Weights	To analyze each industry's contribution to manufacturing sector total factor productivity growth as measured using gross output, industry weights for each NIPA industry are defined as the share of each industry's current dollar gross output in gross output for the manufacturing sector.					

Source: Bureau of Labor Statistics

Table A-4. Total Factor Productivity Based on Value-Added Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Total Factor Productivity *Annual Percent Change*																									Total Factor Productivity *Annual Percent Change, Selected Time Periods*			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
Manufacturing		3.4	2.1	4.9	5.1	-3.4	5.8	10.5	4.8	1.5	4.1	1.2	1.3	-9.3	8.6	-1.4	-3.3	-1.1	2.8	-2.8	-3.7	3.1	1.3	-4.2	-1.6	10.2	1.0	3.4	-0.8	4.1
321	Wood products	-6.4	-5.4	-1.8	-0.7	1.9	6.5	2.7	-6.0	4.9	-1.9	10.2	4.3	0.6	9.8	8.5	-2.3	0.1	-5.6	-0.9	6.2	-8.2	-10.1	-1.3	-4.8	17.9	1.3	2.5	-0.1	5.9
327	Nonmetallic mineral products	10.3	-2.5	-1.1	-5.1	-2.5	2.0	6.8	3.4	5.4	-11.9	-1.6	0.5	-12.1	2.7	9.3	4.4	6.6	-2.3	-2.0	-2.2	7.3	-3.7	-1.2	0.8	7.0	0.6	0.0	0.4	3.9
331	Primary metals	1.1	1.9	7.6	12.7	-8.1	8.9	2.5	13.2	-1.4	-3.3	-1.0	-2.0	1.6	0.4	0.8	13.9	3.9	-1.7	6.2	16.2	-8.2	-7.4	1.3	16.2	-18.2	1.2	1.3	1.8	-2.5
332	Fabricated metal products	-1.0	-5.3	0.8	4.3	-7.5	1.8	8.1	5.0	0.8	0.6	1.9	-3.3	-18.9	10.7	2.8	-2.6	-3.0	-0.4	-5.3	-2.6	10.5	-1.1	-4.8	-5.3	16.5	-0.1	1.4	-1.8	5.0
333	Machinery	0.6	6.0	-6.9	-0.8	-4.8	10.2	3.6	9.3	5.1	4.2	-0.3	0.1	-11.6	9.8	7.4	-3.5	-2.5	-3.6	-9.0	-7.8	12.4	2.0	-5.2	-2.4	8.9	0.8	3.8	-1.2	3.1
334	Computer and electronic products	30.1	23.3	22.7	38.1	-3.5	14.6	26.6	15.8	13.6	14.8	5.7	14.5	2.6	12.0	3.9	-6.4	1.6	1.6	3.9	-1.6	7.3	6.5	-2.0	1.4	3.5	6.2	12.1	3.5	2.5
335	Electrical equipment, appliances and components	0.2	-17.7	9.9	4.2	7.0	5.9	10.7	-2.3	5.4	15.2	-8.8	6.8	-10.7	3.0	-4.6	-0.2	6.2	-6.9	10.7	-3.8	1.8	4.4	-7.4	-3.1	8.8	1.6	4.5	-0.3	2.7
3361-3363	Motor vehicles, bodies and trailers, and parts	1.2	9.9	3.0	-3.3	-18.9	41.0	18.0	-9.5	2.8	9.9	8.5	-17.1	-85.4	158.9	8.9	62.7	-10.2	-4.9	-11.7	-1.2	-2.5	3.8	-10.7	-17.8	6.4	-3.4	5.9	-7.9	-6.5
3364-3369	Other transportation equipment	-8.4	-2.8	9.0	-3.0	-3.8	-3.8	-1.9	1.0	8.1	4.0	14.2	-1.3	-1.2	5.1	-2.4	-6.1	5.2	0.5	1.3	-1.9	-6.5	1.4	-10.2	9.0	-17.3	-0.5	2.4	-1.4	-5.0
337	Furniture and related products	2.9	-1.4	3.0	-6.7	-8.6	5.0	-1.0	7.7	5.6	1.0	-8.5	4.8	-20.2	16.1	13.3	-18.9	4.2	2.1	7.2	0.1	0.6	2.1	-5.3	-10.5	3.2	-0.4	0.0	-0.1	-3.9
339	Miscellaneous manufacturing	-5.0	2.7	13.1	-6.9	10.7	0.0	3.3	4.0	1.1	5.8	-0.9	-1.8	1.8	16.5	-4.0	1.5	-9.3	1.9	-7.9	16.6	-4.4	3.2	-5.2	-5.4	7.4	1.4	3.4	0.4	0.8
311,312	Food and beverage and tobacco products	-5.8	-0.8	6.1	-3.9	4.2	-2.2	6.5	0.8	-0.8	7.5	1.9	-7.6	1.5	-5.3	1.5	-5.4	-1.5	2.1	-5.2	-11.4	10.9	-3.7	1.0	-2.6	30.1	0.8	2.5	-2.1	12.6
313,314	Textile mills and textile product mills	8.0	0.2	2.3	8.5	-5.0	5.4	-8.2	26.4	-2.6	-1.0	3.7	13.0	-18.8	4.4	-3.7	6.0	7.7	5.6	-5.6	1.6	-2.9	-6.0	-1.4	-10.7	12.7	0.5	2.2	-0.4	0.3
315,316	Apparel and leather and applied products	-12.5	12.4	0.4	1.0	48.3	-28.7	15.3	5.6	-11.0	-2.7	10.5	-3.8	-43.5	32.0	-9.9	50.4	0.4	-0.7	-7.5	-6.4	16.1	-0.9	-5.0	-30.2	-14.0	-1.8	3.0	-0.7	-22.5
322	Paper products	2.7	-6.0	3.8	0.0	-11.2	7.6	5.2	12.4	-1.7	9.6	-4.0	-7.5	7.7	-4.9	-3.0	4.1	3.8	1.0	1.6	1.4	-6.8	3.4	1.8	8.1	6.3	1.5	2.3	0.1	7.2
323	Printing and related support activities	-6.2	-1.1	2.6	2.3	-1.0	4.1	7.3	6.2	10.4	10.0	6.0	1.9	-8.6	6.1	6.7	5.4	2.6	-0.8	-3.0	-0.6	5.2	3.9	-5.0	-5.9	8.0	2.7	6.1	1.1	0.8
324	Petroleum and coal products	24.7	22.0	-15.4	10.1	12.5	-18.8	80.9	-1.5	-16.4	-12.9	-11.8	52.5	-21.8	10.2	-22.6	-21.1	12.9	53.8	0.1	-31.5	20.2	11.4	-7.7	-10.4	13.7	1.1	0.6	1.4	0.9
325	Chemical products	-0.8	-10.2	3.5	3.8	-7.2	5.9	2.1	7.2	-2.0	7.5	0.8	-8.2	-5.0	2.4	-5.9	-13.2	-9.0	0.2	-6.5	-1.2	-0.6	-0.9	-4.1	4.7	13.5	-1.1	1.9	-4.4	9.0
326	Plastics and rubber products	2.6	-1.2	6.7	5.1	-3.1	4.7	6.6	9.6	0.0	-7.9	6.2	-8.8	6.0	5.5	-1.7	-1.3	-3.3	-1.7	6.2	2.9	-6.1	0.5	-2.8	-4.1	47.1	2.1	2.1	-0.5	18.8

Table A-5. Total Factor Productivity Based on Sectoral Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Total Factor Productivity *Annual Percent Change*																									Total Factor Productivity *Annual Percent Change, Selected Time Periods*			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
	Manufacturing	1.8	0.9	2.4	2.9	-1.6	2.7	5.0	2.7	0.8	2.2	0.5	0.1	-3.9	4.2	-0.5	-1.6	-0.2	1.3	-1.1	-1.8	1.4	0.9	-1.8	-0.9	4.4	0.6	1.8	-0.3	1.7
321	Wood products	-2.3	-1.7	-0.8	-0.1	0.6	2.0	0.8	-1.8	2.1	-0.5	3.1	1.7	0.2	3.7	3.5	-1.0	-0.5	-1.9	0.2	1.9	-2.5	-3.7	-0.5	-2.3	4.6	0.4	0.9	0.1	1.1
327	Nonmetallic mineral products	4.7	-1.3	-0.4	-2.2	-1.3	1.1	3.1	1.6	2.3	-5.1	-0.5	-0.2	-4.9	1.2	3.6	1.8	2.8	-0.8	-0.9	-0.9	3.5	-1.6	-0.3	0.3	3.4	0.4	0.1	0.2	1.8
331	Primary metals	0.4	0.7	2.1	3.9	-2.4	3.2	1.0	4.2	-0.4	-1.2	0.1	-0.5	0.7	-0.3	0.4	3.7	0.9	-0.5	2.2	4.1	-2.7	-2.4	0.9	4.4	-10.0	0.2	0.6	0.5	-3.1
332	Fabricated metal products	-0.6	-2.6	0.2	2.1	-3.6	0.9	3.5	2.3	0.5	0.5	0.7	-1.0	-8.3	4.6	1.3	-0.8	-1.6	-0.2	-2.5	-1.2	4.2	-0.2	-1.7	-2.6	6.4	0.0	0.7	-0.7	1.8
333	Machinery	-0.2	2.0	-2.9	0.0	-2.4	3.0	1.9	4.1	2.7	2.0	0.1	0.4	-5.0	4.2	3.3	-1.0	-1.2	-1.7	-4.3	-3.3	4.7	1.2	-2.0	-1.3	5.1	0.5	1.6	-0.4	1.8
334	Computer and electronic products	13.1	10.4	9.8	16.7	-1.6	7.0	13.2	8.2	7.2	8.2	3.9	7.1	1.1	8.4	2.5	-3.5	1.0	0.9	2.9	-1.3	6.2	5.9	-1.6	1.6	3.0	3.7	6.5	2.4	2.3
335	Electrical equipment, appliances and components	0.1	-7.7	3.8	1.8	1.6	2.2	4.8	-1.1	2.3	6.6	-4.1	2.9	-5.2	1.7	-1.9	-0.2	2.8	-3.1	5.1	-2.7	1.0	2.3	-3.6	-1.8	4.7	0.6	1.7	-0.1	1.4
3361-3363	Motor vehicles, bodies and trailers, and parts	0.4	3.0	0.6	-0.6	-4.8	9.4	5.1	-1.9	1.6	3.4	1.3	-4.8	-17.2	17.1	3.5	7.2	-1.6	-0.6	-2.5	-0.3	-0.3	0.7	-1.7	-3.5	3.5	0.4	1.9	-0.3	0.0
3364-3369	Other transportation equipment	-3.8	-0.7	3.7	-2.0	-0.5	-1.5	-0.9	0.6	3.9	1.4	6.4	-0.7	-0.5	2.5	-0.8	-3.0	2.5	0.5	0.9	-1.3	-2.2	0.7	-4.1	2.6	-7.3	-0.1	1.3	-0.5	-2.5
337	Furniture and related products	1.2	-1.1	0.9	-2.2	-3.9	1.6	-0.4	3.2	2.3	0.7	-3.9	0.6	-7.9	4.9	3.6	-4.9	2.0	0.9	3.1	0.0	-0.1	1.1	-2.3	-3.6	1.6	-0.1	-0.1	0.0	-1.0
339	Miscellaneous manufacturing	-2.1	1.1	5.1	-1.7	2.6	1.1	1.6	1.9	1.5	2.9	-0.4	0.7	1.1	6.5	-2.4	-0.6	-4.1	0.8	-4.1	6.6	-1.5	2.4	-3.4	-2.7	5.1	0.7	1.6	0.1	1.1
311,312	Food and beverage and tobacco products	-1.2	-0.4	1.3	-1.0	1.2	-0.9	2.0	0.6	-0.1	2.3	0.1	-1.8	0.8	-1.4	0.0	-1.1	-0.7	0.5	-0.9	-3.1	2.5	-0.9	0.6	-0.8	7.4	0.3	0.7	-0.5	3.2
313,314	Textile mills and textile product mills	1.7	-0.4	0.9	2.9	-2.3	1.4	-3.1	8.9	-0.8	0.0	0.4	3.6	-6.4	1.6	-1.2	2.1	2.9	1.4	-2.2	0.5	-0.8	-2.4	-0.4	-3.5	4.9	0.2	0.6	-0.1	0.6
315,316	Apparel and leather and applied products	-3.3	0.9	-0.8	0.2	6.0	-8.2	2.4	1.5	-2.4	-2.1	-5.3	-2.3	-12.5	11.8	-2.8	16.0	1.1	0.1	-3.1	-1.6	6.2	0.0	-1.9	-14.0	-0.9	-0.8	-1.2	0.7	-7.7
322	Paper products	0.9	-3.0	1.9	-0.1	-5.0	3.1	1.9	4.8	-0.6	4.0	-1.8	-2.7	3.5	-2.2	-1.0	1.3	1.2	0.2	0.4	-0.1	-2.5	1.6	1.0	2.8	2.0	0.5	0.9	0.0	2.4
323	Printing and related support activities	-2.6	-0.5	1.5	1.1	-0.2	1.9	2.9	2.8	4.6	4.1	2.8	1.2	-3.6	2.7	3.4	2.0	1.2	-0.6	-1.5	0.3	1.6	2.2	-2.2	-2.9	3.2	1.2	2.7	0.5	0.1
324	Petroleum and coal products	6.4	7.0	-6.3	3.2	3.8	-6.3	18.5	-1.4	-6.7	-3.0	-3.3	7.8	-4.7	2.4	-4.8	-4.1	1.9	9.1	0.3	-9.3	3.7	3.6	-2.1	-2.2	2.0	0.1	-0.1	0.2	-0.1
325	Chemical products	-0.3	-5.1	2.0	1.7	-3.3	3.1	0.2	3.2	-1.3	3.0	1.4	-4.6	-3.6	2.8	-2.7	-5.9	-1.9	-0.2	-3.1	-0.2	-0.3	-0.1	-2.1	2.0	5.3	-0.4	0.9	-1.8	3.6
326	Plastics and rubber products	1.0	-0.6	2.7	2.1	-1.3	1.4	2.3	3.5	0.1	-2.6	1.0	-2.9	2.1	2.2	-0.7	-0.2	-1.0	-0.9	2.1	0.7	-1.6	0.4	-0.8	-1.3	9.3	0.5	0.6	-0.1	3.9

Table A-6. Total Factor Productivity Based on Gross Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Total Factor Productivity *Annual Percent Change*																									Total Factor Productivity *Annual Percent Change, Selected Time Periods*			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
	Manufacturing	1.2	0.7	1.6	2.0	-1.0	1.8	3.5	1.8	0.5	1.5	0.4	0.3	-2.8	2.8	-0.4	-1.3	-0.1	1.0	-0.7	-1.4	1.1	0.6	-1.2	-0.6	3.2	0.4	1.2	-0.2	1.3
321	Wood products	-2.0	-1.4	-0.7	0.1	0.6	1.8	0.7	-1.6	1.7	-0.5	2.6	1.4	0.5	3.0	2.9	-0.9	-0.4	-1.7	0.1	1.7	-2.3	-3.2	-0.3	-2.1	4.2	0.4	0.7	0.0	1.0
327	Nonmetallic mineral products	4.4	-1.2	-0.4	-2.1	-1.2	0.9	2.8	1.4	2.0	-4.9	-0.4	-0.1	-4.6	1.3	3.3	1.6	2.6	-0.9	-0.7	-0.9	3.2	-1.5	-0.3	0.3	3.0	0.3	0.1	0.2	1.7
331	Primary metals	0.4	0.7	1.8	3.3	-1.9	2.7	0.7	3.3	-0.4	-1.0	0.1	-0.4	0.7	-0.4	0.3	3.0	0.9	-0.5	1.9	3.5	-2.3	-2.0	0.8	3.7	-8.3	0.2	0.5	0.4	-2.5
332	Fabricated metal products	-0.5	-2.4	0.3	1.9	-3.3	0.7	3.3	2.0	0.4	0.3	0.8	-1.1	-7.4	4.0	1.1	-0.9	-1.3	-0.2	-2.0	-0.9	3.8	-0.4	-1.5	-2.3	5.6	0.0	0.6	-0.6	1.6
333	Machinery	-0.1	2.1	-2.6	-0.1	-1.9	2.9	1.5	3.5	2.3	1.6	0.2	0.1	-4.5	3.8	2.9	-1.2	-0.9	-1.5	-3.7	-3.0	4.3	1.0	-1.7	-1.1	4.3	0.4	1.4	-0.4	1.6
334	Computer and electronic products	11.4	9.0	8.2	14.2	-1.4	6.1	11.7	7.2	6.6	7.4	3.6	6.4	1.5	7.4	2.3	-3.4	1.1	1.2	3.0	-1.1	5.4	5.4	-1.6	1.3	3.0	3.4	5.8	2.2	2.2
335	Electrical equipment, appliances and components	0.2	-7.3	3.6	1.7	1.9	2.3	4.5	-1.3	2.0	6.1	-3.7	2.8	-4.9	1.3	-2.0	0.0	2.9	-3.2	5.0	-2.5	1.0	2.2	-3.5	-1.7	4.2	0.6	1.6	-0.1	1.2
3361-3363	Motor vehicles, bodies and trailers, and parts	0.3	2.5	0.5	-0.4	-3.9	7.6	4.0	-1.6	1.2	2.7	1.2	-3.9	-15.1	14.4	3.0	6.3	-1.4	-0.7	-2.1	-0.3	-0.2	0.6	-1.4	-2.9	2.9	0.3	1.5	-0.3	-0.1
3364-3369	Other transportation equipment	-3.5	-0.7	3.5	-1.6	-0.7	-1.4	-0.8	0.5	3.6	1.3	5.9	-0.8	-0.5	2.3	-0.8	-2.7	2.0	0.3	0.8	-1.0	-2.1	0.6	-3.6	2.6	-6.7	-0.1	1.2	-0.5	-2.2
337	Furniture and related products	1.2	-0.8	1.1	-2.1	-3.6	1.5	-0.3	2.9	2.2	0.7	-3.1	0.4	-7.1	4.8	3.2	-5.3	1.5	0.8	2.9	0.1	-0.1	1.0	-2.1	-3.5	1.3	-0.1	0.0	0.0	-1.1
339	Miscellaneous manufacturing	-1.9	1.1	5.0	-2.0	2.8	0.8	1.4	1.8	1.0	2.6	-0.2	0.1	1.3	6.7	-2.1	0.3	-4.2	0.7	-3.8	6.8	-1.3	2.0	-2.9	-2.5	4.2	0.7	1.5	0.2	0.8
311,312	Food and beverage and tobacco products	-1.1	-0.4	1.2	-0.9	1.0	-0.8	1.6	0.3	-0.2	2.0	0.2	-1.7	0.7	-1.4	0.0	-1.1	-0.4	0.4	-0.9	-2.7	2.1	-0.8	0.5	-0.6	6.1	0.2	0.6	-0.5	2.7
313,314	Textile mills and textile product mills	1.4	-0.1	1.0	2.6	-1.6	1.4	-2.6	7.2	-0.7	-0.2	1.1	2.6	-5.6	1.2	-1.0	1.8	2.4	1.5	-1.8	0.6	-0.8	-2.0	-0.3	-3.0	4.1	0.2	0.6	-0.1	0.5
315,316	Apparel and leather and applied products	-2.9	1.8	0.1	1.0	7.5	-7.1	3.0	2.1	-2.4	-0.9	1.5	0.1	-15.2	9.8	-2.9	12.8	0.7	-0.5	-3.5	-1.9	6.3	-0.1	-2.1	-13.8	-1.9	-0.6	0.4	0.1	-8.1
322	Paper products	0.8	-2.4	1.6	-0.1	-4.0	2.5	1.6	4.0	-0.4	3.2	-1.5	-2.3	2.8	-1.9	-0.9	0.9	1.0	0.3	0.5	0.0	-2.0	1.2	0.8	2.3	1.4	0.4	0.7	0.0	1.9
323	Printing and related support activities	-2.3	-0.4	1.5	1.0	-0.1	1.9	2.8	2.5	4.3	4.1	2.6	0.9	-3.7	2.7	3.2	2.0	1.3	-0.4	-1.3	0.2	1.6	2.1	-2.1	-2.9	3.1	1.2	2.6	0.5	0.0
324	Petroleum and coal products	6.0	6.8	-6.1	2.8	3.7	-5.9	17.6	-1.0	-5.9	-3.2	-3.4	8.2	-5.0	2.0	-4.6	-3.9	2.2	8.5	0.5	-8.9	3.5	3.2	-1.9	-1.9	1.7	0.1	0.0	0.2	-0.1
325	Chemical products	-0.2	-4.2	1.6	1.2	-2.7	2.4	0.5	2.9	-1.1	2.9	0.6	-3.6	-2.0	1.6	-2.6	-5.1	-2.4	0.0	-2.4	-0.4	-0.3	-0.2	-1.7	2.0	4.6	-0.4	0.8	-1.6	3.3
326	Plastics and rubber products	1.0	-0.4	2.5	1.9	-1.1	1.3	2.1	3.2	-0.1	-2.4	1.4	-2.9	2.3	1.7	-0.7	-0.2	-0.9	-0.7	2.1	0.6	-1.6	0.4	-0.7	-1.2	8.6	0.5	0.6	-0.1	3.6

Table A-7. Shares based on Value-Added Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Shares: Industry Value-Added Output Relative to Manufacturing Sector Value-Added Output																									Average Shares			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	0.020	0.020	0.020	0.019	0.018	0.019	0.019	0.020	0.020	0.019	0.017	0.015	0.013	0.013	0.013	0.013	0.014	0.015	0.015	0.016	0.017	0.017	0.016	0.018	0.023	0.017	0.019	0.015	0.019
327	Nonmetallic mineral products	0.028	0.029	0.029	0.029	0.028	0.029	0.028	0.028	0.029	0.029	0.028	0.026	0.024	0.022	0.021	0.022	0.024	0.025	0.026	0.027	0.029	0.028	0.028	0.029	0.030	0.027	0.029	0.025	0.029
331	Primary metals	0.035	0.035	0.033	0.031	0.029	0.028	0.027	0.030	0.034	0.035	0.035	0.037	0.031	0.026	0.031	0.034	0.033	0.032	0.030	0.028	0.028	0.029	0.029	0.028	0.030	0.031	0.031	0.031	0.029
332	Fabricated metal products	0.081	0.080	0.079	0.079	0.078	0.075	0.073	0.072	0.073	0.073	0.073	0.074	0.072	0.068	0.068	0.070	0.072	0.072	0.071	0.071	0.070	0.069	0.070	0.071	0.070	0.072	0.074	0.071	0.070
333	Machinery	0.076	0.079	0.079	0.075	0.074	0.072	0.069	0.067	0.069	0.070	0.071	0.073	0.073	0.072	0.076	0.080	0.081	0.081	0.077	0.072	0.071	0.072	0.073	0.075	0.073	0.073	0.071	0.075	0.074
334	Computer and electronic products	0.137	0.138	0.130	0.135	0.131	0.116	0.119	0.123	0.123	0.124	0.122	0.124	0.131	0.135	0.135	0.128	0.123	0.122	0.124	0.125	0.127	0.128	0.129	0.133	0.131	0.127	0.124	0.127	0.131
335	Electrical equipment, appliances and components	0.034	0.031	0.029	0.030	0.030	0.031	0.031	0.029	0.027	0.028	0.029	0.030	0.032	0.031	0.029	0.028	0.029	0.029	0.029	0.030	0.030	0.030	0.029	0.029	0.029	0.029	0.029	0.030	0.029
3361-3363	Motor vehicles, bodies and trailers, and parts	0.082	0.084	0.089	0.090	0.085	0.087	0.094	0.091	0.082	0.075	0.070	0.058	0.037	0.036	0.049	0.056	0.061	0.063	0.066	0.070	0.071	0.068	0.065	0.062	0.057	0.068	0.084	0.059	0.062
3364-3369	Other transportation equipment	0.048	0.047	0.049	0.049	0.050	0.051	0.048	0.047	0.049	0.053	0.058	0.063	0.067	0.069	0.068	0.067	0.067	0.068	0.070	0.071	0.070	0.067	0.066	0.066	0.061	0.061	0.050	0.067	0.064
337	Furniture and related products	0.020	0.021	0.022	0.022	0.022	0.022	0.021	0.020	0.020	0.020	0.018	0.017	0.015	0.013	0.013	0.012	0.012	0.013	0.014	0.015	0.015	0.014	0.014	0.014	0.014	0.016	0.021	0.014	0.014
339	Miscellaneous manufacturing	0.037	0.036	0.038	0.037	0.038	0.041	0.041	0.040	0.039	0.038	0.038	0.039	0.042	0.045	0.044	0.042	0.041	0.039	0.038	0.041	0.043	0.041	0.040	0.041	0.040	0.040	0.039	0.041	0.040
311,312	Food and beverage and tobacco products	0.090	0.089	0.096	0.100	0.104	0.111	0.111	0.105	0.099	0.098	0.099	0.100	0.114	0.118	0.105	0.101	0.103	0.106	0.111	0.115	0.115	0.110	0.111	0.123	0.128	0.109	0.103	0.108	0.121
313,314	Textile mills and textile product mills	0.020	0.020	0.020	0.019	0.018	0.017	0.015	0.013	0.013	0.012	0.011	0.010	0.010	0.009	0.009	0.008	0.009	0.009	0.009	0.009	0.009	0.008	0.007	0.008	0.007	0.011	0.015	0.009	0.007
315,316	Apparel and leather and applied products	0.018	0.016	0.015	0.014	0.014	0.013	0.011	0.010	0.008	0.007	0.007	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.007	0.011	0.005	0.003
322	Paper products	0.043	0.040	0.040	0.040	0.039	0.037	0.036	0.034	0.032	0.032	0.032	0.030	0.032	0.033	0.030	0.028	0.029	0.029	0.029	0.029	0.028	0.026	0.027	0.028	0.027	0.031	0.035	0.029	0.027
323	Printing and related support activities	0.028	0.027	0.028	0.028	0.028	0.028	0.027	0.026	0.026	0.026	0.026	0.025	0.024	0.022	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.017	0.016	0.023	0.027	0.021	0.017
324	Petroleum and coal products	0.032	0.035	0.033	0.033	0.041	0.041	0.045	0.060	0.077	0.083	0.083	0.088	0.079	0.070	0.080	0.086	0.082	0.079	0.075	0.056	0.052	0.072	0.073	0.046	0.041	0.065	0.058	0.075	0.053
325	Chemical products	0.129	0.129	0.128	0.127	0.130	0.140	0.144	0.144	0.141	0.142	0.148	0.151	0.166	0.176	0.171	0.165	0.161	0.160	0.158	0.162	0.166	0.161	0.162	0.171	0.181	0.156	0.139	0.162	0.172
326	Plastics and rubber products	0.042	0.042	0.043	0.043	0.043	0.043	0.042	0.041	0.039	0.037	0.035	0.033	0.034	0.036	0.035	0.035	0.036	0.035	0.036	0.039	0.038	0.036	0.036	0.037	0.038	0.038	0.040	0.036	0.037

Table A-8. Shares based on Sectoral Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Shares *Industry Sectoral Output Relative to Manufacturing Sector Sectoral Output*																									Average Shares			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	0.030	0.030	0.031	0.030	0.028	0.028	0.028	0.029	0.029	0.028	0.025	0.022	0.019	0.018	0.016	0.016	0.018	0.019	0.021	0.023	0.024	0.024	0.024	0.026	0.029	0.024	0.028	0.021	0.026
327	Nonmetallic mineral products	0.031	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.030	0.027	0.025	0.023	0.022	0.023	0.024	0.026	0.029	0.030	0.029	0.030	0.032	0.032	0.029	0.032	0.027	0.031
331	Primary metals	0.056	0.054	0.051	0.048	0.045	0.043	0.042	0.046	0.051	0.053	0.055	0.058	0.051	0.049	0.056	0.056	0.054	0.053	0.051	0.048	0.047	0.049	0.049	0.047	0.050	0.050	0.048	0.052	0.049
332	Fabricated metal products	0.087	0.088	0.088	0.087	0.086	0.085	0.083	0.081	0.081	0.082	0.084	0.086	0.084	0.079	0.077	0.077	0.078	0.079	0.082	0.083	0.082	0.083	0.085	0.087	0.087	0.083	0.084	0.081	0.086
333	Machinery	0.097	0.098	0.097	0.095	0.093	0.089	0.087	0.085	0.085	0.087	0.087	0.087	0.086	0.084	0.086	0.090	0.091	0.090	0.090	0.087	0.085	0.086	0.088	0.089	0.087	0.088	0.088	0.087	0.088
334	Computer and electronic products	0.150	0.153	0.153	0.157	0.153	0.134	0.121	0.117	0.112	0.107	0.104	0.100	0.099	0.097	0.090	0.083	0.077	0.075	0.076	0.079	0.080	0.080	0.081	0.086	0.085	0.100	0.126	0.086	0.084
335	Electrical equipment, appliances and components	0.040	0.040	0.040	0.040	0.039	0.037	0.035	0.033	0.032	0.032	0.033	0.032	0.032	0.031	0.030	0.029	0.029	0.029	0.030	0.031	0.030	0.030	0.030	0.032	0.032	0.032	0.035	0.030	0.031
3361-3363	Motor vehicles, bodies and trailers, and parts	0.132	0.135	0.142	0.142	0.132	0.136	0.144	0.140	0.131	0.122	0.115	0.101	0.087	0.090	0.097	0.102	0.109	0.116	0.129	0.139	0.138	0.134	0.134	0.132	0.125	0.122	0.133	0.115	0.130
3364-3369	Other transportation equipment	0.054	0.060	0.063	0.057	0.057	0.060	0.058	0.055	0.055	0.056	0.060	0.064	0.068	0.068	0.062	0.061	0.064	0.067	0.072	0.073	0.072	0.071	0.068	0.064	0.058	0.063	0.057	0.067	0.063
337	Furniture and related products	0.023	0.025	0.026	0.026	0.026	0.026	0.026	0.025	0.025	0.024	0.022	0.020	0.019	0.017	0.015	0.015	0.016	0.016	0.017	0.019	0.019	0.018	0.018	0.018	0.018	0.020	0.025	0.018	0.018
339	Miscellaneous manufacturing	0.038	0.038	0.038	0.039	0.040	0.042	0.043	0.042	0.040	0.040	0.039	0.038	0.041	0.042	0.038	0.035	0.035	0.035	0.036	0.038	0.037	0.035	0.035	0.036	0.036	0.038	0.041	0.037	0.036
311,312	Food and beverage and tobacco products	0.171	0.170	0.169	0.166	0.173	0.180	0.181	0.181	0.174	0.166	0.163	0.166	0.185	0.193	0.183	0.181	0.182	0.185	0.193	0.201	0.201	0.194	0.193	0.208	0.211	0.185	0.173	0.186	0.204
313,314	Textile mills and textile product mills	0.028	0.028	0.027	0.025	0.024	0.023	0.022	0.021	0.019	0.018	0.016	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.011	0.010	0.010	0.010	0.010	0.015	0.021	0.012	0.010
315,316	Apparel and leather and applied products	0.030	0.028	0.025	0.023	0.021	0.018	0.015	0.012	0.010	0.009	0.007	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.003	0.008	0.015	0.004	0.003
322	Paper products	0.049	0.047	0.047	0.046	0.047	0.047	0.045	0.043	0.041	0.040	0.039	0.038	0.040	0.040	0.038	0.037	0.037	0.036	0.037	0.038	0.037	0.036	0.036	0.037	0.036	0.040	0.044	0.038	0.037
323	Printing and related support activities	0.037	0.037	0.036	0.036	0.036	0.035	0.033	0.031	0.029	0.028	0.027	0.026	0.025	0.024	0.022	0.020	0.020	0.019	0.020	0.021	0.021	0.020	0.020	0.020	0.019	0.025	0.032	0.022	0.020
324	Petroleum and coal products	0.067	0.057	0.053	0.068	0.077	0.076	0.079	0.093	0.118	0.139	0.150	0.168	0.164	0.157	0.183	0.198	0.193	0.180	0.144	0.112	0.116	0.135	0.139	0.110	0.107	0.132	0.100	0.157	0.119
325	Chemical products	0.137	0.136	0.134	0.134	0.138	0.145	0.151	0.155	0.159	0.162	0.166	0.169	0.170	0.173	0.172	0.169	0.169	0.169	0.169	0.172	0.172	0.168	0.167	0.172	0.177	0.164	0.151	0.170	0.172
326	Plastics and rubber products	0.058	0.058	0.059	0.059	0.059	0.060	0.060	0.059	0.057	0.056	0.054	0.050	0.049	0.050	0.049	0.049	0.050	0.051	0.054	0.057	0.057	0.056	0.056	0.057	0.058	0.055	0.058	0.052	0.057

Table A-9. Shares based on Gross Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Shares *Industry Gross Output Relative to Manufacturing Sector Gross Output*																									Average Shares			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	0.023	0.023	0.024	0.023	0.022	0.022	0.023	0.023	0.024	0.023	0.020	0.017	0.015	0.014	0.013	0.013	0.014	0.016	0.017	0.018	0.019	0.019	0.019	0.020	0.024	0.019	0.023	0.017	0.021
327	Nonmetallic mineral products	0.023	0.023	0.024	0.023	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.022	0.020	0.019	0.018	0.017	0.018	0.019	0.020	0.022	0.023	0.022	0.023	0.024	0.024	0.022	0.024	0.021	0.024
331	Primary metals	0.044	0.043	0.040	0.038	0.036	0.035	0.034	0.038	0.042	0.044	0.047	0.049	0.044	0.042	0.049	0.048	0.046	0.045	0.042	0.039	0.039	0.041	0.041	0.039	0.042	0.042	0.039	0.044	0.041
332	Fabricated metal products	0.063	0.064	0.064	0.063	0.063	0.063	0.061	0.060	0.060	0.062	0.063	0.064	0.064	0.061	0.059	0.059	0.059	0.060	0.061	0.062	0.062	0.062	0.064	0.065	0.066	0.062	0.062	0.061	0.065
333	Machinery	0.071	0.072	0.071	0.069	0.068	0.066	0.065	0.064	0.064	0.065	0.065	0.065	0.065	0.064	0.066	0.069	0.069	0.068	0.068	0.066	0.065	0.066	0.067	0.068	0.067	0.066	0.066	0.066	0.067
334	Computer and electronic products	0.115	0.117	0.118	0.123	0.120	0.104	0.094	0.091	0.086	0.083	0.081	0.078	0.077	0.076	0.070	0.063	0.059	0.058	0.059	0.061	0.061	0.060	0.060	0.063	0.063	0.077	0.098	0.066	0.062
335	Electrical equipment, appliances and components	0.029	0.029	0.029	0.029	0.029	0.027	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.023	0.022	0.022	0.022	0.021	0.022	0.023	0.023	0.022	0.023	0.024	0.024	0.024	0.026	0.023	0.023
3361-3363	Motor vehicles, bodies and trailers, and parts	0.109	0.111	0.118	0.117	0.110	0.114	0.121	0.118	0.110	0.102	0.096	0.084	0.072	0.075	0.081	0.085	0.091	0.098	0.108	0.118	0.117	0.113	0.113	0.111	0.104	0.103	0.111	0.096	0.109
3364-3369	Other transportation equipment	0.040	0.044	0.046	0.042	0.042	0.044	0.043	0.041	0.041	0.042	0.045	0.049	0.052	0.053	0.048	0.048	0.051	0.053	0.056	0.057	0.057	0.056	0.053	0.051	0.045	0.048	0.042	0.052	0.050
337	Furniture and related products	0.016	0.017	0.018	0.018	0.018	0.019	0.019	0.018	0.018	0.017	0.016	0.015	0.014	0.013	0.012	0.011	0.012	0.012	0.013	0.014	0.014	0.013	0.013	0.013	0.013	0.015	0.018	0.013	0.013
339	Miscellaneous manufacturing	0.027	0.027	0.028	0.028	0.029	0.031	0.032	0.031	0.030	0.030	0.029	0.028	0.031	0.032	0.030	0.028	0.027	0.027	0.027	0.029	0.028	0.027	0.027	0.028	0.028	0.029	0.030	0.029	0.028
311,312	Food and beverage and tobacco products	0.134	0.133	0.131	0.129	0.134	0.141	0.144	0.144	0.139	0.132	0.130	0.135	0.153	0.161	0.152	0.151	0.152	0.155	0.160	0.166	0.166	0.160	0.159	0.173	0.176	0.151	0.137	0.154	0.169
313,314	Textile mills and textile product mills	0.023	0.023	0.022	0.021	0.020	0.019	0.019	0.017	0.016	0.015	0.013	0.011	0.010	0.010	0.010	0.009	0.009	0.009	0.010	0.010	0.009	0.009	0.008	0.009	0.008	0.012	0.018	0.010	0.008
315,316	Apparel and leather and applied products	0.021	0.020	0.019	0.017	0.016	0.014	0.012	0.010	0.008	0.008	0.006	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.006	0.011	0.004	0.003
322	Paper products	0.040	0.039	0.039	0.038	0.039	0.039	0.038	0.036	0.034	0.033	0.033	0.032	0.034	0.035	0.033	0.031	0.031	0.031	0.032	0.033	0.033	0.032	0.032	0.033	0.033	0.034	0.036	0.033	0.033
323	Printing and related support activities	0.026	0.025	0.025	0.025	0.025	0.025	0.024	0.022	0.021	0.020	0.019	0.018	0.018	0.018	0.016	0.015	0.014	0.014	0.014	0.015	0.015	0.014	0.014	0.014	0.014	0.018	0.023	0.016	0.014
324	Petroleum and coal products	0.047	0.040	0.037	0.048	0.055	0.055	0.058	0.068	0.088	0.103	0.111	0.126	0.124	0.119	0.138	0.149	0.145	0.137	0.109	0.084	0.088	0.104	0.107	0.084	0.082	0.099	0.073	0.119	0.091
325	Chemical products	0.109	0.109	0.107	0.107	0.111	0.116	0.122	0.126	0.130	0.133	0.136	0.138	0.141	0.145	0.145	0.142	0.139	0.137	0.137	0.138	0.137	0.134	0.133	0.136	0.140	0.133	0.123	0.139	0.136
326	Plastics and rubber products	0.041	0.041	0.041	0.042	0.042	0.043	0.044	0.043	0.042	0.041	0.040	0.038	0.037	0.038	0.037	0.037	0.038	0.039	0.041	0.043	0.043	0.042	0.042	0.043	0.044	0.041	0.042	0.040	0.043

Table A-10. Industry Contributions Based on Value-Added Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Industry Contributions *Annual Percent Change*												
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
321	Wood products	-0.131	-0.108	-0.036	-0.014	0.035	0.117	0.050	-0.121	0.097	-0.035	0.161	0.062	0.008
327	Nonmetallic mineral products	0.276	-0.075	-0.032	-0.149	-0.072	0.057	0.187	0.095	0.152	-0.368	-0.046	0.012	-0.312
331	Primary metals	0.037	0.064	0.241	0.373	-0.247	0.239	0.068	0.373	-0.047	-0.116	-0.036	-0.074	0.049
332	Fabricated metal products	-0.081	-0.434	0.061	0.336	-0.603	0.137	0.563	0.351	0.060	0.044	0.136	-0.246	-1.507
333	Machinery	0.043	0.462	-0.565	-0.063	-0.364	0.704	0.243	0.603	0.343	0.288	-0.024	0.009	-0.895
334	Computer and electronic products	3.595	2.894	2.665	4.368	-0.470	1.579	2.813	1.806	1.569	1.703	0.674	1.682	0.336
335	Electrical equipment, appliances and components	0.007	-0.611	0.278	0.121	0.206	0.178	0.311	-0.069	0.141	0.398	-0.267	0.197	-0.359
3361-3363	Motor vehicles, bodies and trailers, and parts	0.099	0.794	0.263	-0.297	-1.782	2.982	1.559	-0.909	0.230	0.710	0.568	-1.090	-7.152
3364-3369	Other transportation equipment	-0.420	-0.133	0.423	-0.149	-0.195	-0.199	-0.092	0.047	0.384	0.206	0.768	-0.083	-0.080
337	Furniture and related products	0.059	-0.029	0.064	-0.153	-0.196	0.105	-0.021	0.148	0.109	0.019	-0.164	0.079	-0.334
339	Miscellaneous manufacturing	-0.188	0.098	0.464	-0.267	0.388	0.002	0.131	0.157	0.043	0.216	-0.034	-0.068	0.073
311,312	Food and beverage and tobacco products	-0.541	-0.075	0.564	-0.394	0.432	-0.247	0.696	0.079	-0.075	0.706	0.182	-0.789	0.171
313,314	Textile mills and textile product mills	0.155	0.004	0.044	0.153	-0.092	0.090	-0.126	0.309	-0.034	-0.012	0.040	0.127	-0.200
315,316	Apparel and leather and applied products	-0.241	0.192	0.005	0.014	0.551	-0.442	0.157	0.053	-0.098	-0.020	0.066	-0.024	-0.303
322	Paper products	0.112	-0.250	0.147	0.001	-0.460	0.273	0.181	0.392	-0.055	0.290	-0.130	-0.232	0.237
323	Printing and related support activities	-0.178	-0.030	0.072	0.063	-0.028	0.111	0.194	0.158	0.257	0.248	0.151	0.048	-0.215
324	Petroleum and coal products	0.702	0.697	-0.554	0.316	0.480	-0.855	2.644	-0.093	-1.374	-1.146	-1.043	3.700	-1.935
325	Chemical products	-0.104	-1.388	0.447	0.477	-0.972	0.806	0.292	1.005	-0.288	1.031	0.119	-1.289	-0.851
326	Plastics and rubber products	0.106	-0.050	0.280	0.214	-0.135	0.197	0.269	0.371	0.001	-0.302	0.213	-0.308	0.197

NAICS Industry		Industry Contributions *Annual Percent Change*												Industry Contributions *Annual Percent Change, Selected Time Periods*			
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	0.117	0.102	-0.030	0.002	-0.088	-0.014	0.097	-0.145	-0.179	-0.021	-0.090	0.384	0.024	0.044	-0.008	0.146
327	Nonmetallic mineral products	0.059	0.187	0.093	0.150	-0.057	-0.051	-0.061	0.200	-0.107	-0.032	0.024	0.200	0.015	0.001	0.007	0.112
331	Primary metals	0.009	0.024	0.442	0.125	-0.056	0.181	0.425	-0.238	-0.220	0.037	0.416	-0.612	0.035	0.033	0.059	-0.099
332	Fabricated metal products	0.696	0.189	-0.185	-0.219	-0.031	-0.388	-0.188	0.702	-0.080	-0.342	-0.389	1.077	-0.012	0.098	-0.135	0.341
333	Machinery	0.674	0.542	-0.284	-0.201	-0.300	-0.728	-0.585	0.835	0.140	-0.387	-0.178	0.622	0.049	0.256	-0.100	0.221
334	Computer and electronic products	1.530	0.511	-0.839	0.189	0.198	0.472	-0.208	0.887	0.805	-0.261	0.184	0.455	0.740	1.377	0.439	0.320
335	Electrical equipment, appliances and components	0.089	-0.135	-0.006	0.178	-0.208	0.298	-0.117	0.052	0.126	-0.226	-0.093	0.244	0.045	0.128	-0.009	0.075
3361-3363	Motor vehicles, bodies and trailers, and parts	3.412	0.416	2.717	-0.660	-0.315	-0.813	-0.083	-0.182	0.250	-0.742	-1.218	0.354	-0.105	0.470	-0.384	-0.435
3364-3369	Other transportation equipment	0.342	-0.165	-0.417	0.339	0.031	0.087	-0.137	-0.466	0.093	-0.713	0.571	-1.147	-0.040	0.131	-0.098	-0.292
337	Furniture and related products	0.197	0.159	-0.261	0.050	0.027	0.095	0.002	0.009	0.030	-0.076	-0.161	0.043	-0.007	0.000	-0.002	-0.059
339	Miscellaneous manufacturing	0.688	-0.177	0.065	-0.400	0.076	-0.316	0.625	-0.192	0.128	-0.218	-0.225	0.285	0.059	0.129	0.023	0.030
311,312	Food and beverage and tobacco products	-0.647	0.153	-0.557	-0.153	0.216	-0.593	-1.392	1.188	-0.419	0.116	-0.324	3.368	0.096	0.253	-0.227	1.505
313,314	Textile mills and textile product mills	0.039	-0.032	0.048	0.063	0.048	-0.051	0.014	-0.026	-0.049	-0.010	-0.085	0.088	0.007	0.025	-0.003	0.002
315,316	Apparel and leather and applied products	0.130	-0.047	0.190	0.002	-0.003	-0.035	-0.028	0.061	-0.003	-0.019	-0.121	-0.043	0.001	0.038	-0.007	-0.082
322	Paper products	-0.166	-0.092	0.115	0.106	0.029	0.047	0.041	-0.196	0.089	0.048	0.218	0.168	0.043	0.070	0.002	0.193
323	Printing and related support activities	0.132	0.138	0.107	0.051	-0.015	-0.059	-0.012	0.097	0.070	-0.091	-0.106	0.127	0.065	0.156	0.021	0.011
324	Petroleum and coal products	0.679	-2.052	-2.047	0.989	3.405	0.006	-2.107	0.954	0.781	-0.590	-0.507	0.522	0.006	-0.207	0.130	0.006
325	Chemical products	0.422	-1.036	-2.335	-1.517	0.027	-1.059	-0.194	-0.103	-0.145	-0.682	0.791	2.293	-0.181	0.282	-0.733	1.539
326	Plastics and rubber products	0.193	-0.060	-0.044	-0.120	-0.060	0.215	0.111	-0.239	0.017	-0.101	-0.155	1.458	0.081	0.087	-0.017	0.648

Table A-11. Industry Contributions Based on Sectoral Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Industry Contributions *Annual Percent Change*																									Industry Contributions *Annual Percent Change, Selected Time Periods*			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	-0.071	-0.051	-0.025	-0.002	0.016	0.056	0.023	-0.052	0.062	-0.014	0.076	0.037	0.003	0.064	0.057	-0.017	-0.009	-0.037	0.003	0.044	-0.061	-0.090	-0.012	-0.060	0.134	0.011	0.024	-0.001	0.037
327	Nonmetallic mineral products	0.142	-0.041	-0.014	-0.071	-0.042	0.035	0.098	0.050	0.072	-0.171	-0.015	-0.006	-0.134	0.029	0.080	0.041	0.064	-0.021	-0.023	-0.027	0.102	-0.047	-0.010	0.008	0.106	0.009	0.004	0.004	0.057
331	Primary metals	0.025	0.039	0.107	0.184	-0.108	0.136	0.043	0.189	-0.018	-0.064	0.004	-0.028	0.038	-0.017	0.021	0.201	0.051	-0.028	0.110	0.193	-0.127	-0.118	0.044	0.204	-0.526	0.009	0.026	0.028	-0.162
332	Fabricated metal products	-0.052	-0.231	0.017	0.182	-0.321	0.074	0.288	0.183	0.040	0.039	0.063	-0.083	-0.729	0.357	0.102	-0.066	-0.124	-0.015	-0.203	-0.097	0.334	-0.019	-0.146	-0.229	0.542	-0.001	0.052	-0.058	0.155
333	Machinery	-0.024	0.199	-0.285	-0.002	-0.227	0.259	0.161	0.340	0.226	0.173	0.012	0.032	-0.441	0.345	0.281	-0.087	-0.107	-0.151	-0.395	-0.291	0.387	0.104	-0.178	-0.120	0.431	0.036	0.135	-0.042	0.155
334	Computer and electronic products	1.834	1.506	1.431	2.432	-0.245	0.901	1.500	0.927	0.779	0.848	0.397	0.684	0.110	0.784	0.220	-0.292	0.076	0.068	0.215	-0.100	0.483	0.456	-0.127	0.137	0.253	0.383	0.728	0.214	0.195
335	Electrical equipment, appliances and components	0.006	-0.325	0.148	0.073	0.064	0.080	0.162	-0.036	0.074	0.206	-0.138	0.091	-0.170	0.053	-0.056	-0.007	0.079	-0.089	0.150	-0.086	0.030	0.069	-0.110	-0.059	0.149	0.022	0.059	-0.004	0.045
3361-3363	Motor vehicles, bodies and trailers, and parts	0.052	0.402	0.082	-0.090	-0.650	1.222	0.709	-0.262	0.207	0.407	0.146	-0.494	-1.649	1.422	0.332	0.702	-0.178	-0.071	-0.323	-0.044	-0.039	0.093	-0.233	-0.465	0.433	0.058	0.253	-0.042	-0.017
3364-3369	Other transportation equipment	-0.212	-0.040	0.228	-0.115	-0.030	-0.088	-0.052	0.031	0.210	0.080	0.368	-0.046	-0.037	0.168	-0.050	-0.188	0.158	0.035	0.061	-0.098	-0.162	0.048	-0.286	0.165	-0.439	-0.007	0.074	-0.033	-0.138
337	Furniture and related products	0.027	-0.027	0.023	-0.057	-0.102	0.042	-0.010	0.079	0.055	0.017	-0.088	0.011	-0.152	0.080	0.054	-0.076	0.032	0.014	0.052	0.001	-0.002	0.021	-0.042	-0.067	0.029	-0.002	-0.001	-0.001	-0.019
339	Miscellaneous manufacturing	-0.081	0.043	0.191	-0.066	0.104	0.045	0.068	0.078	0.059	0.114	-0.015	0.025	0.046	0.263	-0.091	-0.021	-0.143	0.028	-0.149	0.242	-0.054	0.084	-0.122	-0.099	0.179	0.030	0.065	0.009	0.040
311,312	Food and beverage and tobacco products	-0.214	-0.071	0.227	-0.168	0.203	-0.167	0.359	0.105	-0.024	0.373	0.008	-0.309	0.149	-0.282	0.006	-0.201	-0.131	0.084	-0.170	-0.644	0.493	-0.180	0.113	-0.160	1.507	0.053	0.122	-0.090	0.670
313,314	Textile mills and textile product mills	0.049	-0.010	0.024	0.073	-0.055	0.032	-0.070	0.175	-0.016	-0.001	0.005	0.047	-0.084	0.020	-0.014	0.024	0.032	0.016	-0.027	0.006	-0.009	-0.025	-0.004	-0.037	0.049	0.003	0.010	-0.001	0.006
315,316	Apparel and leather and applied products	-0.101	0.026	-0.020	0.005	0.124	-0.152	0.034	0.019	-0.025	-0.019	-0.040	-0.012	-0.063	0.050	-0.012	0.058	0.004	0.000	-0.012	-0.006	0.023	0.000	-0.007	-0.054	-0.003	-0.004	-0.008	0.002	-0.028
322	Paper products	0.043	-0.144	0.088	-0.005	-0.237	0.141	0.084	0.205	-0.023	0.155	-0.070	-0.105	0.135	-0.088	-0.037	0.047	0.042	0.006	0.015	-0.003	-0.095	0.057	0.035	0.103	0.071	0.021	0.036	0.001	0.087
323	Printing and related support activities	-0.099	-0.020	0.053	0.038	-0.006	0.065	0.095	0.085	0.132	0.112	0.074	0.032	-0.095	0.064	0.072	0.041	0.025	-0.012	-0.030	0.006	0.033	0.043	-0.044	-0.058	0.060	0.033	0.079	0.011	0.001
324	Petroleum and coal products	0.415	0.390	-0.344	0.211	0.291	-0.491	1.345	-0.133	-0.819	-0.420	-0.511	1.260	-0.786	0.380	-0.902	-0.824	0.363	1.563	0.041	-1.096	0.421	0.478	-0.297	-0.243	0.211	-0.011	-0.108	0.047	-0.016
325	Chemical products	-0.042	-0.718	0.271	0.233	-0.458	0.435	0.037	0.487	-0.214	0.485	0.224	-0.798	-0.617	0.480	-0.480	-1.032	-0.316	-0.032	-0.527	-0.037	-0.055	-0.011	-0.358	0.340	0.916	-0.074	0.142	-0.316	0.627
326	Plastics and rubber products	0.058	-0.033	0.155	0.120	-0.079	0.083	0.139	0.201	0.005	-0.146	0.051	-0.149	0.101	0.106	-0.033	-0.009	-0.049	-0.048	0.110	0.039	-0.092	0.024	-0.043	-0.075	0.520	0.031	0.036	-0.004	0.222

Table A-12. Industry Contributions Based on Gross Output, by Manufacturing Industry, 1997-2021

NAICS Industry		Industry Contributions *Annual Percent Change*																									Industry Contributions *Annual Percent Change, Selected Time Periods*			
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000-2021	2000-2007	2007-2019	2019-2021
321	Wood products	-0.046	-0.032	-0.016	0.001	0.014	0.039	0.015	-0.038	0.041	-0.012	0.052	0.024	0.007	0.042	0.039	-0.012	-0.005	-0.026	0.001	0.031	-0.043	-0.063	-0.006	-0.042	0.096	0.007	0.016	-0.001	0.027
327	Nonmetallic mineral products	0.097	-0.028	-0.009	-0.049	-0.027	0.022	0.066	0.033	0.048	-0.122	-0.009	-0.003	-0.097	0.026	0.057	0.028	0.046	-0.016	-0.014	-0.021	0.072	-0.034	-0.007	0.008	0.073	0.006	0.001	0.003	0.040
331	Primary metals	0.016	0.028	0.073	0.123	-0.069	0.092	0.026	0.122	-0.016	-0.045	0.007	-0.019	0.031	-0.015	0.013	0.144	0.041	-0.024	0.079	0.134	-0.088	-0.082	0.032	0.141	-0.361	0.007	0.016	0.020	-0.110
332	Fabricated metal products	-0.031	-0.153	0.018	0.121	-0.212	0.046	0.200	0.117	0.022	0.017	0.048	-0.074	-0.491	0.235	0.065	-0.052	-0.075	-0.015	-0.126	-0.059	0.230	-0.022	-0.098	-0.153	0.360	-0.002	0.034	-0.040	0.103
333	Machinery	-0.007	0.152	-0.186	-0.004	-0.133	0.188	0.094	0.219	0.142	0.104	0.016	0.009	-0.295	0.242	0.190	-0.083	-0.059	-0.103	-0.255	-0.200	0.274	0.066	-0.118	-0.074	0.280	0.024	0.090	-0.028	0.103
334	Computer and electronic products	1.242	1.013	0.935	1.632	-0.169	0.619	1.040	0.635	0.548	0.589	0.282	0.485	0.116	0.541	0.157	-0.220	0.062	0.066	0.172	-0.067	0.321	0.314	-0.095	0.083	0.186	0.269	0.506	0.154	0.134
335	Electrical equipment, appliances and components	0.005	-0.218	0.102	0.049	0.054	0.061	0.112	-0.031	0.047	0.139	-0.091	0.066	-0.118	0.030	-0.044	0.001	0.062	-0.069	0.108	-0.058	0.023	0.048	-0.079	-0.040	0.098	0.015	0.041	-0.003	0.029
3361-3363	Motor vehicles, bodies and trailers, and parts	0.030	0.272	0.056	-0.051	-0.440	0.836	0.476	-0.194	0.136	0.273	0.110	-0.334	-1.177	1.002	0.237	0.516	-0.126	-0.066	-0.229	-0.030	-0.027	0.065	-0.165	-0.331	0.299	0.038	0.170	-0.029	-0.017
3364-3369	Other transportation equipment	-0.141	-0.033	0.158	-0.069	-0.028	-0.063	-0.033	0.021	0.142	0.053	0.257	-0.038	-0.027	0.118	-0.036	-0.129	0.099	0.018	0.043	-0.060	-0.119	0.034	-0.196	0.128	-0.317	-0.006	0.050	-0.024	-0.095
337	Furniture and related products	0.019	-0.015	0.019	-0.037	-0.066	0.029	-0.006	0.053	0.039	0.011	-0.052	0.006	-0.103	0.060	0.037	-0.062	0.017	0.010	0.036	0.001	-0.001	0.014	-0.028	-0.047	0.017	-0.002	0.001	-0.001	-0.015
339	Miscellaneous manufacturing	-0.052	0.029	0.135	-0.058	0.081	0.026	0.045	0.055	0.031	0.075	-0.006	0.004	0.039	0.206	-0.063	0.009	-0.117	0.020	-0.105	0.190	-0.038	0.053	-0.079	-0.071	0.115	0.022	0.044	0.010	0.022
311,312	Food and beverage and tobacco products	-0.149	-0.049	0.163	-0.120	0.135	-0.109	0.229	0.050	-0.029	0.263	0.026	-0.227	0.100	-0.235	0.002	-0.171	-0.054	0.059	-0.143	-0.458	0.340	-0.125	0.079	-0.103	1.048	0.032	0.081	-0.070	0.471
313,314	Textile mills and textile product mills	0.033	-0.003	0.021	0.053	-0.032	0.026	-0.050	0.122	-0.012	-0.003	0.014	0.029	-0.061	0.012	-0.010	0.017	0.021	0.014	-0.017	0.006	-0.007	-0.017	-0.002	-0.026	0.034	0.003	0.009	-0.001	0.004
315,316	Apparel and leather and applied products	-0.063	0.036	0.002	0.017	0.116	-0.103	0.034	0.021	-0.020	-0.007	0.010	0.001	-0.072	0.038	-0.011	0.040	0.002	-0.002	-0.011	-0.006	0.018	0.000	-0.006	-0.041	-0.005	0.000	0.007	-0.001	-0.023
322	Paper products	0.031	-0.094	0.060	-0.003	-0.158	0.095	0.059	0.141	-0.015	0.104	-0.048	-0.074	0.094	-0.065	-0.028	0.029	0.032	0.008	0.016	0.001	-0.066	0.039	0.025	0.075	0.047	0.015	0.025	0.001	0.061
323	Printing and related support activities	-0.061	-0.011	0.037	0.026	-0.003	0.046	0.064	0.055	0.087	0.080	0.050	0.017	-0.069	0.046	0.049	0.029	0.018	-0.006	-0.018	0.004	0.024	0.030	-0.030	-0.042	0.041	0.023	0.054	0.008	0.000
324	Petroleum and coal products	0.274	0.265	-0.234	0.131	0.201	-0.335	0.940	-0.065	-0.529	-0.337	-0.385	0.994	-0.636	0.239	-0.651	-0.593	0.313	1.122	0.052	-0.783	0.300	0.331	-0.210	-0.164	0.137	-0.004	-0.074	0.038	-0.014
325	Chemical products	-0.026	-0.471	0.173	0.131	-0.307	0.276	0.061	0.366	-0.145	0.381	0.079	-0.508	-0.289	0.227	-0.383	-0.747	-0.334	-0.003	-0.338	-0.060	-0.040	-0.021	-0.225	0.269	0.632	-0.053	0.101	-0.227	0.451
326	Plastics and rubber products	0.040	-0.017	0.103	0.078	-0.048	0.057	0.093	0.134	-0.002	-0.100	0.056	-0.111	0.083	0.063	-0.026	-0.006	-0.035	-0.029	0.083	0.027	-0.067	0.015	-0.028	-0.052	0.363	0.022	0.027	-0.003	0.155

Table A-13. Comparison of Research and BLS Published Sectoral Output Measures, by Manufacturing Industry, 1997-2021

NAICS Industry	Unpublished Manufacturing Production Account Sectoral Output less BLS Published Sectoral Output *Difference in Annual Growth Rates*																								
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Manufacturing Sector	0.001	-0.001	0.000	0.001	0.000	-0.002	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.001	0.001	-0.001	0.000	0.001	0.000	0.003	0.002	-0.004	0.003	0.002	-0.007	-0.004
321, Wood Products	0.000	0.000	-0.001	0.001	-0.001	0.000	0.000	0.000	0.001	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.001	0.000	0.000	-0.007	0.010
327, Nonmetallic Mineral Products	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.001
331, Primary Metals	-0.001	0.001	-0.001	0.000	0.001	0.000	0.000	0.000	-0.001	0.001	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	0.002	0.001
332, Fabricated Metal Products	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.001	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.002	-0.002	0.004
333, Machinery	-0.001	0.000	0.001	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.002	-0.001	0.000	0.000	0.001	-0.001
334, Computer and Electronic Products	0.000	0.000	-0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.002	0.000	-0.001	0.000	0.002	0.000	0.000	0.000	0.001	-0.001	0.001	0.000	-0.004	0.003
335, Electrical Equipment, Appliances, and Components	0.001	0.000	0.000	0.000	-0.001	-0.001	0.001	-0.001	0.000	0.001	0.000	0.000	0.001	0.002	0.000	-0.001	-0.001	0.000	-0.001	0.001	0.000	0.000	0.000	0.003	-0.001
3361-3363, Motor Vehicles, Bodies and Trailers, and Parts	0.000	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.001	-0.001	0.000	0.000	0.001	0.000	0.000	-0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	-0.006	0.003
3364-3369, Other Transportation Equipment	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.001	0.000	0.001	-0.003	-0.002
337, Furniture and Related Products	0.000	0.000	0.000	0.000	0.000	0.001	0.000	-0.001	0.001	0.000	-0.001	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.003	0.001
339, Miscellaneous Manufacturing	0.000	0.000	-0.001	0.001	-0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	-0.001	0.001	-0.001	0.003	-0.001	0.000	-0.003	0.002	-0.001	0.001	-0.018	0.009
311-312, Food and Beverage and Tobacco Products	0.004	-0.001	-0.004	0.002	-0.002	-0.002	-0.003	0.003	0.000	0.001	-0.003	0.003	0.000	0.000	-0.005	0.002	0.000	-0.001	0.007	0.006	-0.011	0.005	0.003	0.002	-0.018
313-314, Textile Mills and Textile Product Mills	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.001	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.001	0.001	-0.010	0.007
315-316, Apparel and Leather and Allied Products	0.000	0.000	0.000	0.000	-0.002	0.002	-0.001	0.000	0.002	0.000	-0.002	0.005	0.013	-0.007	0.004	-0.016	0.001	-0.001	0.001	0.002	-0.002	0.001	0.001	-0.122	-0.047
322, Paper Products	0.000	-0.001	0.001	-0.001	0.001	0.001	-0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.001	0.000	0.001	0.000	0.003	-0.003
323, Printing and Related Support Activities	0.001	0.000	0.012	0.003	0.008	0.007	-0.008	-0.004	-0.006	-0.011	-0.003	0.002	0.008	-0.003	0.003	-0.014	0.002	-0.002	0.006	0.021	-0.030	0.008	0.013	0.000	-0.023
324, Petroleum and Coal Products	0.001	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
325, Chemical Products	0.000	0.001	0.001	-0.001	0.000	0.001	-0.001	0.000	0.000	-0.001	0.001	-0.001	0.001	0.001	-0.003	0.000	0.004	0.000	0.001	0.000	0.001	0.001	-0.001	-0.001	-0.004
326, Plastics and Rubber Products	0.000	0.000	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.001	-0.001	-0.001	0.001	0.000	0.000	0.000	0.000	-0.001	0.001	0.000	0.000	0.001	-0.001	0.000	0.003

Table A-14. Comparison of Research and BLS Published Capital Services Measures, by Manufacturing Industry, 1997-2021

NAICS Industry	Unpublished Manufacturing Production Account Capital Services less BLS Published Capital Services *Difference in Annual Growth Rates*																								
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Manufacturing Sector	-0.022	-0.012	-0.014	-0.016	-0.005	-0.004	0.006	0.007	0.006	-0.001	0.005	0.010	-0.020	0.007	0.016	0.000	0.001	0.000	-0.008	0.001	0.013	-0.002	-0.006	0.001	0.021
321, Wood Products	-0.008	-0.006	-0.016	-0.004	-0.003	-0.004	-0.005	0.000	0.001	0.005	0.001	0.013	-0.019	-0.025	-0.020	-0.009	0.000	0.002	0.013	0.015	0.010	0.018	0.009	0.023	-0.007
327, Nonmetallic Mineral Products	-0.009	-0.020	-0.015	0.005	-0.018	-0.020	0.021	0.012	-0.013	0.059	-0.009	-0.022	-0.012	0.001	-0.002	0.034	-0.008	-0.009	-0.006	-0.004	-0.006	-0.001	-0.001	0.001	-0.004
331, Primary Metals	0.001	-0.003	-0.001	-0.014	0.020	-0.002	-0.001	0.002	0.003	0.003	-0.002	0.001	-0.013	-0.015	0.000	0.001	-0.001	-0.006	-0.002	-0.006	-0.008	0.000	0.000	-0.009	-0.078
332, Fabricated Metal Products	-0.008	-0.008	-0.010	-0.004	-0.011	-0.007	0.000	0.001	0.003	-0.001	-0.012	-0.019	-0.011	-0.004	-0.004	-0.002	-0.002	-0.003	-0.002	0.000	-0.001	-0.002	0.001	0.000	-0.022
333, Machinery	-0.061	-0.084	-0.069	-0.030	-0.006	-0.010	0.111	0.042	0.059	0.019	-0.007	-0.011	-0.023	-0.022	0.001	-0.003	-0.007	-0.003	-0.001	-0.003	-0.007	-0.001	-0.001	-0.003	0.007
334, Computer and Electronic Products	0.001	-0.008	0.007	0.078	0.112	0.080	0.001	0.002	0.000	0.000	-0.001	0.003	-0.006	-0.013	-0.013	0.002	-0.001	0.003	0.005	0.079	0.188	0.025	0.005	0.027	0.073
335, Electrical Equipment, Appliances, and Components	0.000	-0.009	-0.005	-0.008	0.022	-0.070	-0.006	0.010	-0.036	0.017	0.190	-0.093	-0.023	0.012	-0.033	0.016	-0.001	-0.011	-0.009	-0.011	-0.011	-0.015	-0.012	-0.019	-0.036
3361-3363, Motor Vehicles, Bodies and Trailers, and Parts	0.001	-0.001	0.000	0.001	-0.001	-0.007	0.014	0.006	-0.002	-0.007	-0.005	-0.001	-0.009	0.003	-0.012	0.001	0.001	0.003	0.004	0.001	0.002	0.007	0.004	0.001	-0.002
3364-3369, Other Transportation Equipment	-0.152	0.017	-0.020	-0.105	-0.073	0.000	0.005	0.018	0.001	0.008	0.000	-0.001	-0.009	0.001	-0.009	0.000	0.002	0.001	0.003	-0.010	-0.002	0.015	0.001	0.003	0.000
337, Furniture and Related Products	-0.023	-0.048	-0.052	-0.031	-0.014	-0.021	-0.023	-0.022	0.010	-0.005	-0.010	0.006	0.011	0.000	-0.044	-0.040	-0.016	-0.004	-0.004	-0.015	-0.019	-0.023	-0.023	-0.004	0.041
339, Miscellaneous Manufacturing	0.020	-0.001	0.025	0.027	0.014	-0.016	0.001	0.001	0.003	0.016	-0.002	0.033	0.039	0.032	0.018	0.005	0.010	0.009	0.008	0.000	-0.004	0.002	0.010	0.019	0.054
311-312, Food and Beverage and Tobacco Products	-0.005	-0.004	-0.008	-0.010	-0.006	-0.003	-0.001	-0.003	-0.002	-0.004	-0.006	-0.009	-0.002	-0.001	-0.005	-0.002	-0.004	-0.003	0.000	-0.002	-0.002	-0.003	-0.001	-0.001	-0.007
313-314, Textile Mills and Textile Product Mills	-0.003	-0.015	-0.012	-0.007	0.000	0.026	0.000	-0.006	0.003	0.002	0.000	0.001	-0.003	0.001	-0.003	0.001	-0.001	-0.001	-0.002	0.003	0.000	-0.005	0.000	0.008	0.033
315-316, Apparel and Leather and Allied Products	0.057	0.048	0.047	0.056	-0.032	-0.004	0.000	0.005	0.004	0.000	0.000	-0.002	-0.008	-0.034	-0.008	0.037	0.001	0.003	0.003	0.006	0.000	0.002	0.008	0.009	0.011
322, Paper Products	-0.008	-0.008	-0.008	0.003	-0.006	0.013	0.006	0.005	0.013	-0.003	-0.009	-0.003	-0.002	0.007	0.000	-0.002	-0.004	-0.006	-0.006	-0.010	-0.013	0.003	0.003	-0.008	-0.026
323, Printing and Related Support Activities	0.004	0.011	0.006	0.069	0.086	0.004	0.003	-0.001	-0.003	-0.005	-0.002	0.001	-0.005	0.004	-0.002	0.000	0.003	0.000	0.002	0.001	-0.001	0.000	-0.002	-0.001	0.000
324, Petroleum and Coal Products	-0.011	-0.023	-0.002	-0.042	0.011	0.018	-0.007	-0.014	-0.004	-0.007	-0.010	0.034	-0.080	-0.033	0.004	-0.002	-0.013	0.000	0.006	-0.008	-0.029	-0.022	-0.005	-0.007	-0.001
325, Chemical Products	-0.043	-0.040	-0.037	-0.026	-0.029	-0.019	-0.021	-0.008	-0.020	-0.033	-0.044	-0.066	-0.069	-0.036	-0.016	-0.028	-0.007	0.002	0.003	0.005	0.005	0.006	0.006	0.011	-0.016
326, Plastics and Rubber Products	-0.001	0.000	-0.001	0.001	0.002	-0.002	0.001	0.002	-0.002	0.002	0.001	-0.017	-0.026	0.007	0.011	0.002	0.007	-0.005	-0.005	-0.008	-0.007	0.000	0.000	0.001	-0.092