Why Real Value Added Is Not My Favorite Concept[1]

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Suppose that a flour substitute, Carhyd, derived from petroleum, sold in 1971 for $5.00 per pound, but thereafter the price falls to around 20 cents per pound while flour prices rise to 60 cents per pound, Meanwhile, bakers learn to use Carhyd so that by 1984, a loaf of bread is made of one pound of Carhyd and half a pound of flour. In 1971 prices, that is $5.00 of Carhyd and $.05 of flour per loaf, and since there are two loaves in 1971 dollar's worth of bread, the coefficients in the bread column are Carhyd=10.00, Flour = .10. The sum of just these two coefficients is greater than 1.0 … therefore, we don't restrict the coefficients to sum to 1.0. If you anyone who does, mark him down as a rank amateur.

Almon, Buckler, Horwitz & Reimbold, 1974, p.165

1. Introduction

Real value added is the most commonly used measure of output for productivity studies, as well as for the determination of industries' contributions to GDP growth. It is recommended by the System of National Accounts (SNA) as the best way to measure industry productivity, and by the United Nations and ESA95 as the correct method for obtaining constant price input-output tables. Its attractiveness derives from the fact that it is intuitively plausible, simple to understand, and that real value added by industry sums to real GDP.

However, more than 60 years after it was first introduced, there is still no fundamental agreement on the meaning of real value added, or its price. Although nearly every major statistical organization in the world computes it, few have attempted to define what it measures. Perhaps the meaning is considered too obvious to require explanation. Most who use it for the study of productivity loosely describe it as a measure of "real output", although strictly speaking it is not that.

Though value added is income, real value added does not represent the purchasing power of that income. To understand what it does represent, we must turn to the descriptions of how it is calculated. Real value added is calculated by three main methods.

1. *Extrapolation.* One method to calculate real value added is to extrapolate value added from a base year with indicators that follow real output growth, which is what it then measures.
2. *Single Deflation.* Another method is to deflate industry value added with the industry output deflator. This measures how much of the industry's product, in base year prices, can be purchased by the value added.
3. *Double Deflation.* This is the method recommended by the SNA, UN and ESA 95. In general, the idea is to subtract deflated inputs from deflated output(s). In its most elegant versions, it is constructed as an approximation to a Divisia index. Real value added may be regarded as a subfunction $g(K,L)$ of a production

[1] The title and method of this paper were borrowed from Kernighan (1981).

function $f(K,L,M)$. If the conditions for separability do not hold, it is not clear what this method measures.

Conflicting views on real value added can be found already in writings of the 1940s by Wassily Leontief and Richard Stone, who had quite different ideas about what was the function and meaning of constant price input-output tables. Leontief felt that inputs and outputs in real terms should be considered to be much like quantities of physical units, and therefore that sums of coefficients had no meaningful interpretation in prices of a different year. Stone argued for a framework that would balance in the same way in constant prices as in current prices, meaning that the constant price input-output coefficients plus the value added coefficient would always sum to 1.0.

This paper first traces the history of real value added, and the related idea of constant price input-output tables, in which the input-output coefficients sum to 1.0 down the column. Next it reviews the current practice of statistical organizations, and the statistical recommendations of the SNA, ESA95 and the United Nations Input-Output Handbook. The sparse economic literature on real value added and double deflation is covered briefly. Following this, some examples are set out which illustrate the difficulties of double deflation. In the final section, U.S. data on real value added is analyzed, to see if any of the problems illustrated in the previous section can be found in these data. This section closes with some broader questions relating to the topic.

2. A Brief History of Real Value Added

As early as 1940, Solomon Fabricant was using the concept of real value added to measure and compare the real growth of manufacturing industries. He termed it "the ideal index of the net physical output of an industry". He introduced a formula for double deflation, whereby the components of industry cost were forced to sum up to output in real terms as well as in nominal money units.

The nominal value added identity for an industry *j* is

$$V_j = p_j^q q_j - \sum_i p_{ij}^m m_{ij}$$

where V_j is nominal industry value added, q_j is real industry gross output, p_j^q is the output price, m_{ij} is real intermediate use of commodity *i* by industry *j*, and p_{ij}^m is the price of intermediate input *i*. To calculate real value added v_j by double deflation, one simply takes the difference of real output and real inputs:

$$v_j = q_j - \sum_i m_{ij}$$

In Britain, Geary (1944), in a study of Irish data, used the real value added formula to show the "trends in the amount of work done in each industry". He argued the advantages of this measure, especially since it was additive over industries, so that the same research question could be explored at various levels of aggregation.

The demand for real value added data to study industry productivity was stimulated by Solow's seminal (1957) paper, and in 1961, the Conference on Research in Income and

Wealth included several papers that used measures of real value added for this purpose. Included in this volume was one of the first studies done by a statistical agency, the Canadian Dominion Bureau of Statistics (DBS, now Statistics Canada), highlighting the use of measures of "real net output" for projecting real GDP by industry of origin.[2]

In parallel with these developments, national income accountants in the U.K. began using real value added as an alternative way to calculate real GDP. Richard Stone, in his little book on national income accounting, presented the idea in a fashion that has become typical of the statistical agencies. His line of reasoning is that GDP measured by real expenditures is the difference between real output and real intermediate sales by product. Therefore, subtracting real intermediate from real output by industry yields a measure which must sum to the same total. Calculation of this real value added by double deflation therefore should provide a good check on the computation of real GDP by expenditure category.[3] As we will see below, Stone's vision of using real value added as an integral step in GDP estimation was later taken up in the SNA and other standards.

By the 1970s, most of the statistical agencies in the main OECD countries featured calculations of industry real value added as a regular release. In addition to their use in growth accounting exercises and studies of inflation, these data have been used in hundreds of analyses of industry productivity. The alternative to the use of real value added to study productivity is to use real gross output. Although gross output has been used for many labor productivity studies, the multifactor productivity literature using gross output is less voluminous. This is undoubtedly because it requires annual data on intermediate purchases, which are generally unavailable or unreliable. Studies comparing results using real value added versus real gross output for productivity analysis on the same data are even less numerous.[4]

3. The Approach of the Statistical Community

Without fail, the statistical agencies and the organizations that promulgate standards for those agencies appear to have accepted the use of real value added with very little debate. This attests to the strong attraction it offers as a way to measure industry productivity and contributions to GDP growth. It is interesting that in every introduction to the topic, the authors first explain that value added (especially capital income) is something which does not have a quantity and price, and therefore cannot be directly deflated. Following this statement, they invariably suggest that double deflation provides an "indirect" way to

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[2] Beringuette and Leacy (1961) make the interesting observation that the double-deflated value added is used as an independent check on the deflation of the final expenditure side of GDP.

[3] Stone (1977), p. 110. This book is a later edition of a book first published by Richard Stone and James Meade in 1944.

[4] Jorgenson, Gollop and Fraumeni (1987) provide excellent discussion on the development of data and methods for this line of approach.

deflate value added. In this section, I survey the usage of the concept in the statistical community, and provide some direct quotes to help understand their reasoning.[5]

The United States. The Office of Business Economics (OBE, now BEA) announced the advent of their program to calculate real GNP by industry in a 1962 *Survey of Current Business* article by Martin Marimont. The preferred method of calculation is double deflation. Marimont does not explain why double deflation should yield an appropriate measure of real value added, or why real intermediate and real value added should add up to real output by industry. The author simply states that "these income and related items cannot be converted into physical volume terms directly; appropriate techniques for doing so are not available. Indirect methods must be used."

The appendix to the article contains a good explanation and interpretation of the double deflation calculation. The starting point is the thesis that real GDP is the sum of each industry's real GDP. Therefore, the problem is of determining each industry's real GDP, and therefore its contribution to total growth. The author makes a statement in the appendix about the value added prices:

> These implicit deflator indexes measure the percent that the gross product – sales minus purchases – of an industry in a given period is compared to the gross product which the same composite of sales and purchases would have yielded in the prices of the base period.

Real GNP by industry became a regular annual feature in the *Survey* throughout the 1960s to the 1980s, but did not undergo any further substantive published analysis until 1988[6], when the BEA felt compelled to address some recent criticisms of the real value added data. Parker (1991) reported on numerous improvements in the program, including the incorporation of import prices, more current and extensive use of detailed input-output data, and a better method for allocating company based data to industries defined on establishments.

One remaining criticism was that the real value added growth rates were very sensitive to the choice of base year, and examples had been constructed where real value added would be negative, even though nominal value added was positive. BEA addressed both these criticisms in a *Survey* article by Bob Yuskavage (1996). At this time BEA had just adopted "chain-type" Fisher indexes for the calculation of prices and quantity indexes in the national accounts, and the method was extended to the calculation of double-deflated value added. The use of the Fisher ideal indexes made the growth rates of real value added invariant to the choice of base year, and the possibility of negative real value added was reduced. Yuskavage explains in a box on the first page:

> Estimates of real gross domestic income are not prepared, because price indexes cannot be associated with income measures as they can be with the goods and services that make up the expenditure measures. Real GPO estimates for most industries are derived using the formula for calculating chain-type measures with separate estimates of gross output and intermediate inputs.

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[5] Due to space and time constraints, I have only focused on a small group of statistical agencies. I apologize if my selection is heavily weighted towards English speaking countries, but I think these agencies are representative of international practice.

[6] de Leeuw (1988) responded to criticisms on the use of the hedonic deflator for computers, the lack of knowledge of detailed input purchases, and the failure to deflate imported inputs separately.

Note that BEA does not use the double-deflation technique for all industries. For various reasons, an extrapolator of constant price value added is used in certain industries, and in other industries, the single-deflation technique is used, where value added is deflated by the output price index. Note that if any industries are calculated by a procedure other than double deflation, real value added by industry is no longer guaranteed to sum to GDP, and the total is sensitive to the level of aggregation.

One problem remaining for BEA was that the measure of value added in the input-output accounts was not consistent with that used in the GPO (now called GDP-by-industry) accounts. This problem was resolved in June, 2004, when BEA presented a set of integrated annual input-output and GDP-by-industry accounts.[7] BEA's strategic plan currently includes the development of a time-series of constant price input-output tables.

The United Kingdom. Since 1992, the U.K. Office of National Statistics (ONS) has integrated the current and constant price input-output (KPIO) framework within the National Accounts production process. Ahmad (1999) states that "constant price Input-Output supply and use tables are increasingly receiving international recognition as the best way in which to balance the constant price national accounts and produce constant price GDP". It is interesting that for this project, the ONS does not follow the double deflation procedure to deflate value added. Rather, they deflate intermediate in such a way that total intermediate in constant dollars is constrained to be a constant "share" of real output. This forces real value added (the difference) to grow at the same rate as output as well.

Canada. Canada was one of the first countries to derive real GDP by industry using double deflation, beginning this effort on a trial basis in the late 1950s. For many years, it maintained a program very similar to that of the U.S. "GDP-by-Industry". Now this program has been discontinued, and the measures of real value added are published jointly with the constant price input-output tables. Statistics Canada furnishes excellent documentation on methodology on their website. The following text is from *A Guide to Deflating the Input-Output Accounts*:

> The double deflation method is appropriate because it is difficult to visualize how to factor some of the primary inputs into quantum and price. Under certain assumptions on the change in their quality, more specifically referred to as productivity, it is possible to conceive of price and quantum measures for labour income and for capital consumption allowances. … But the construction of price and quantum indexes for mixed income of unincorporated business and for the remaining parts of operating surplus, principally for profits, calls for even more heroic assumptions. Because of these problems, constant price domestic product for business industries has been calculated indirectly by the double deflation method.[8]

Australia. The Australian Bureau of Statistics (ABS) follows a similar approach to Canada, but does not rely wholly on double deflation to deflate value added. They also use either an output indicator method, where value added moves like a volume indicator

[7] The integrated accounts were released and described in Moyer, Planting, Kern and Kish (2004).

[8] Statistics Canada (2001), p. 22.

of output (thus leaving the real value added share constant), an input indicator method, which extrapolates by an input measure such as hours worked.[9]

Denmark. In the system of Statistics Denmark, gross value added at constant prices is calculated before a calculation of GDP at constant prices is made. This is then compared and reconciled to the calculation of GDP in constant prices from the expenditures side. Much of the language in the Statistics Denmark manual is similar to that found elsewhere. However, they go further than most in examining the issue:

> As it is not meaningful from a conceptual perspective to split up gross value added (GVA) at current prices into a price and a volume component, one could ask how the development of gross value added at constant prices can be interpreted, considering the way in which it is calculated in national accounts.
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> GVA at constant prices by industry reflects the industry's product in real terms. It reflects the GVA that the industry would have achieved in the base year provided that it had produced the output combination of the year under survey, with the input composition of the year under survey. Changes in relative prices imply that the development of GVA at constant prices cannot be considered to reflect the development in real incomes in each industry. …
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> In calculating GVA at constant prices for a given industry using double deflation it is conceptually possible that it will become negative. This is the case when intermediate consumption accounts for a comparatively large share of production, and when there is a considerable distinction between the price development of intermediate consumption and price development of production. However, this is to a larger extent more a theoretical possibility than a practical problem.[10]

While it may be hazardous to extrapolate from this limited sample of countries, I think they are representative of the approaches to real value added across the world. These agencies are in agreement on the desirability of compiling real value added estimates by industry, and they also agree that double deflation is the preferred method, although most of them use extrapolation or single deflation where double deflation is too difficult, or causes problems to arise. If pressed for definition, most would say it is similar to real output or real product, and is one of the methods for measuring growth in an industry.

The System of National Accounts

The first version of the System of National Accounts (SNA) was produced in 1953. The original report was concerned only with presenting flows in money terms, and did not explore making estimates at constant prices. It also did not discuss the relationship of commodities, industries and input-output tables with national accounts. However, the 1968 SNA treated input-output accounts and constant price tables as central pillars of the system, presenting them in Chapters III and IV, respectively. Chapter III distinguishes between industries and commodities, and introduces the supply and use tables as the preferred framework for the compilation of input-output accounts. It also contains a discussion of methods for generating various types of direct requirements matrices from

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[9] ABS (2000), chapter 24.

[10] Statistics Denmark (2002), p.64.

the supply and use tables. Chapter IV deals with the important question of decomposing values into price components and quantity components, in order to make valid comparisons over time. The framework of methods of valuation is introduced, distinguishing between basic values, producers' values and purchasers' values. However, the issue of when and where an aggregate can be expressed as an index of its detailed components is not explicitly tackled. There seems to be an implicit assumption throughout Chapter IV that it is perfectly natural to aggregate constant price detail to form constant price aggregates, and that the same balances that hold in the current price accounts should hold in the constant price accounts. This is made clear in section 4.41 on the deflation of value added:

> By definition, index numbers of value added should be derived from the difference between measures of gross output and measures of intermediate consumption. This method of compilation is usually referred to as the double-deflation method.[11]

There is no discussion anywhere in the text of what is the index of real value added, or what the value added price is attempting to measure. The mathematical appendix contains a hint:

> 4.123. The outcome of the method described is a measure of value added. Although little experience is available, it would be interesting to compare measures of value added at constant prices with measures of primary input at constant prices.
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> 4.124. The association of price and quantity measures with primary inputs is a subject on which more work is needed. The choice of a suitable quantity index unit for labour has been widely discussed and agreement on this subject could probably be reached. The choice of a suitable quantity unit for capital is more difficult; but to the extent that capital embodied in tangible assets were acceptable as a first approximation, the concept of the gross stock of tangible assets at constant replacement costs might prove an acceptable point of departure. The comparison of an index number of value added with an index number of primary inputs would give rise to measures of productivity ... [12]

It should be clear that the SNA is *not* saying that real value added is a measure of primary inputs, but rather that if such a measure could be constructed, then the ratio of real value added over that measure would be a measure of productivity. This indeed has been one of the primary uses of real value added.

In the 1968 volume, there is not yet any presentation of a constant price set of input-output tables, nor a discussion of the meaning of constant price input-output coefficients in prices other than the base year. However, any national accountant trained in this system of accounting would certainly tell you that the coefficients, including value added coefficients, must surely sum to 1.0 in every year, no matter what the system of prices. It is interesting that this version of the SNA that really established input-output as a fundamental tool for the development of national accounts paid so little heed to Leontief's own interpretation of the meaning of constant price input-output coefficients:

> All figures in this table are shown in dollars. They might as well have been given in physical units appropriate for the description of the output of the individual sectors of the economy – tons of coal, bushels of wheat, ton miles of transportation, man-house of work, and so on. As a

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[11] UN (1968), p. 57.

[12] UN, *op. cit.*, p. 69.

> matter of fact, the dollar figures entered in each particular row can be interpreted in this sense provided one defines the physical units in which they have been measured as 'the amount (i.e. number of tones, yards, ton miles, or hours) of the particular product purchasable for one dollar at the prevailing 1947 prices.' Only the 'total inputs' do not lend themselves to this kind of physical interpretation: tons of coal, yards of cloth, and man-hours of labor cannot be added for any useful purpose.[13]

The 1993 SNA is more than triple the size of the 1968 volume, and the chapters on input-output and price and volume measures have been relegated to chapters XV and XVI. Section E ("Some aspects of input-output compilation") in chapter XV includes a section on constant price supply and use tables, which is new. As in the earlier volume, little attention is given to methodological difficulties of balancing tables in constant prices. The section on value added states simply:

> 15.162. Constant price measures for gross value added are possible in the input-output framework by using the double deflation method, as the difference between:
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> (a) The value of output deflated by a price index of output.
>
> (b) The value of intermediate consumption deflated by a price index for these inputs.[14]

Section E in chapter XVI includes some interesting comments on real value added:

> 16.61 Within an integrated set of price and volume measures such as those relating to the flows of goods and services in the use matrix or in an input-output table, gross value added has to be measured by the double deflation method. Otherwise, it will not be possible to balance uses and resources identically. However, the measurement of gross value added in year *t* at the prices of some base year is liable to throw into sharp relief some underlying index number problems. Vectors of prices and quantities are not independent of each other. In practice, relative quantities produced or consumed are functions of the relative prices at the time. If relative prices change, relative quantities will be adjusted in response. A process of production which is efficient at one set of prices may not be very efficient at another set of relative prices. If the other set of prices is very different the inefficiency of the process may reveal itself in a very conspicuous form, namely *negative gross value added.* Even if the revalued gross value added is not actually negative, the gross operating surplus may change from positive to negative, thereby signaling the fact that the production process would not be used at those prices.

It is significant that the authors do seem to understand the logical difficulties of the double-deflated value added concept. However, in the following section, they continue to advocate its use, and suggest that the problems can be alleviated by using chain indexes.

The United Nations Input-Output Manual

There are at least two versions of the UN I-O Manual (1973, 1999), and these are quite different in approach and emphasis. In the earlier volume, there is no discussion of the

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[13] Leontief (1953), pp. 8-10. Although I have not yet found a comment by Leontief on the technique of double-deflating value added, he surely would wonder what could be its operational meaning.

[14] UN (1993), p.374.

compilation of constant price input-output tables, and the discussion of double-deflation is found in the last chapter, on applications, in the section on index numbers. After an exposition of the method that closely follows the SNA, several warnings are given:

> 5.130. Paradoxical results may arise if some important input is used in much larger quantities than in the base year because of a considerable fall in its relative price; in this case the quantity index of value added may show a decline, even if both value added at current prices and the quantity index of gross output increase substantially. If a considerable decrease in the quantity of gross output takes place at the same time, value added at constant prices could even become negative. Since such unrealistic results are likely to be caused by one, or a few major factors, it should, however, be possible to identify the reasons for them. A change of base year may be necessary if a considerable change in the price structure for either output or input is found to be the major reason.
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> 5.131. If the indicators utilized in double-deflation are not sufficiently accurate, unrealistic quantity series of value added may also be obtained when input-output coefficients are high. For instance, if the quantity indicators utilized in respect of intermediate input and output are not representative, an increase in intermediate input, may be reflected differently in the two indicators and may result in spurious changes in the quantity index of value added. Similar spurious changes in the price of quantity measures may, of course, result if unrepresentative price indices are used in respect of, or to deflate, gross output and intermediate input.[15]

As in the SNA manual, the authors understand some of the pitfalls of double deflation, yet continue to recommend it, as long as the problems are not egregious.

The newer version of the handbook devotes an entire chapter (XI) to input-output tables and production accounts in constant prices. It is very similar in spirit to the ESA I-O manual, described below.[16] The exposition begins with the discussion of the double deflation method for calculating real value added and real GDP, and gives this part of the process central importance.

The Eurostat Input-Output Manual

The Eurostat I-O manual provides a framework for the compilation of input-output tables at 60 products and 60 industries for member countries, consistent with ESA 95. In the second paragraph of the introduction, it states that "the tables in the input-output system provide a consistent framework for balancing supply and demand in current and constant prices. In the ESA program, the supply and use tables and symmetric I-O tables have shifted into the center of the compilation of national accounts. In addition, the tables in both current and constant prices are a key element in the data delivery program of the ESA 95 regulation.

The Eurostat manual is a significant document for producers of I-O tables, as it goes into much more detail on the compilation of constant price I-O tables than either the SNA or the UN I-O manual. Chapter 9 of the Eurostat manual is devoted to the estimation of supply and use tables in constant prices. Several basic principles are seen to guide this estimation:

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[15] UN (1973), p. 145.

[16] UN (1999), pp. 227 ff.

- Values at constant prices for aggregates should equal the sum of values at constant prices for constituent parts, applying the same index number formula.
- For every commodity, total supply at constant prices equals total use at constant prices.
- For every industry, total output at constant prices equals total intermediate consumption at constant prices plus total value added at constant prices.

It is striking that both the ESA and the SNA take the position that certain balancing items must be deflated in such a way that the accounting identities balance in current and constant prices. Presumably, this same position is taken to the deflation of net exports or net foreign capital flows.

4. Theoretical Views on Real Value Added

As mentioned above, empirical studies using 'net output' (double-deflated value added) as the numerator in productivity studies preceded theoretical discussions by quite a few years. David's (1962) critical paper was an early attempt to make sense of the results of the double deflation process in terms of production theory. He considered it a serious shortcoming that the double deflation method could give rise to negative values when relative price changes are large, or when input proportions change significantly. However, he regarded this as an index number problem, and not a fundamental problem with the concept of real value added. In a later (1966) paper, David advocated the use of a single-deflation technique for the estimation of real value added, which involved dividing nominal industry value added by the industry output price.

Sims (1969) demonstrated that "one can justify the double-deflation process as a fixed-weight linear approximation to an ideal variable-weight logarithmic index under assumptions no more restrictive than those required to justify the notion of 'real value added' itself." In fact, these assumptions are not much stronger than those made by many models of growth. If we write the production function as weakly separable in capital and labor:

$$q = f(K, L, M) = g(h(K, L), M)$$

where: q = real output, K = real capital input, L = real labor input, and M = real intermediate input, then the sub-function $h(K,L)$ can be viewed as real value added. If one forms a Divisia index

$$\frac{\dot{h}}{h} = \frac{\dot{q}/q - s_M \dot{M}/M}{s_h}$$

where s_M is the intermediate share of nominal output and s_h is the value added share. In the continuous case, this resolves to

$$\dot{h} = \dot{q} - \dot{M}$$

This equation can be approximated by a continuously chained Divisia index, if that periods for chaining are frequent enough, and the weights *s* are continuously altered to reflect the relative shares of intermediate and value added. The assumption required to reach this conclusion is that a first-degree-homogenous production function in value added and materials exist. Sims points out in his last footnote that negative real value added estimates can arise, but only through violation of the assumptions necessary to justify the notion of real value added itself.

Rymes (1971) took a diametrically opposite position, and even proposed abandonment of the real value added concept, questioning whether it had valid economic meaning.[17] While recognizing the identity that the sum of deflated net outputs across industries must equal the sum of deflated final outputs, he observed that there were severe problems of interpretation in the presence of changes in terms of trade, particularly with imported intermediate and capital goods. He recognized a similar problem arising from changes in technology, that results in the introduction of new production processes, manifesting as a change in the structure of input coefficients and prices. The succinct version of Rymes is similar to Almon (2006):

> To measure current-period outputs and inputs in base-period prices is to ask what would have been the income originating if the current-period outputs and inputs had been assembled under base-period conditions of technology. This is, itself, a meaningless question, since under base-period conditions of technology, the optimum quantity of imported intermediate inputs was in fact being used … To express net output in constant base-period prices is merely to create a fictitious measure of output with no meaning.[18]

Sato (1976) was really the first thoroughgoing attempt to derive a theoretical basis for real value added and significantly extended the work of Sims. Although he was familiar with the work of Rymes, he maintained that the validity of the real value added concept was no more difficult to accept than the validity of the aggregate neoclassical production function. This paper was fundamental to the understanding of several aspects of the problem, and a characteristic representative of what Rymes considered to be the neoclassical view of production.

First, he pointed out that the attractiveness of the SNA Laspeyres approach to the double-deflation of value added derives from the Laspeyres deflation of Gross National Expenditures (GNE). In the aggregate, if the intermediate and output deflators are consistent with those used for the deflation of GNE, then total GDP formed as the sum of real value added by industry is necessarily equal to GNE. Second, he noted that David's (1966) proposal for a single-deflated index fails because then the measure of aggregate GDP depends on the degree of aggregation. Like Sims, he proposed the use of a Divisia index to estimate real value added, but warned that the Divisia index is not path independent. If period to period changes are small, the Divisia can be approximated by a discrete measure such as the Fisher or Törnqvist index.

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[17] Rymes' chapter 7 "On the Concept of Net Output" presents a sophisticated attack on the concept of real net output (real value added) in the larger context of a theory of capital and technical change that provides a fertile alternative to neoclassical studies of industry productivity.

[18] Rymes, op.cit., p. 156.

Sato noted that in the presence of technical change or economies of scale, the estimate of real value added was a product of a quantum index of primary factor inputs and these other “intangible” factors. He was also aware of Rymes’ point that there is a “terms-of-trade” effect captured in the measure of real value added, when reduction in intermediate prices (due to reduced import costs or otherwise) causes value added to increase. If one intends the measure of real value added to capture economic welfare, then this terms-of-trade effect should be left in; if one wants to determine the contribution of primary inputs, then it should be removed.

Finally, Sato showed that the Laspeyres index is a lower bound, and the Paasche index an upper bound to true indexes of real value added. “Correctly measured”, real value added should not be negative as long as nominal value added is not negative.

Whether the conditions necessary for a valid real value added index indeed hold is an empirical question. Denny and May (1978) test the hypotheses of homotheticity and weak separability using Canadian industry data from 1950 to 1970, and reject both hypotheses. Jorgenson, Gollop and Fraumeni test for separability in their 1987 study and also reject the hypothesis in 40 out of 45 industries).

Brian Moyer (2000) presented an elegant analysis of the real value added aggregation problem as a multistage optimization problem. He shows that if the industry production function can be written as a weakly separable function of aggregate real intermediate and aggregate real value added, then the Fisher ideal index is close to a true superlative index of real value added.

The concept of real value added has more recently come under attack from Eladio Febrero Paños from a ‘modern classical’ viewpoint, in the stream of Sraffa and Pasinetti. He points to difficulties that statistical agencies have had in constructing unique, robust measures of real value added. He believes that the difficulties are not related to index number problems, the level of disaggregation, or the accuracy of deflators, but rather reflect lack of clarity on fundamental definitions. In his opinion, value added cannot be deflated, because it is not the outcome of multiplying a price times a quantity. He points to the fact that the output price is related intimately to the prices and quantities of all inputs, the labor cost, and the need, in equilibrium, to provide a competitive rate of return to capital input. The output price and level of value added relate to the structure of prices in each period. The measure of value added calculated by double deflation is using the prices and quantities of different period, which have no relation to each other.[19]

The dichotomy in thinking about constant price input-output accounts exemplified by Leontief and Stone has continued in the discussion of real value added. The neoclassical approach of writing value added as a subaggregate in a weakly separable production function is theoretically attractive, but most statistical agencies that compile real value added have not tested their data to see if the separability conditions hold. When they do not hold, it is unclear what double-deflated real value added is measuring.

[19] Unfortunately, Paños papers on this topic are unpublished. They can be requested from him by E-mail at eladio.febrero@uclm.es.

5. Hypothetical Problems with Double Deflated Value Added

In this section I will demonstrate features of the double deflated real value added index in some hypothetical situations. A practical minded national income accountant may object that these examples are far-fetched, and unlikely to occur in practice. However, I will argue that there are elements of these examples occurring in the real world data, but they are harder to find, partly because the actual data shows less drastic behavior than these examples, and partly because of the way the statistical agencies release their results.

First I will construct two simple examples which try to bring out the logical appeal of real value added.

Example 1 below captures the flavor of the typical simple textbook example of the deflation of a balanced set of accounts. Assume the economy is composed of one aggregate industry (and commodity). In period A, the base period, the industry (and commodity) price is 1.0. In period B, the price increases to 1.2, but there is no change in the level or distribution of production and final demand. In order to deflate the accounts in period B back into the prices of period A, we can deflate across the row to obtain intermediate, final demand and output in base period prices. Analyzing the column, industry output can be deflated using the same deflator as commodity output. Should we deflate value added? If we are to obtain a full constant price input-output table, one would think that this is necessary. In fact, real GDP should be the same whether measured as the sum of final demand, or the sum of value added. We notice immediately that the deflated output (100) minus the deflated intermediate (100) must yield the same figure as deflated final demand. Therefore, we reach the obvious conclusion that the deflated value added must also be 100, and the value added price deflator must be the same as that of output and intermediate, which is 1.2. The precise meaning of the quantity or price of real value added need not trouble us, because everything adds up.

Example 1: Simple Economy, One Industry, One Commodity

Period A: Price = 1.0

	Industries	Final Demand	Output
Products	100	100	200
Value Added	100		
Output	200		

Period B: Price = 1.2 (No quantity change)

	Industries	Final Demand	Output
Products	120	120	240
Value Added	120		
Output	240		

One might protest that this example is useless for understanding the real accounting issues. Let's turn to a slightly more complicated example. In Example 2, the simple economy has been divided into two commodities and industries, Goods and Services.

The prices in the period A are all 1.0, and we assume that there is homogenous price change in period B.

Deflating back to the prices of period A (not shown), it should be obvious that we will obtain the same table as in period A. In this case, it is also obvious that double deflation yields the result that the value added deflator should be the same as the overall deflator, and that the sum of real value added by industry is equal to the sum of real final demand by commodity. In fact, this will always be the case if all price change is equal across industries, and if real input-output coefficients (deflated intermediate divided by deflated output) do not change.

Example 2: Two Sector Economy, No Change in Relative Prices

Period A: Prices = 1.0

	Goods	Services	Final Demand	Output
Goods	40	10	50	100
Services	10	40	50	100
Value Added	50	50		
Output	100	100		

Period B: Prices = 1.2

	Goods	Services	Final Demand	Output
Goods	48	12	60	120
Services	12	48	60	120
Value Added	60	60		
Output	120	120		

Example 3 is the first example that shows what may be a problem in interpreting industry patterns of growth. In this example, there are still only two industries and commodities, but in this case relative prices do change, and there is price response with unitary elasticity in the intermediate sector. To keep the results simple, final demands in constant prices do not change, but of course they do change in current prices.

Also, this case has been constructed so that diagonal demands are smaller than off-diagonal demands.

In period B, the goods price deflator falls from 1.0 to 0.8, and the services deflator rises to 1.2. In nominal values, intermediate purchases do not change, because of the assumption of unitary price elasticity. We assume however, that final demands show no price response, so the nominal values show the full effect of the price change. As a result, nominal output of goods falls by 10 percent, and nominal output of services rises by 10 percent.

Example 3: Two Sector Economy with Relative Price Change (Quantities of Inputs Adjust, Final Demand Quantities the Same)

Period A: Same as example 2

	Goods	Services	Final Demand	Output
Goods	10	40	50	100
Services	40	10	50	100
Value Added	50	50	**100**	
Output	100	100		

Period B: Price (Goods) = 0.8, Price (Services) = 1.2

	Goods	Services	Final Demand	Output
Goods	10	40	40	90
Services	40	10	60	110
Value Added	40	60	**100**	
Output	90	110		

Deflated to period A prices

	Goods	Services	Final Demand	Output
Goods	12.5	50	50	112.5
Services	33.33	8.33	50	91.67
Value Added	66.67	33.33	**100**	
Output	112.5	91.67		

The last table shows the results of deflation. Due to the changes in intermediate purchase patterns, real output of goods has risen (12.5%), and real output of services has fallen (8.3%). Real value added has been computed as the difference between real output and real intermediate purchases. Note that total real GDP has not changed, but real value added has been redistributed from period A. Real value added in the goods industry increases by 1/3, while real value added in the services industry has fallen by 1/3.

What this means precisely, is that if prices had been the same as in period A during period B, the value of the output of the goods industry would have been higher, and the costs of input lower, than they in fact were in period B. The reverse is true for services. However, period A's prices did not hold in period B, and the adjustments in intermediate input use occurred in response to price change. The conventional interpretation of these results would be that the goods industry contributed strongly to the growth of GDP, whereas the service industry subtracted from that growth, with the net result that there was no change in GDP.

The last example used a Laspeyres quantity index for value added calculation, since values were put back into the prices of the base year. (The corresponding measure of value added price would be a Paasche price index.) In the U.S., BEA calculated double-deflated value added indices using the Laspeyres method until 1996, when they switched to using the Fisher chain-weighted index.

The Fisher chain index is constructed so that the period-to-period movement of the index is the square root of the product of the period-to-period movement of the Laspeyres and Paasche quantity or price index. The Fisher index has the convenient property that a Fisher quantity index multiplied by a Fisher price index yields the original nominal series. The Fisher index is undefined when either the Laspeyres or Paasche index is negative (the value of the series flips sign).

The calculation of the Fisher index will be illustrated in the next few hypothetical examples involving a single industry. These examples are all concocted to bring out different conceptual problems of the real value added index. Three examples will be analyzed:

1. Input substitution due to relative price change.
2. Increase in income due to terms-of-trade improvement.
3. Hedonically deflated inputs and outputs.

For each version, a more extreme example is shown first, for which one or both of the Laspeyres or Paasche index is negative. The second version avoids the negativity, but shows the same problems in lesser degree.

Relative Price Change

Example 4 shows the problem that can occur when there is large relative price change, and price response in intermediate consumption. The columns P(A), Q(A) and $(A) show the price, constant price level, and nominal level of the intermediate inputs and output in period A. The columns P(B), Q(B) and $(B) show the corresponding values in period B. The last two columns show intermediate calculations used in constructing the Laspeyres (base period weights) or Paasche (current period weights) indexes. The value added row (VA), shows value added in each of the four possible combinations of quantities and prices. These are the components used in constructing the index numbers shown below.

Example 4: Single industry substitution due to relative price change (extreme version)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Plastic	10	10	100	5	20	100	200	50
Metal	10	10	100	20	5	100	50	200
VA			25			25	-25	-25
Output	1	225	225	1		225	225	225

This simple case shows the crux of the real value added conceptual problem when there is relative price change. Here we have a simple industry with two inputs plastic and metal. The industry uses very little labor. It experiences a change in relative prices, with unitary input elasticities, so that intermediate input costs are preserved after the relative price change. In this case, it is logical to assume that the output price would remain unchanged.

Using the Laspeyres quantity index for the calculation of real value added, we obtain:

$$V_{A,B}^{L} = \frac{p_A^q q_B - \sum_i p_{i,A}^m m_{i,B}}{p_A^q q_A - \sum_i p_{i,A}^m m_{i,A}} = \frac{(1)(225) - [(10)(20) + (10)(5)]}{(1)(225) - [(10)(10) + (10)(10)]} = \frac{-25}{25} = -1$$

where

$V_{A,B}^{L}$ is the Laspeyres quantity index between period A and period B

p_A^q, p_B^q are the output prices in period A and period B

q_A, q_B are the levels of constant price output in period A and B

$p_{i,A}^m, p_{i,B}^m$ are the price indices of intermediate input *i* in period A and B

$m_{i,A}, m_{i,B}$ are the levels of constant price purchases of intermediate input *i*

The Paasche quantity index for real value added yields:

$$V_{A,B}^{P} = \frac{p_B^q q_B - \sum_i p_{i,B}^m m_{i,B}}{p_B^q q_A - \sum_i p_{i,B}^m m_{i,A}} = \frac{(1)(225) - [(20)(5) + (5)(20)]}{(1)(225) - [(5)(10) + (20)(10)]} = \frac{25}{-25} = -1$$

The Fisher index is defined as $V_{A,B}^{F} = \sqrt{V_{A,B}^{L} V_{A,B}^{P}}$. However, it cannot be calculated for this example.

Example 5 has less drastic relative price change and substitution.

Example 5: Single industry substitution due to relative price change (moderate)

	P(A)	Q(A)	\$(A)	P(B)	Q(B)	\$(B)	P(A)*Q(B)	P(B)*Q(A)
Plastic	10	10	100	7	15	105	150	70
Metal	10	10	100	15	7	105	70	150
VA			25			15	5	5
Output	1	225	225	1		225	225	225

$$V_{A,B}^{L} = \frac{(1)(225) - [(10)(7) + (10)(15)]}{(1)(225) - [(10)(10) + (10)(10)]} = \frac{5}{25} = 0.2$$

$$V^{P}_{A,B} = \frac{(1)(225) - [(15)(7) + (7)(15)]}{(1)(225) - [(15)(10) + (7)(10)]} = \frac{15}{5} = 3$$

$$V^{F}_{A,B} = \sqrt{(0.2)(3)} \cong 1.225$$

According to the Laspeyres index, real value added declined in this industry by 80% between case A and case B. According to the Paasche index, it tripled. The Fisher yields a seemingly innocuous index of 1.225. So, "correctly measured", real value added increased by slightly more than 20 percent. But, what does it mean? Experiments I have conducted with this case indicate that the Laspeyres always falls, the Paasche always rises, and the Fisher may rise or fall, depending on the relative sizes of the input-output coefficients and the relative price change.

Improvement in the Terms of Trade

In example 6, we assume that all of the plastic and metal is imported, and that the terms of trade improve by a factor of 2.

Example 6: Improvement in the terms of trade (extreme version)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Plastic	10	10	100	5	15	75	150	50
Metal	10	10	100	5	15	75	150	50
VA			25			50	-75	100
Output	1	225	225	0.889	225	200	225	200

In this example, the inputs, now exceptionally cheaper in period B, are being used in greater amounts. This behavior is often observed when certain inputs become cheaper, that firms don't try as hard to economize on their use, and more waste may be tolerated. Total intermediate costs are nevertheless lower than in period A. The industry has reduced its price, but is earning twice the value added, taking advantage of the cheap imports. We assume that total production remain unchanged.

Valuing quantities in period B of the prices in period A yields negative value added. Valuing quantities in period A in the prices of period B yield an exaggerated measure of value added. What do the real value added quantity indexes show?

$$V^{L}_{A,B} = \frac{-75}{25} = -3$$

$$V_{A,B}^{P} = \frac{50}{100} = 0.5$$

Example 7 is the moderate version where we don’t get negatives when revaluing in different period prices:

Example 7: Improvement in the terms of trade (moderate version)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Plastic	10	10	100	7.5	11	82.5	110	75
Metal	10	10	100	7.5	11	82.5	110	75
VA			25			35	5	50
Output	1	225	225	0.889	225	200	225	200

In this case, there is only a 25% improvement in the terms of trade, only a slight increase in the use of plastic and metal inputs, and an improvement in value added of only 10 units. In this case we can calculate the Fisher index.

$$V_{A,B}^{L} = \frac{5}{25} = 0.2$$

$$V_{A,B}^{P} = \frac{35}{50} = 0.7$$

$$V_{A,B}^{F} = \sqrt{(0.3)(0.7)} \cong 0.458$$

In this case, at least both price indexes indicate the same direction of movement of the real value added index, and the Fisher index is a good compromise between the two versions of the index. However, one is left grasping at how to interpret the measure: 'Due to terms of trade improvement, the real aggregate of factor inputs declined by roughly half" seems to be the conclusion.

Hedonic Price Indexes

Example 8 illustrates the difficulties of the real value added concept in conjunction with the use of hedonic deflators in an integrated input-output framework. According to BEA and BLS price data, the computer deflator fell from 8.6 to 2.2 from 1987 to 1997, while the semiconductor deflator only fell from 3.5 to 2.3. Semiconductors were an important input into computers. In nominal terms, the I-O coefficient was .05 in 1987 and .14 in 1997.[20]

In example 8, the production of computers in current dollars has increased by 25% from period A to period B. However, according to the hedonic index for computers, which has declined by a factor of 4 (similar to the 1987 to 1997 period), the measured "real" production of computers has increased by 500%. We will assume that the nominal share of total cost of semiconductors is constant. So in nominal terms, the intermediate purchases of semiconductors also increase by 25%. The price decline in semiconductors according to the hedonic index is not as drastic as that for computers, so the real input goes up only by 250%. Prices of the other inputs, plastic and metal, rise by roughly 10% between period A and B. Nominal value added rises slightly, maintaining a similar

[20] The input-output relationships can be studied using BEA's excellent interactive input-output table web site, a vision of Mark Planting, at http://www.bea.gov/bea/industry/iotables.

proportion to nominal output in period B as in period A. These figures are not uncharacteristic of what is shown in the U.S. data for the 1987 to 1997 period.

Example 8: The computer industry, purchasing semiconductors (extreme version)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Semiconductors	3.5	10	35	2	25	50	87.5	20
Plastic and metal	4.5	10	45	5	10	50	45	50
VA			15			25	367.5	-45
Output	10	10	95	2.5	50	125	500	25

What has happened to the real value added index?

$$V^L_{A,B} = \frac{367.5}{15} = 24.5$$

$$V^P_{A,B} = \frac{25}{-45} = -0.555$$

The Fisher index cannot be calculated.

The logic of chain indexing is to form many chain indexes between adjacent periods, where differences in price are (hopefully) not so drastic. Following this logic, let's construct a model where the price change is only 1/10 of the above (that example represented a 10 year price change).

Example 9. Computer industry purchasing semiconductors (moderate version)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Semiconductors	3.5	10	35	3.3	15.15	50	53	33
Plastic and metal	4.5	10	45	5	10	50	45	50
VA			15			27.5	52	2
Output	10	10	95	8.5	15	127.5	150	85

$$V^L_{A,B} = \frac{52}{15} = 3.46$$

$$V^P_{A,B} = \frac{27.5}{2} = 13.75$$

$$V^F_{A,B} = \sqrt{(3.46)(13.75)} \cong 6.9$$

So, according to the Fisher index, even for this (small?) year to year change in prices of computers and semiconductors, we obtain a value added index that increases by almost 700%. In this case, the driving factor seems to be the incredible difference in growth rates between the prices of output and inputs. Experiments with U.S. input-output data conducted by the author show that using either the 1992 or the 1997 I-O coefficients, the price growth of computer output measured by BEA and BLS is inconsistent with the price growth of inputs. The hedonic price indexes for semiconductors and computers (and other goods) are not constructed in a systematic input-output framework, where price relationships between inputs and outputs must hold. Rather, they are estimated in isolation, constructed as linear functions of the characteristics of each good that are deemed to be economically important. It would only be through good luck that such indexes could serve as part of an internally consistent system of prices.

In all of these examples, the crucial problem of the real value added index is that it measures value added as a residual for the quantities of one period in the prices of another period. The national income accounting community must decide if this is merely a "difficult index number problem" or a measure without basis.

Champions of double deflation would no doubt argue that these examples are too artificial, and that we are unlikely to observe such discontinuous changes in quantities and prices in real world data. This is indeed true, and in the next section I will use BEA data to explore where problems may lie. Keep in mind that the only cases in which conceptual problems do not emerge is where prices all grow at the same rate, and input-output coefficients do not change. If relative price changes are not extreme, and coefficients are relatively constant, then we are living in the world of example 2, where double deflation is harmless. If not, then statements about the relative importance of manufacturing, services and information and communication technology (ICT) in GDP growth may be incorrect, or at least unclear in their interpretation.

6. An Examination of BEA GDP-by-Industry Data

The most recent full release of the BEA GDP-by-industry accounts was in December 2005, and included data on output, intermediate and value added in current and constant prices, as well as price indexes for each component, from 1998 to 2004. These measures are released for 61 private sector industries, and 4 government "industries". At the same time, BEA released a time series of aggregate input-output make and use tables, in current prices for the same period.[21]

Table 1 is a summary of the chain-type quantity indexes for value added constructed by BEA for this release. I have highlighted industries and periods for which there was significant movement in this index, as candidates for examination.

The value added quantity indexes are estimated by compiling a Fisher index of intermediate inputs and output at a more detailed level than what is published. Intermediate purchases are separately deflated by commodity deflators formed as an average of the domestic commodity price and the import price, weighted by the import share of total supply. If one had the commodity output and import deflators at the 65-commodity level, it would be possible to replicate the BEA double deflation technique.

[21] See Smith and Lum (2005) for the text and published tables for this release. Unfortunately, neither constant price measures or price deflators are made available for the annual I-O tables.

However, BEA publishes only the aggregate intermediate price index. Although the annual I-O tables are also published, no prices are provided for them. Due to this, we are severely limited in the analysis we can undertake on the published data.

However, we do know that problems can arise when the growth rate of the deflator for output moves significantly differently from the deflator for intermediate. Table 2 shows the growth rates of output price and intermediate prices, and the difference between them. I have highlighted the entries where the difference is greater than 7 per cent.

For example, Computer and electronic products (21) experiences decline in the output price at 13.8% from 1998 to 1999, and a decline in input prices at 4.8%, with a difference of 9.0%. I'll use the data from the BEA release to construct a table of the form of the previous section.

334 - Computer and electronic products 1998(A)-1999(B)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Intermediate	1.085	241609	262122	1.034	281964	291551	305903	249824
Value Added			165673			162777	215749	122760
Output	1.293	330803	427795	1.126	403381	454328	521652	372584

Here are the calculations for the Laspeyres, Paasche and Fisher quantity indexes for real value added:

$$V_{A,B}^{L} = \frac{215749}{165673} = 1.302$$

$$V_{A,B}^{P} = \frac{162777}{122760} = 1.326$$

$$V_{A,B}^{F} = \sqrt{(1.302)(1.326)} \cong 1.314$$

In this example, the index is very similar whether constructed as Laspeyres or Paasche. Why is that? Remember that the Laspeyres calculation uses each period's quantities, but period A prices, and the Paasche calculation uses each period's quantities, but with period B prices. Look now at the two right hand side columns. The column labeled 'P(A)*Q(B) shows in the middle row the value added as it would have been in period B, with period A prices. The column labeled P(B)*Q(A) shows the value added in period A with period B prices. The fact that the two versions of the price index are similar can be stated: Putting period B quantities into period A prices raises value added from 165673 to 215749. Putting period A quantities into period B prices reduces value added from 162777 to 122760. The proportion of the change is about the same in each measure because we have only two components of the index (output and intermediate), and two periods under study.

We can calculate the Fisher price index of value added as a dual to the Fisher quantity index. The ratio of change in nominal value added between the two periods is .983

(162777/165673). Therefore, the ratio of price is .7476 (.9825/1.314). This means that the value added price for this sector declined by near 25 % between the two periods. To summarize the results for this period to period change, nominal value added declined slightly (less than 2%). Nominal output rose by 6%. Nominal intermediate rose by 11%. The output price fell by nearly 14% and the intermediate price fell by nearly 5%. So, real output increased at a rate of 22%, and real intermediate increased at 16%. The result is that real value added increased by 31% and the real value added price fell by 25%.

Another sector that experiences a large difference in input and output price is Oil and gas extraction (3), in the period 1999 to 2000. Input price growth in this period was 51.7%, while output price growth was only 32.7%, for a difference of 19%. Nominal value added increased significantly, from 47217 to 80990, or 71.5%. Nominal output and intermediate inputs also increased about 71%. Real output increased at 2.4%, and real intermediate increased at 24%.

211 - Oil and gas extraction, 1999(A)-2000(B)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Intermediate	0.7211	45573	32863	1	56600	56600	40814	45573
Value Added			47217			80990	41203	88766
Output	0.5961	134340	80080	1	137590	137590	82017	134340

The quantity index calculations are as follows

$$V_{A,B}^{L} = \frac{41203}{47217} = 0.873$$

$$V_{A,B}^{P} = \frac{80990}{88766} = 0.912$$

$$V_{A,B}^{F} = \sqrt{(0.873)(0.912)} \cong 0.892$$

The nominal value added index is 1.715. So the value added price index is 1.922 (1.715/0.892). In conclusion, the accounts call for a decline of real value added of about 11%, and an increase in value added price of 92%.

Let’s look at one more example, before we conclude this section. This time, let’s look at a large sector, that doesn’t have an extreme difference in price growth. I will argue that the distortionary effects that can sometimes cause real value added to be negative, or that can lead to counterintuitive or illogical results with large price and coefficient changes can also be observed in sectors with mild relative price differences. The industry of interest this time is Hospitals and nursing and residential care facilities (55), from 2000 to 2001. In this year, the growth rate of the output price index was 4.4%, the growth rate of the intermediate price was 0.7%, and the difference was 3.7%. Nominal value added increased by 8.1%, nominal output increased by 7.9%, and nominal intermediate increased by 7.6%. The growth rates real output and intermediate were 3.3% and 6.9%, respectively. The calculations of the quantity indexes are shown below the table.

622HO - Hospitals and nursing and residential care 2000(A)-2001(B)

	P(A)	Q(A)	$(A)	P(B)	Q(B)	$(B)	P(A)*Q(B)	P(B)*Q(A)
Intermediate	1.000	191410	191410	1.0073	204595	206089	204595	192807
Value Added			238552			258044	239593	256460
Output	1.000	429962	429962	1.0449	444189	464133	444189	449267

$$V_{A,B}^{L} = \frac{239593}{238552} = 1.0044$$

$$V_{A,B}^{P} = \frac{258044}{256460} = 1.0062$$

$$V_{A,B}^{F} = \sqrt{(1.0044)(1.0062)} \cong 1.0053$$

The index of change of nominal value added from 2000 to 2001 was 1.082. Therefore the index of price growth was 1.076 (1.082/1.0053). One way to think of this result is that since the output price was growing faster than the aggregate input price, the value added price has to grow even faster, so that the weighted sum of intermediate and value added price growth will equal the output price growth. But this means that the real value added must grow more slowly than either output or intermediate. We obtain the somewhat counterintuitive result that holding the line on input cost growth has allowed value added to increase. However, this calculation results in a measure of real value added that grows only 0.5%. We now see a very mild form of the results we examined in the last section as examples 7 and 8, the improvement in the terms of trade. Whenever there is a productivity improvement in the use of inputs, or some factor that causes their price to grow more slowly than output, real value added will also grow more slowly than output, or even decline. As Almon (2006) has argued: "nonsense in small increments is still nonsense".[22] If one doesn't agree with the way double deflation works in the terms of trade example in the last section, then one should find fault with this seemingly innocuous example.

The way the data are released by BEA masks the full extent of the problem. If the full set of intermediate data in current and constant prices were made available, more features of the real value added calculation would be revealed. Many of the issues we have discussed in this paper, such as price response or substitution of intermediate inputs, is not visible when all intermediate has been combined into one aggregate quantity and price.

[22] Almon (2006), p.5

Some Questions for Discussion

1. Is the real value added problem an index number problem?
2. If not, why is it different from the problem of compiling an index of real GDP on the expenditure side, where we have prices and quantities (almost) everywhere?
3. Is it meaningful to ask a question such as "What are real net exports?"? If not, then aren't we doing this when we calculate real output using $q=Aq+f$ or GDP?
4. Is the least evil way to aggregate constant price units with different price movements the chain index? Is Fisher the best choice?
5. Once we use chaining, is it now more meaningful to speak of I-O coefficients summing to 1.0 down the column?
6. If so, then how should we construct real I-O coefficients? ("$a_{ij} = x_{ij} / q_j$" may not be appropriate in a Fisher framework.)
7. Must the condition of a weakly separable industry production function, with (K,L) as a subaggregate hold for the measure to be valid in some sense? Would its validity mean? That it is a reasonable way to assign the share of real GDP growth to an industry? That it yields meaningful measures of labor productivity and MFP? Have any recent tests of this condition been made recently on the BEA database?
8. If one camp accepts the fact that real value added is neither a valid measure of productivity *per se* nor of relative industry contributions to GDP aggregate price growth, what is it then? Sato said that it included the effects of some technology change, of terms-of-trade improvements, in addition to "real output". How can it be characterized, if we don't have a separable production function?

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Table 1. Chain Quantity Indexes for Real Value Added (2000 = 100)

#	Industry	1998	1999	2000	2001	2002	2003	2004
1	Farms	86.11	87.92	100.00	91.73	98.00	106.22	106.17
2	Forestry, fishing, and related activities	86.42	92.62	100.00	99.29	100.78	106.02	115.12
3	Oil and gas extraction	111.89	113.02	100.00	95.95	101.20	95.55	94.55
4	Mining, except oil and gas	90.76	98.93	100.00	95.43	89.52	90.08	93.15
5	Support activities for mining	87.67	82.36	100.00	86.76	52.00	58.54	68.05
6	Utilities	90.48	94.67	100.00	95.08	99.14	106.88	108.05
7	Construction	97.09	99.41	100.00	100.16	98.20	96.90	99.31
8	Food and beverage and tobacco products	98.90	100.16	100.00	100.78	99.27	99.01	100.64
9	Textile mills and textile product mills	99.28	96.63	100.00	81.46	80.80	87.16	87.76
10	Apparel and leather and allied products	105.29	97.36	100.00	90.68	84.31	74.67	78.69
11	Wood products	95.20	96.85	100.00	98.26	96.46	99.80	103.00
12	Paper products	107.95	109.75	100.00	87.75	91.44	87.87	96.17
13	Printing and related support activities	97.41	98.94	100.00	92.37	88.80	86.80	90.69
14	Petroleum and coal products	138.95	127.51	100.00	91.20	123.80	99.40	94.07
15	Chemical products	95.35	100.03	100.00	97.47	108.55	110.08	110.51
16	Plastics and rubber products	93.55	96.90	100.00	92.05	94.22	95.98	106.09
17	Nonmetallic mineral products	96.52	98.64	100.00	98.75	99.54	101.90	107.12
18	Primary metals	95.23	99.87	100.00	89.58	91.56	88.46	96.43
19	Fabricated metal products	94.00	94.39	100.00	89.94	85.78	88.33	91.01
20	Machinery	104.12	96.03	100.00	91.86	85.37	84.41	92.16
21	Computer and electronic products	51.88	67.58	100.00	98.02	100.10	115.87	140.27
22	Electrical equipment, appliances, and components	88.12	94.93	100.00	95.88	96.56	98.70	97.44
23	Motor vehicles, bodies and trailers, and parts	94.64	97.04	100.00	88.56	107.96	121.21	117.88
24	Other transportation equipment	106.01	104.61	100.00	101.21	99.67	89.79	89.94
25	Furniture and related products	92.35	96.25	100.00	88.89	89.24	88.26	94.75
26	Miscellaneous manufacturing	87.61	90.51	100.00	96.07	98.03	103.63	115.34
27	Wholesale trade	95.43	100.41	100.00	107.00	108.06	110.47	115.56
28	Retail trade	90.40	95.69	100.00	106.97	109.29	113.20	120.42
29	Air transportation	84.40	91.68	100.00	98.87	108.82	123.19	137.86
30	Rail transportation	95.65	97.16	100.00	97.05	95.76	96.85	100.53
31	Water transportation	96.99	88.16	100.00	94.74	77.88	80.80	73.59
32	Truck transportation	97.99	99.03	100.00	94.74	94.28	95.51	98.48
33	Transit and ground passenger transportation	98.73	101.90	100.00	100.17	101.13	99.28	99.64
34	Pipeline transportation	79.72	88.75	100.00	95.65	110.26	115.37	119.29
35	Other transportation and support activities	89.13	94.23	100.00	98.79	100.52	102.47	107.58
36	Warehousing and storage	88.00	93.88	100.00	97.68	102.64	107.63	104.69
37	Publishing industries (includes software)	86.37	103.79	100.00	99.10	98.87	101.73	112.05
38	Motion picture and sound recording industries	90.26	99.20	100.00	98.01	110.05	112.83	122.29
39	Broadcasting and telecommunications	80.10	91.52	100.00	106.57	107.57	109.36	125.40
40	Information and data processing services	78.91	95.97	100.00	106.52	115.75	125.16	140.43

Table 1. Chain Quantity Indexes for Real Value Added (2000 = 100)

#	Industry	1998	1999	2000	2001	2002	2003	2004
41	Federal Reserve banks, credit intermediation	95.85	102.95	100.00	108.43	119.48	128.49	127.45
42	Securities, commodity contracts, and investments	54.93	67.75	100.00	111.12	101.22	104.47	114.99
43	Insurance carriers and related activities	95.67	94.04	100.00	96.07	94.32	98.10	96.66
44	Funds, trusts, and other financial vehicles	166.06	131.79	100.00	81.14	77.32	91.22	95.95
45	Real estate	93.34	97.16	100.00	104.03	104.36	106.65	113.11
46	Rental and leasing services	90.97	97.46	100.00	98.59	96.29	94.75	95.35
47	Legal services	95.25	97.41	100.00	101.15	97.38	100.27	99.59
48	)rofessional, scientific and technical services	86.28	91.70	100.00	100.68	98.93	101.27	111.02
49	Computer systems design and related services	79.31	89.41	100.00	99.63	101.47	102.80	111.08
50	Management of companies and enterprises	100.37	101.22	100.00	98.13	101.08	104.63	110.95
51	Administrative and support services	100.64	105.87	100.00	97.28	98.46	103.85	109.74
52	Waste management and remediation services	88.72	97.94	100.00	96.22	97.38	100.05	100.75
53	Educational services	95.44	97.35	100.00	99.84	102.44	103.59	104.41
54	Ambulatory health care services	94.07	95.97	100.00	105.79	111.54	116.31	122.04
55	Hospitals and nursing and residential care facilities	98.93	99.61	100.00	100.52	102.96	103.90	105.17
56	Social assistance	89.93	94.75	100.00	105.37	113.30	119.27	125.84
57	Performing arts, spectator sports, etc.	98.51	100.39	100.00	101.55	107.34	109.21	106.76
58	Amusements, gambling, and recreation industries	93.11	98.06	100.00	104.46	106.31	106.22	112.32
59	Accommodation	92.39	96.01	100.00	94.14	95.60	99.28	100.83
60	Food services and drinking places	92.94	96.11	100.00	100.00	100.89	104.63	109.15
61	Other services, except government	101.87	100.24	100.00	98.34	98.67	99.78	101.00
62	Federal government enterprises	95.36	95.29	100.00	87.88	89.78	87.67	92.31
63	Federal general government	99.95	99.15	100.00	100.53	102.52	105.22	106.21
64	State and local government enterprises	92.41	96.15	100.00	96.84	93.79	95.54	94.98
65	State and local general government	96.23	97.95	100.00	102.39	104.36	105.32	106.16

Table 2. Comparison of U.S. Output and Intermediate Price Growth Rates: 1999 to 2004

		Output Price Growth						Intermediate Price Growth						Difference					
Sec	Title	99	00	01	02	03	04	99	00	01	02	03	04	99	00	01	02	03	04
1	Farms	-6.1	1.0	4.9	-4.6	8.7	13.4	-0.6	6.3	1.7	-1.8	5.8	5.7	-5.5	-5.3	3.2	-2.8	2.9	7.7
2	Forestry, fishing, and related activities	-0.8	-1.3	-4.6	-1.8	1.8	5.0	-0.9	-0.8	-3.0	-1.6	2.5	6.8	0.1	-0.6	-1.6	-0.2	-0.7	-1.8
3	Oil and gas extraction	21.2	51.7	-4.1	-14.9	35.8	18.2	12.0	32.7	-0.5	-9.0	23.3	12.2	9.2	19.0	-3.7	-5.9	12.5	6.0
4	Mining, except oil and gas	-3.7	0.1	3.4	3.2	3.1	7.0	0.3	4.1	1.3	0.4	4.8	6.4	-4.0	-4.0	2.1	2.8	-1.7	0.5
5	Support activities for mining	-3.6	4.1	21.2	17.2	8.1	6.0	2.2	5.0	-0.9	0.8	4.3	8.0	-5.8	-0.9	22.1	16.3	3.8	-2.0
6	Utilities	-0.1	5.9	8.8	-5.4	8.6	5.6	3.2	21.2	4.5	-11.3	24.1	7.6	-3.3	-15.3	4.2	5.8	-15.5	-2.0
7	Construction	3.8	4.3	4.0	2.7	3.7	5.8	1.6	2.1	0.5	0.5	2.1	4.8	2.2	2.2	3.5	2.2	1.6	1.0
8	Food and beverage and tobacco products	1.8	1.9	4.2	-0.2	3.9	4.7	-1.1	2.3	3.1	-2.3	5.9	7.8	3.0	-0.4	1.1	2.1	-2.0	-3.0
9	Textile mills and textile product mills	-2.2	-0.1	-0.3	-1.2	0.2	1.6	-3.3	1.3	-2.7	-0.7	2.1	1.6	1.0	-1.5	2.4	-0.6	-1.9	0.0
10	Apparel and leather and allied products	0.2	0.5	0.2	-0.6	0.5	0.2	-1.2	1.6	0.0	-0.2	1.4	2.6	1.4	-1.1	0.1	-0.5	-0.9	-2.4
11	Wood products	3.1	-2.4	-1.3	-0.6	3.2	10.7	1.3	-1.3	-2.7	-0.4	2.3	8.7	1.7	-1.1	1.4	-0.2	0.8	2.0
12	Paper products	0.3	7.6	-0.3	-1.9	0.6	2.5	-0.7	5.2	-0.6	-2.2	2.8	5.3	1.0	2.3	0.3	0.3	-2.2	-2.8
13	Printing and related support activities	0.8	2.2	1.8	0.0	0.5	0.7	-0.2	3.7	0.3	-1.3	1.2	2.9	1.0	-1.5	1.5	1.2	-0.7	-2.2
14	Petroleum and coal products	13.3	38.0	-7.8	-4.3	19.8	19.8	21.2	37.6	-14.1	3.4	15.7	21.3	-7.9	0.4	6.3	-7.7	4.2	-1.6
15	Chemical products	0.2	5.4	0.7	0.0	4.7	5.6	1.9	8.7	-0.5	0.2	5.9	7.8	-1.7	-3.3	1.2	-0.2	-1.2	-2.2
16	Plastics and rubber products	0.2	2.3	0.9	-0.2	2.1	2.6	0.1	5.2	-0.6	-1.0	4.5	6.0	0.1	-2.9	1.4	0.7	-2.4	-3.4
17	Nonmetallic mineral products	2.6	1.4	0.6	0.9	0.6	3.3	1.2	2.6	1.7	0.2	2.9	4.1	1.4	-1.2	-1.2	0.7	-2.3	-0.8
18	Primary metals	-5.0	4.0	-3.4	-0.1	2.1	17.7	-3.2	5.1	-2.8	0.0	4.9	17.3	-1.8	-1.0	-0.7	0.0	-2.8	0.5
19	Fabricated metal products	0.5	0.9	0.5	0.3	0.6	6.6	-1.4	2.9	-1.1	0.2	2.2	9.8	1.9	-1.9	1.6	0.1	-1.6	-3.2
20	Machinery	0.9	0.7	0.9	0.4	0.7	2.2	-0.3	1.6	-0.3	0.2	1.4	5.6	1.2	-0.9	1.2	0.2	-0.7	-3.4
21	Computer and electronic products	-13.8	-11.9	-12.6	-5.1	-5.3	-4.1	-4.8	-3.3	-3.8	-1.6	-0.9	1.0	-9.0	-8.5	-8.8	-3.5	-4.5	-5.1
22	Electrical equipment, appliances, and components	-0.5	1.2	0.0	-0.9	-0.4	3.6	-0.8	2.3	-1.1	-0.3	1.8	6.5	0.3	-1.1	1.1	-0.6	-2.2	-2.9
23	Motor vehicles, bodies and trailers, and parts	0.2	0.3	-0.5	-1.2	-0.2	1.1	-0.8	0.7	-0.4	0.4	0.7	3.2	1.1	-0.4	-0.1	-1.6	-0.9	-2.1
24	Other transportation equipment	0.8	2.6	2.3	1.1	2.5	3.5	-0.2	1.2	-0.1	0.3	1.8	4.0	1.1	1.4	2.4	0.8	0.7	-0.5
25	Furniture and related products	1.2	1.5	1.3	1.0	0.9	1.7	0.5	1.4	-0.5	0.0	1.7	6.0	0.6	0.1	1.9	1.0	-0.8	-4.3
26	Miscellaneous manufacturing	0.8	0.8	1.4	1.1	1.3	1.5	0.0	2.3	-0.6	-0.4	2.1	5.0	0.8	-1.5	2.0	1.5	-0.8	-3.5
27	Wholesale trade	1.0	2.6	-2.9	0.4	1.0	4.4	0.5	1.9	0.4	0.4	1.9	3.4	0.4	0.7	-3.3	0.0	-0.9	1.0
28	Retail trade	0.8	0.8	-1.4	1.5	1.2	0.7	1.8	2.9	0.7	0.9	2.1	3.9	-1.0	-2.1	-2.1	0.6	-0.9	-3.2
29	Air transportation	-0.3	3.8	-7.7	-6.7	3.9	-2.6	4.5	13.2	-0.5	-1.2	6.3	7.7	-4.8	-9.4	-7.2	-5.4	-2.4	-10.3
30	Rail transportation	-0.1	1.5	2.0	2.1	2.0	3.9	1.2	2.8	0.3	-0.4	1.6	5.2	-1.3	-1.4	1.7	2.4	0.3	-1.3
31	Water transportation	4.5	3.9	2.1	3.5	8.9	1.8	1.3	7.6	-1.4	0.3	3.4	3.9	3.2	-3.7	3.5	3.3	5.5	-2.1
32	Truck transportation	2.5	4.5	2.8	1.4	2.7	3.8	2.0	6.3	0.2	0.0	3.4	4.8	0.5	-1.8	2.5	1.4	-0.7	-1.0
33	Transit and ground passenger transportation	1.5	3.8	2.4	1.6	4.3	4.1	1.8	5.7	0.0	-0.4	3.6	4.8	-0.3	-1.9	2.4	2.0	0.7	-0.7
34	Pipeline transportation	-0.8	4.0	3.3	-0.5	4.4	4.9	4.0	14.1	0.3	-5.3	14.2	7.9	-4.8	-10.1	3.0	4.8	-9.8	-3.0
35	Other transportation and support activities	2.1	3.6	2.1	0.8	2.5	4.0	1.7	6.7	0.3	0.1	3.7	4.9	0.4	-3.1	1.7	0.7	-1.3	-0.8
36	Warehousing and storage	2.8	2.0	2.7	1.4	1.3	0.3	1.9	5.2	2.2	0.2	3.7	4.5	0.8	-3.2	0.5	1.2	-2.4	-4.1

Table 2. Comparison of U.S. Output and Intermediate Price Growth Rates: 1999 to 2004

		Output Price Growth						Intermediate Price Growth						Difference					
Sec	Title	99	00	01	02	03	04	99	00	01	02	03	04	99	00	01	02	03	04
37	Publishing industries (includes software)	1.1	1.9	1.5	0.3	-1.1	-1.3	0.1	1.6	0.5	0.0	0.7	1.6	1.0	0.3	1.0	0.2	-1.8	-2.9
38	Motion picture and sound recording industries	5.3	5.2	3.5	2.4	4.7	2.7	3.4	3.9	2.2	1.8	3.2	2.6	1.8	1.3	1.2	0.6	1.4	0.1
39	Broadcasting and telecommunications	-2.2	-0.8	-1.2	-0.9	0.1	-0.8	-0.9	0.5	-0.3	0.4	1.2	1.3	-1.3	-1.3	-0.8	-1.4	-1.1	-2.0
40	Information and data processing services	0.5	0.1	1.7	1.1	0.5	-1.4	-0.3	1.1	0.4	0.0	0.6	0.9	0.9	-1.0	1.2	1.1	-0.1	-2.3
41	Federal Reserve banks, credit intermediation	1.9	4.1	2.2	3.7	0.9	3.3	-0.3	0.5	-0.6	0.9	1.7	2.6	2.2	3.7	2.8	2.9	-0.7	0.7
42	Securities, commodity contracts, and investments	-13.1	-13.8	-8.2	-3.1	1.1	1.4	-9.2	-6.3	-6.3	-1.0	2.8	1.5	-3.9	-7.5	-1.9	-2.0	-1.7	-0.1
43	Insurance carriers and related activities	1.9	2.6	2.4	3.2	3.8	4.4	2.5	1.8	2.3	3.3	2.1	3.9	-0.6	0.8	0.1	-0.1	1.6	0.6
44	Funds, trusts, and other financial vehicles	3.6	-0.5	1.1	2.0	-2.2	3.5	-7.1	-7.8	-7.8	-1.5	2.7	2.1	10.7	7.3	8.9	3.5	-4.8	1.4
45	Real estate	2.7	3.1	3.4	2.8	2.1	2.5	2.1	2.7	2.2	0.8	2.2	3.3	0.6	0.4	1.2	2.1	-0.1	-0.9
46	Rental and leasing services	1.1	4.4	0.2	-0.1	3.2	2.9	1.3	3.7	0.2	1.0	1.7	2.5	-0.3	0.7	-0.1	-1.1	1.6	0.3
47	Legal services	2.4	3.5	4.6	3.3	3.2	4.7	1.0	1.8	1.7	1.4	1.8	2.0	1.4	1.6	2.9	1.8	1.4	2.7
48	Professional, scientific and technical services	1.2	0.6	1.9	2.2	1.0	0.6	0.9	1.4	1.0	0.9	1.5	1.7	0.3	-0.8	0.9	1.3	-0.5	-1.1
49	Computer systems design and related services	2.0	3.2	0.9	-1.2	-1.5	-1.7	-0.9	0.8	-0.5	0.1	0.4	1.2	2.8	2.5	1.4	-1.3	-2.0	-2.9
50	Management of companies and enterprises	5.1	6.0	0.1	0.7	1.0	6.0	1.3	1.9	2.2	1.1	1.7	1.9	3.8	4.0	-2.1	-0.4	-0.7	4.1
51	Administrative and support services	3.3	5.0	3.5	1.5	1.0	3.2	0.9	2.4	0.4	0.3	2.1	2.7	2.5	2.5	3.0	1.2	-1.1	0.5
52	Waste management and remediation services	2.0	3.0	3.2	2.6	4.2	6.2	3.0	6.4	1.9	1.2	6.1	4.8	-0.9	-3.4	1.3	1.5	-2.0	1.4
53	Educational services	3.6	4.3	4.7	4.1	4.0	4.4	1.3	2.3	1.4	0.8	1.9	2.5	2.3	2.0	3.3	3.3	2.1	1.9
54	Ambulatory health care services	2.1	2.4	3.0	1.3	2.0	2.5	1.4	2.6	1.3	1.0	2.0	2.9	0.7	-0.2	1.7	0.3	0.0	-0.4
55	Hospitals and nursing and residential care facilities	2.7	3.6	4.4	3.6	3.9	4.1	0.6	1.7	0.7	0.5	2.3	2.7	2.1	2.0	3.7	3.2	1.7	1.4
56	Social assistance	3.1	4.4	2.8	1.1	1.5	1.3	1.4	2.9	1.2	0.6	2.6	3.5	1.7	1.5	1.6	0.5	-1.0	-2.2
57	Performing arts, spectator sports, etc.	5.2	5.2	4.0	2.9	3.3	3.5	2.9	3.6	2.5	1.9	2.3	2.9	2.3	1.6	1.5	1.0	1.0	0.6
58	Amusements, gambling, and recreation industries	2.8	3.2	3.3	2.4	2.2	2.5	1.6	2.7	1.9	1.1	2.2	3.3	1.2	0.5	1.4	1.3	0.0	-0.8
59	Accommodation	3.1	3.2	2.2	0.3	1.8	4.6	1.6	3.1	1.8	0.4	2.3	2.9	1.5	0.1	0.5	-0.1	-0.5	1.7
60	Food services and drinking places	1.5	2.7	3.1	2.6	2.0	3.0	0.9	2.7	2.1	-0.1	3.3	3.7	0.6	0.0	1.1	2.7	-1.2	-0.7
61	Other services, except government	2.9	3.7	4.1	2.7	2.6	3.1	0.7	1.8	0.9	1.0	1.5	2.3	2.2	1.9	3.2	1.7	1.1	0.8
62	Federal government enterprises	1.8	0.5	5.5	3.7	3.0	0.6	1.1	5.4	-1.2	-0.2	4.5	3.6	0.8	-4.9	6.8	3.9	-1.5	-3.1
63	Federal general government	2.7	3.6	2.3	4.3	4.3	4.5	1.6	3.3	1.7	1.6	2.8	3.1	1.2	0.3	0.6	2.6	1.6	1.4
64	State and local government enterprises	1.4	3.7	3.9	1.0	3.3	4.3	1.9	7.5	2.0	-1.0	5.6	4.8	-0.5	-3.8	1.9	2.0	-2.2	-0.5
65	State and local general government	2.9	4.4	3.0	2.8	4.3	3.8	2.4	5.6	1.8	0.6	4.4	4.7	0.5	-1.2	1.2	2.1	-0.1	-0.8