Multifactor Productivity Measurement and Forecasting in the Inforum LIFT Model

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The indicated importance of productivity increase may be taken to be some sort of measure of our ignorance.

Moses Abramovitz (1956)

This paper will describe some exciting new developments in the Inforum *LIFT* model of the U.S. The model is grounded in a new set of detailed annual input-output tables, derived by Inforum from U.S. data published by the Bureau of Economic Analysis (BEA). This set of tables brings us closer to the goal of developing an integrated model of multifactor productivity, which is consistent at the industry and aggregate level.

Since economists first started to develop economic statistics and national accounts, a motivating principal has been to measure the growth of the economy, and discover its sources. Classical economists such as Smith, Ricardo and Mill had observed that more output could be produced with a given quantity of labor by employing machinery and other capital. But it wasn't until the 1920s that comparable measures of labor and output became available, and the first estimates of labor productivity growth appeared[1]. By the 1950s, the concept of the production function became formalized, and the idea of segregating growth in output per head into technical change and the availability of capital per head caught on, especially after Solow's (1957) introduction of the aggregate production function. Solow's work stimulated numerous studies relating real value added growth to real capital and labor inputs, and deriving the residual as a measure of technical change and other factors.

Dissatisfaction with the real value added concept stimulated the desire for a comprehensive measure of productivity that would relate real gross output to capital, labor and intermediate inputs. A convenient classification of intermediate inputs into the categories of energy, materials and services led to KLEMS (capital, labor, energy, materials and services) databases and productivity studies. In either case, KL or KLEMS, the resulting measure of productivity is called multifactor productivity (MFP) defined as

$$MFP = \frac{Q}{I} \qquad \textbf{(1)}$$

where Q is real gross output, and I is a suitably defined aggregate of real inputs.

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[1] The productivity program at the U.S. Bureau of Labor Statistics (BLS) is actually older than the U.S. National Accounts, and BLS pioneered the measurement of output and employment at the industry level. See Dean and Harper (2001).

Since June 2004, the U.S. Bureau of Economic Analysis has been developing and improving a time series of annual input-output (IO) tables, with 65 industries.[2] A satellite account is the BEA KLEMS dataset, which apportions intermediate inputs to energy, materials or services.[3]

A new version of the Inforum *LIFT* model has been developed, which is based on the 2002 benchmark IO table and the time series of annual IO tables. All industry data in the new *LIFT* model is on the same sectoral basis. These data include output, employment, investment, capital stocks and value added components. As described below, a KLEMS dataset has also been incorporated into *LIFT*, with the goal of dynamically forecasting industry and aggregate MFP. The list of industry sectors and their definitions in terms of the 2002 North American Industry Classification System (NAICS) are shown in Appendix A.

The first part of this paper will discuss the background of MFP development in the U.S. and its current status. The second part will describe the incorporation of an MFP module within the *LIFT* model, and present some historical and forecasted results. The conclusion will evaluate the worthiness of our exercise and chart some directions for extending and improving this work.

MFP: A Curriculum Vitae[4]

A Productivity Index

The measure of output per unit of input is more easily considered if we ignore intermediate inputs for a moment, and write

$$pQ = wL + rK \tag{2}$$

where p is the price of output, w is the wage of labor, and r is the cost of capital. If we deflate to a base year, say t=0, we need to use a scaling factor S to bring both sides into equality:

$$p_0 Q_t = S_t[w_0 L_t + r_0 K_t] \tag{3}$$

The variable S can be viewed as an index of output over input. This method of measuring productivity was mentioned by Copeland (1937), and later implemented by Stigler (1947). Note that this index is basically a type of Laspeyres index since it uses base period quantity weights. Its growth rate over time is sensitive to the choice of the base period.

[2] Moyer et.al. (2004) describes the first release of this series, which was then based on a modified version of the U.S. 1997 Benchmark IO table. The most current release, described in Gilmore et.al. (2011) includes tables from 1998 to 2010.

[3] First described in Strassner et.al (2005) and now also available from 1998 to 2010.

[4] For a fuller biography, see Hulten (2001). This section owes a debt to that paper and to Griliches (1996).

Production Functions, Sources of Growth and the "Residual"

Solow began the study of productivity using a production function with a shift parameter:

$$Q_t = A_t F(K_t, L_t)] \qquad \textbf{(4)}$$

The shift parameter *A* was identified by Solow with technical change, although it includes many other factors. It is related to the scaling factor *S* described above, but is a more general indicator of output per unit of input, or MFP. Without imposing a specific form on the production function *F*, but making a few assumptions, we can derive an expression for the growth of *A* over time.

First, logarithmically differentiate the production function (4):

$$\frac{\dot{Q}_t}{Q_t} = \frac{\partial Q}{\partial K}\frac{K_t}{Q_t}\frac{\dot{K}_t}{K_t} + \frac{\partial Q}{\partial L}\frac{L_t}{Q_t}\frac{\dot{L}_t}{L_t} + \frac{\dot{A}_t}{A_t} \qquad \textbf{(5)}$$

If each input is paid the value of its marginal product:

$$\frac{\partial Q}{\partial K} = \frac{r_t}{p_t} \quad and \quad \frac{\partial Q}{\partial L} = \frac{w_t}{p_t} \qquad \textbf{(6)}$$

then we can write the unobserved output elasticities as income shares *s*:

$$\mathfrak{R}_t = \frac{\dot{A}_t}{A_t} = \frac{\dot{Q}_t}{Q_t} - s_t^K \frac{\dot{K}_t}{K_t} - s_t^L \frac{\dot{L}_t}{L_t} \qquad \textbf{(7)}$$

The total differential $\mathfrak{R}$ is the Solow residual, or the growth in output not explained by the growth in inputs. Like *S*, it is an index number for MFP that can be calculated from prices and quantities.

Equation (7) can be rearranged to show the relationship of the growth of labor productivity to the growth of MFP and the change in the capital-labor ratio. If we write *Q*/*L* as *q*, and *K*/*L* as *k*, then

$$\frac{\dot{q}_t}{q_t} = \frac{\dot{A}_t}{A_t} + s_t^K \frac{\dot{k}_t}{k_t} \qquad \textbf{(8)}$$

The growth of labor productivity is the growth in MFP plus capital's share times the growth in the capital-labor ratio.

MFP in the Input-Output Framework

In most of the analyses based on the above approach, the measure of real output Q used is real value added, usually obtained by double deflation. This may be done with fixed weights, where deflated intermediates are subtracted from deflated output, or using a chain index approach as is done by the BEA in the U.S. However various researchers have found a production model for real value added to be implausible[5]. Real value added is not a measure of output, but is rather a hybrid of output less some inputs.

If data are available, a measure of real gross output can be related to labor, capital and aggregates of intermediate inputs. An ideal dataset is a time series of IO tables in current and constant prices, along with estimates of labor and capital input and cost shares[6]. If intermediate goods are classified as energy, materials or services, the production function can be specified as:

$$Q_t = A_t F(K_t, L_t, E_t, M_t, S_t)] \qquad \textbf{(9)}$$

where now Q is real gross output (not real value added) and the corresponding MFP estimate is derived similarly to (7)

$$\Re_t = \frac{\dot{A}_t}{A_t} = \frac{\dot{Q}_t}{Q_t} - s_t^K \frac{\dot{K}_t}{K_t} - s_t^L \frac{\dot{L}_t}{L_t} - s_t^E \frac{\dot{E}_t}{E_t} - s_t^M \frac{\dot{M}_t}{M_t} - s_t^S \frac{\dot{S}_t}{S_t} \qquad \textbf{(10)}$$

The intermediate value share weights are derived from the nominal IO tables. The cost share for labor is the labor compensation over total nominal gross output. The capital share is derived as the remainder.

When using discrete, annual data, it is common to estimate (10) using a Tornqvist index, in which the rate of change in each variable is approximated by the differences in logarithms, and the shares are the average of the current period share and the lagged share.

Domar (1961) showed that industry and aggregate productivity growth can be related using a set of ratios that sum to more than 1. Each industry share is derived as the industry nominal gross output divided by the sum of value added (GDP) in all industries. This means that intermediate transactions contribute to aggregate productivity by allowing productivity gains in successive industries to augment one another.

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[5] Jorgenson, Gollop and Fraumeini (1987) perform tests on the existence of a value added function and reject the hypothesis in 40 of 45 industries analysed. The existence of a K-L aggregate, necessary for a measure of K-L productivity has also been explored by several investigators and rejected. Meade (2007) discusses the history and problems with the real value added concept, and shows several examples of how the derivation of real value added can lead to questionable results.

[6] Gullickson and Harper (1999, unpublished, I can furnish on request) discuss the characteristics of the ideal IO dataset and the method of aggregating to the all economy MFP using the Domar (1961) aggregation technique.

The Measurement of Capital

Measurement problems abound for all components of the MFP calculation. For example, in many industries, the proper calculation of output price, and therefore real output, may be based on indirect information or on theoretically derived measures of quality. However, the question of the measurement of capital has filled the equivalent of hundreds of books, and so deserves a word.

Ideally, it is not the "quantity" of capital, as measured by real capital stock, that should be important, but rather the *flow of services* provided by capital goods[7]. Since this flow of capital services is not directly observable, in practice we must make use of estimated stocks and assume that the flow is related to that stock. If we have no detail on the composition of the stock by asset type, then the stock/flow distinction is not relevant. However, if stock information is maintained by industry and asset type, then we can make use of the different service lives of different assets to derive weights to estimate the total capital service flow by industry. The essential idea is that since some assets depreciate quickly (computers) and others depreciate slowly (buildings), the contribution to service flow should reflect this. The service flow idea is related to the concept of how much capital is "used up" each period in producing output. This idea is also related to the user cost of capital, which is defined as the total cost (interest, depreciation and revaluation adjusted by tax incidence) of using a unit of capital for a definite period, such as a year.

A Short Review of Published Data for the U.S.

The Bureau of Labor Statistics (BLS) multifactor productivity program has taken the lead in measuring both labor productivity and MFP at the industry and aggregate level. BLS produces two periodic releases: The Major Sector Productivity program publishes annual measures of output per unit of combined inputs for the private business, private nonfarm business, and manufacturing sectors and for 18 NAICS 3-digit manufacturing industries. The aggregate business measures are real value added per combined unit of labor and capital input. The industry measures are derived using the KLEMS method. These are published by BLS annually in "Multifactor Productivity Trends in Manufacturing"[8]. The Industry Productivity program publishes annual measures of output per unit of combined inputs for 86 4-digit NAICS manufacturing industries, the air transportation industry, and the line-haul railroad industry. These estimates do not cover all industries in the U.S. economy. They are derived using the KLEMS method[9].

As mentioned above, the BEA has been producing a set of "KLEMS" accounts since June 2005[10]. These data are derived from the detailed database underlying the annual IO tables and GDP by industry. The intermediate data is divided into energy, materials and services, and show total

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[7] BLS (1983, Appendix C) and Harper (1999) discuss the capital measurement within the BLS MFP program. Jorgenson, Gollop and Fraumeini (1987) describe an ambitious attempt to measure capital service flows by industry.

[8] The latest release can be found at http://www.bls.gov/news.release/pdf/prod5.pdf, published June 2012, with estimates through 2010.

[9] The latest release can be found at http://www.bls.gov/news.release/pdf/prin3.pdf, published September 2011, with estimates through 2009.

[10] Cost, quantity indexes and price indexes for E,M and S are available at http://www.bea.gov/industry/gdpbyind_data.htm, in the link labeled "GDPbyInd_KLEMS_NAICS". Detailed intermediate estimates are available at http://bea.gov/industry/more.htm, in the link labeled "1998-2010 KLEMS Intermediate Use Estimates".

nominal cost, chained quantity indexes and chained price indexes for each major component. Detailed intermediate data underlying the estimates is also available. All data are currently published from 1998 to 2010, with an update expected in December 2012. BEA does not publish quantities and costs of labor and capital with this dataset, but the ingredients necessary for constructing these components are available elsewhere within BEA. The GDP by industry database does show total labor compensation and gross operating surplus, which are needed to estimate the labor and capital cost shares by industry.

The BEA Fixed Assets database contains a wealth of information relating to investment and capital stocks[11]. The Fixed Assets tables present detailed estimates of net stocks, depreciation, and investment by type and by industry (for nonresidential fixed assets only) for private residential and nonresidential fixed assets, and consumer durable goods. Also included are detailed price indexes for nonresidential fixed assets and implied rates of depreciation for selected aggregates by industry. These data are used within BEA to derive depreciation estimates by industry, but are also used by BLS in the MFP program described above.

Incorporation of MFP into the LIFT Model

Overview of LIFT

The *LIFT* model (Long-term Interindustry Forecasting Tool) is the U.S. representative of the INFORUM style interindustry macroeconomic (IM) model.[12] As is typical of this family of models, the *LIFT* model builds up macroeconomic aggregates such as employment, investment, exports, imports and personal consumption from detailed forecasts at the industry or commodity level. This modeling framework is not only applicable to scenario analysis where the interaction of macroeconomic and industry behavior is important, but also for the development of satellite models to study issues such as energy use, greenhouse gas emissions or research and development expenditures[13]. In the current study, we make use of the consistent database of IO tables in current and constant prices, detailed investment and capital stock matrices, and the full set of value added history and forecast in the *LIFT* model to compile historical and projected measures of MFP by industry and for the aggregate economy.

The newest version of *LIFT* is based on the U.S. 2002 Benchmark IO table, and a series of annual IO tables from 1998 to 2010. INFORUM has compiled a time series of estimates of the detailed IO framework at the 399 commodity level, using information from the 2002 Benchmark, the annual IO, and time series of industry output from BEA and commodity imports and exports from the Census Bureau. A new version of the *Iliad* 360 commodity model of the U.S. has been developed based on these same data.

All industry data in *LIFT* is now classified according to the same sectoring scheme, listed in Appendix A, along with the 2002 NAICS concordance. These industry data include employment, hours, labor compensation and other value added components, investment and capital stock, and

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[11] The Fixed Assets data are available at http://www.bea.gov/iTable/index_FA.cfm. The latest data are described in Bennett et.al. (2011).

[12] Grassini (2001) portrays the typical features of an INFORUM model. Meade (1999) introduces an earlier version of the current model.

[13] Meade (2009) is an example of using an expanded module for crops and biofuels to study economic impacts of increased ethanol production and use in the U.S.

industry output. The LIFT model has 110 commodities, and this is the level of detail maintained for the IO table, final demands and commodity output. The IO quantity and price solutions are calculated at the commodity level. Value added at the industry level is bridged to the commodity level using an industry to commodity value added bridge, and the commodity output solution is converted to industry output using a commodity output proportions matrix.

The typical forecast horizon of LIFT is to 2035, although many studies are done with a shorter forecast period. Long-term forecasting for the Medicare Trust Fund Panel is done to 2085, with a slightly modified version of the model. All ingredients necessary to calculate MFP are available through the forecast horizon.

Building KLEMS Accounting into LIFT

There are three main tasks involved into building a KLEMS module into *LIFT*. These are:

1. Estimating current and constant price intermediate consumption by industry, divided into energy, materials and purchased services aggregates.
2. Estimating capital stocks by industry for equipment and structures.
3. Incorporating *LIFT* data on hours worked, labor compensation and constant and current price output by industry.

Before describing step 1, we should first say a few words about the derivation of the IO database used for the *LIFT* model. This database uses detail from the 2002 Benchmark U.S. IO table and the series of U.S. annual IO tables, combined with detailed data on imports, exports and industry output to create a time series of detailed make and use matrices from 1998 to 2010[14]. These are then converted annually to a product-to-product table, based on commodity technology, as described in Almon (2000). The entire framework is converted to constant prices by deflating output by domestic output deflators, deflating imports by imports deflators, and deflating the rest of each row implicitly in a way that preserves the row sum in constant prices.

In the first step we first convert the recipe matrix derived above in flows to a 110 by 65 use table, using the formula:

$$\boldsymbol{U} = \boldsymbol{R}\boldsymbol{M}' \qquad \textbf{(11)}$$

where $\boldsymbol{U}$ is the "new use" matrix described by Almon, and $\boldsymbol{M}$ is the 65 by 110 matrix formed by dividing each cell of the make table by the column total. Once we have obtained this matrix, it is almost straightforward to combine inputs by industry into the energy, materials and services aggregates[15]. Several exceptions to the general classification were made when an energy product was used in the form a material feedstock input, such as natural gas into chemicals or plastic, or

[14] There are two versions of the benchmark and annual IO tables produced by BEA. The first version, known as 'Standard' on the BEA website, is *before redefinitions*, where industry output can be easily related to industry data on shipments and inventory change produced by the Economic Census. The second version, known as 'Supplemental', is *after redefinitions*, where certain components of commodity output have been moved from one industry to another to achieve a table closer to a pure product basis. We start with the after redefinitions tables in our work.

[15] 'Energy' commodities in *LIFT* are the following: Crude oil extraction (4), Natural gas extraction (5), Coal mining (6), Electric utilities (10), and Natural gas utilities (11). 'Materials' commodities are 1-3, 7-8, and 15-60. Services are 9,12-14 and 61-104. See Appendix A for the commodity definitions.

where primary fuels were consumed in producing a final energy output, such as the fuels used in electric utilities. Crude petroleum converted to petroleum products is classified as a material input. The ***U*** matrix is also deflated to constant dollars and the same aggregates are calculated in constant prices.

Capital stocks for equipment and software investment by industry are derived from the time series of investment by industry in the LIFT model. There is still no detailed accounting of structures investment and capital stock by industry. We have derived the structures investment and capital stock keeping an eye on estimates of net stock from the BEA *Fixed Assets* database.

The derivation of the labor component is straightforward, and LIFT maintains historical and forecast data on labor hours worked and total labor compensation. Industry output is also calculated by the model, using the ***M*** matrix described above.

The Tornqvist index formula is used to estimate the growth in the MFP index based on equation (10). The cost shares are estimated as follows:

$$s_{it}^{E} = \frac{EN_{it}}{QN_{it}}, s_{it}^{M} = \frac{MN_{it}}{QN_{it}}, s_{it}^{S} = \frac{SN_{it}}{QN_{it}}, s_{it}^{L} = \frac{LAB_{it}}{QN_{it}}, \qquad \textbf{(12)}$$
$$s_{it}^{K} = 1 - s_{it}^{E} - s_{it}^{M} - s_{it}^{S} - s_{it}^{L}$$

where variables with an ‘N’ indicate nominal values.

Since the index relies on the growth between two periods, the average share is used:

$$\bar{s}_{it}^{j} = (s_{it}^{j} + s_{i,t-1}^{j})/2 \qquad \textbf{(13)}$$

The growth rate (gr) below is calculated as the difference in logarithms:

$$gr(A) = gr(Q) - \bar{s}_{it}^{K} gr(K) - \bar{s}_{it}^{L} gr(L) - \bar{s}_{it}^{E} gr(E) - \bar{s}_{it}^{M} gr(M) - \bar{s}_{it}^{S} gr(S) \qquad \textbf{(14)}$$

The index *A* of MFP can then be derived, and is normalized to equal 100 in 2005.

Notable Trends and Stylized Facts

To the best of our knowledge, no one has embodied a set of KLEMS accounts for the U.S. into a dynamic IO model. Although the database underlying LIFT is unique, it is based on publically available data. It would be useful to find out how our results compare with others, such as BLS. In this section we elucidate some general industry trends, and see how the MFP calculations from our database compare with the BLS MFP releases for manufacturing.

Table 1 summarizes the composition of gross output derived from the BEA value added data and the Inforum current price IO tables, over the 1998-2010 period. Input cost shares are expressed in percentages, for three major aggregations of industrial sectors. The first section of the table shows the composition for all private industries, the middle section shows the composition for the goods-producing industries, and the third section is for the service industries[16]. Within each industrial grouping, inputs are divided into value added or intermediate inputs.

The period of our data includes a period of strong economic growth in the late 1990s, a slowdown in 2001, and then strong growth from 2002 to 2007. The period from 2007 to 2010 is a period of slower economic growth, along with declines in commodity prices from 2007 to 2008. Although the cost shares in the private economy are fairly stable over this period, the share of value added falls from a high of 54.8 percent in 2003 to 52 percent in 2007. The year 2007 is marked by a decline in the share of gross operating surplus to 20.7 percent, but this share has risen to a high point of 22.5 percent by 2010. The share of energy in total output is 1.7 percent in 1998, but reaches as high as 2.3 percent in several years, particularly in periods with relatively high energy prices. The share of purchased services shows a continued upward trend over the period, with only a slight decline from 2008 to 2010.

Table 1. Components of Gross Output by Major Sector

	1998	2000	2003	2005	2007	2010
All Industries	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Value added	54.7	53.4	54.8	52.8	52.0	53.9
Compensation of employees	28.4	28.6	28.7	27.3	27.1	27.2
Taxes on production	4.3	4.0	4.3	4.2	4.2	4.3
Gross operating surplus	22.0	20.8	21.7	21.3	20.7	22.5
Intermediate inputs	45.3	46.6	45.2	47.2	48.0	46.1
Energy	1.7	2.3	1.9	2.3	2.3	2.0
Materials	17.9	17.2	15.7	17.1	17.5	16.1
Purchased services	25.7	27.1	27.7	27.8	28.2	28.0
Private goods-producing Industries	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Value added	36.1	34.5	35.5	31.9	30.0	31.1
Compensation of employees	22.3	22.9	23.2	20.6	19.9	19.9
Taxes on production	1.0	0.9	1.2	1.1	1.3	1.6
Gross operating surplus	12.8	10.7	11.1	10.1	8.8	9.6
Intermediate inputs	63.9	65.5	64.5	68.1	70.0	68.9
Energy	2.3	3.1	2.7	3.6	3.4	3.0
Materials	40.0	39.8	38.5	41.3	43.1	42.7
Purchased services	21.6	22.6	23.3	23.3	23.5	23.2
Private services-producing Industries	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Value added	64.8	62.9	63.4	62.6	62.2	63.2
Compensation of employees	31.7	31.4	31.2	30.4	30.4	30.1
Taxes on production	6.0	5.6	5.7	5.7	5.6	5.4
Gross operating surplus	27.1	25.9	26.5	26.5	26.3	27.7
Intermediate inputs	35.2	37.1	36.6	37.4	37.8	36.8
Energy	1.4	1.9	1.5	1.8	1.7	1.6
Materials	5.9	5.8	5.5	5.7	5.6	5.3
Purchased services	27.9	29.4	29.7	29.9	30.4	29.9

The distributions of the cost shares between goods- and services-producing industries are strikingly different. The intermediate share of goods industries varies between 63 and 70 percent, with a high of 70 percent in 2007. The intermediate share of the services industries is slightly more than half of that, varying between 35 and 38 percent. The services industries have a higher share of value added to total output. The labor compensation component of value added is larger than that of the goods industries, but the gross operating surplus share is much larger, between 25

[16] All private industries include 1-61 from table A-1. Goods producing industries are 1-5 and 7-26. Services are 6 and 27-61.

and 27 percent, compared to a share of 9 to 13 percent for the goods industries. Finally, within the intermediate component, the goods industries purchase a much larger percentage of both energy and materials inputs, and the services industries purchase a high share of purchased services.

Table 2 shows the underlying data for 6 selected industries in 2010, and brings out the variation we observe between industries at this level. Oil and gas extraction has a fairly high share of gross operating surplus (18.1 percent), since it is a capital intensive industry. Purchased services also account for a high share of the costs (38 percent). However, the share of labor compensation in this industry is small, only 12 percent. Retail trade and hospitals on the other hand, have a much higher share of labor compensation (41.2 and 50.8 percent). Taxes on production and imports (TOPI) are high in Oil and gas (energy taxes), Retail trade (sales taxes) and Accommodations (hotel and sales taxes). In 2010, the Computer and electronics industry actually shows negative gross operating surplus. The overall value added share of output ranges from only 23.7 percent in Chemicals to 69.7 percent in Retail trade. The variation in materials use is also quite striking, from a low of 3.1 percent in Retail trade to 41.3 percent in Chemicals. Computers and electronic products are also quite high, at 33.7 percent.

Table 2. Components of Gross Output: Selected Industries, 2010

	3 Oil and gas extraction	28 Retail trade	59 Accomodation	15 Chemical products	55 Hospitals, nursing, residential care	21 Computer and electronic products
Total	100.0	100.0	100.0	100.0	100.0	100.0
Value added	41.4	69.7	63.7	23.7	60.8	27.6
Compensation of employees	12.0	41.2	38.1	13.9	50.8	34.3
Taxes on production	11.3	14.9	12.2	1.1	2.1	1.6
Gross operating surplus	18.1	13.6	13.4	8.8	7.8	-8.3
Intermediate inputs	58.6	30.3	36.3	76.3	39.2	72.4
Energy	4.1	1.2	3.0	7.7	1.5	0.6
Materials	16.5	3.1	4.3	41.3	9.2	33.7
Purchased services	38.0	25.9	28.9	27.2	28.5	38.1

The cost shares surveyed in tables 1 and 2 are used in developing the weights ($\bar{s}_{it}^{j}$in equation 14) for the growth of each input in the construction of MFP by industry. The other important components in the MFP calculation are the growth rates of outputs and KLEMS inputs by industry. Table 3 summarizes the aggregate sectors output and inputs growth rates over selected periods.

Overall, growth in real private output over the period for all industries was 1.4 percent, but output of goods actually declined over the period at -1.0 percent, while services output increased at 2.5 percent. The sub periods were chosen to highlight the effects of the “dot-com” recession in 2001, and the global slowdown that started in late 2007 or early 2008. Total output growth in the first period, from 1998 to 2001 was 3.1 percent, but goods output declined slightly during this period, whereas service industries grew quite rapidly (4.9 percent). The second period includes the 2001-2002 slowdown, but also the period of rapid growth from 2004 to 2007. Average growth of all output (2.3 percent) is somewhat slower than the first period, with the slowdown occurring mostly in services (2.9 percent). Manufacturing industries' output increases over this period (1.0 percent). In the period 2007 to 2010, overall growth is negative (-2.0 percent), but the decline is concentrated in manufacturing (-5.4 percent), with services declining by only 0.6 percent.

Table 3. Aggregate Real Output and KLEMS Real Inputs
Average Annual Growth Rates

	1998-2001	2001-2007	2007-2010	1998-2010
All Private Industries				
Output	3.1	2.3	-2.0	1.4
Inputs				
(K) Capital stock	8.2	3.0	-0.4	3.4
(L) Labor hours	0.7	0.8	-2.5	-0.1
(E) Energy	7.4	-4.3	-7.0	-2.2
(M) Materials	-0.8	1.5	-5.2	-0.8
(S) Services	5.5	3.4	-2.2	2.5
Private goods-producing Industries				
Output	-0.3	1.0	-5.4	-1.0
Inputs				
(K) Capital stock	3.0	1.8	-1.2	1.3
(L) Labor hours	-0.8	-0.7	-6.5	-2.2
(E) Energy	4.8	-2.8	-10.5	-3.0
(M) Materials	-1.4	1.7	-6.3	-1.1
(S) Services	2.1	3.1	-5.7	0.6
Private services-producing Industries				
Output	4.9	2.9	-0.6	2.5
Inputs				
(K) Capital stock	11.1	3.5	-0.1	4.4
(L) Labor hours	1.2	1.3	-1.3	0.6
(E) Energy	9.6	-5.5	-3.9	-1.5
(M) Materials	1.5	0.9	-1.9	0.3
(S) Services	6.9	3.5	-1.1	3.2

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Table 4 shows some of the underlying information used to calculate MFP for the Chemicals industry (NAICS 325). Real output growth is shown in the top line. The next part of the table shows real KLEMS inputs growth. The bottom section shows productivity in relation to each KLEMS input. For example, the line for Labor hours is the well-known measure of labor productivity growth. Finally, the calculated multifactor productivity is shown as the bottom line of the table.

Real output growth for this industry averaged only 0.1 percent over the period, with a period of faster growth (3.4 percent) from 2001 to 2007. This industry has suffered from the global financial crisis, with a growth rate of -6.0 percent from 2007 to 2010. Labor hours worked has declined throughout the period, but the most rapid decline was also in the 2007-2010 period. Both energy and materials use declined faster than output in the 2007-2010 period. Services inputs also declined (-3.8 percent), though not as fast as output.

Table 4. Chemicals Industry: Real Output, Inputs and Productivity Measures Average Annual Growth Rates

	1998-2001	2001-2007	2007-2010	1998-2010
Output	-0.4	3.4	-6.0	0.1
Inputs				
(K) Capital stock	2.3	0.3	1.7	1.2
(L) Labor hours	-2.0	-1.3	-2.8	-1.9
(E) Energy	2.4	0.9	-7.0	-0.7
(M) Materials	-2.2	4.8	-8.1	-0.4
(S) Services	4.4	5.1	-3.8	2.6
Productivity				
(K) Capital stock	-2.7	3.1	-7.5	-1.1
(L) Labor hours	1.6	4.8	-3.3	1.9
(E) Energy	-2.8	2.5	1.1	0.8
(M) Materials	1.8	-1.3	2.4	0.4
(S) Services	-4.7	-1.6	-2.3	-2.5
Multifactor Productivity	-0.8	0.3	-0.4	-0.2

Productivity growth with respect to each input component shows a mixed picture. Labor productivity growth averages 1.9 percent over the 1998-2010 period, but labor productivity actually declined between 2007 and 2010. Services productivity declines throughout the period. This could be due to outsourcing, change in output mix (a switch within Chemicals to detailed industries that consume more services, such as Pharmaceuticals), or increased use of R&D and technical services. Materials productivity improves in every sub period except for 2001 to 2007.

The bottom line is multifactor productivity growth, which can be understood as a weighted average of the productivity growth with respect to each KLEMS input. MFP as measured in our framework declines on average during the period, at -0.2 percent, though there is a small increase (0.3 percent) during the 2001-2007 period.

How do our calculations for MFP compare to those of BLS? Table 5 is a comparison of the growth rates of MFP for manufacturing industries between the Inforum and the BLS estimates. This table shows significant and at this point unexplained differences between the two sets of estimates. In the next section, we will discuss some considerations that may affect the estimates, and compare our approach with what we know about the BLS approach.

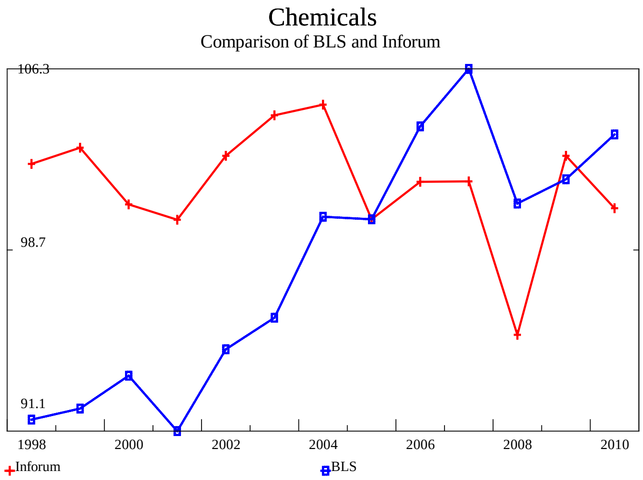
Table 5. Comparison of Inforum and BLS MFP for Manufacturing Industries

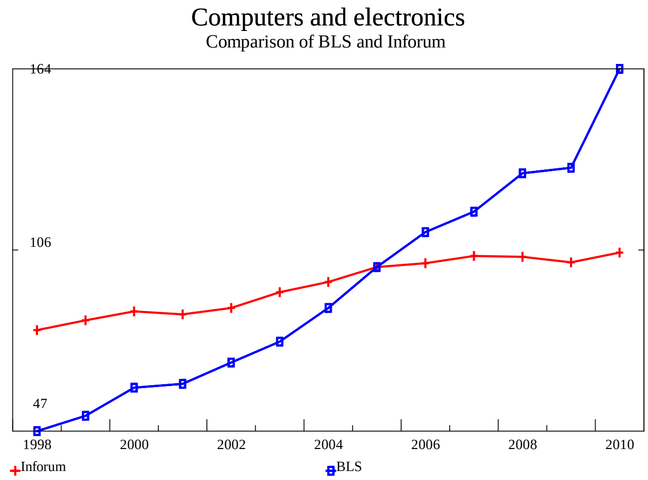
	Average Growth Rate 1998-2010		
	Inforum	**BLS**	**Correlation**
Manufacturing	**0.8**	**1.9**	**0.806**
Nondurables	**0.4**	**0.7**	**0.045**
Food, beverages & tobacco	-0.6	0.2	-0.225
Textiles	2.1	0.7	0.730
Apparel & leather	0.4	3.5	0.170
Paper	1.1	0.2	0.663
Printing	0.9	0.8	0.917
Petroleum & coal	0.8	0.3	-0.381
Chemicals	-0.2	1.0	-0.152
Plastics & rubber	0.3	0.8	0.448
Durables	**1.1**	**2.9**	**0.969**
Wood products	1.1	1.6	0.830
Nonmetallic minerals	0.1	-0.7	0.045
Primary metals	-0.9	0.5	0.196
Fabricated metal products	0.3	0.5	0.398
Machinery	1.4	1.4	0.892
Computers & electronics	2.3	10.5	0.941
Electrical equipment & appliances	1.2	1.0	0.750
Transportation equipment	1.3	0.8	0.667
Furniture	1.6	0.5	0.558
Miscellaneous manufacturing	1.7	2.7	0.917

The growth rate for all manufacturing is lower in the Inforum data, 0.8 percent compared to 1.9 percent of BLS. BLS is only slightly higher for nondurables (0.7 percent compared to 0.4 percent for Inforum), but quite different for durables. The largest difference is for computers and electronics. Inforum does not make use of the hedonic deflator for computers espoused by BEA and BLS, but rather uses a deflator that falls more gradually. The third column of the table shows the simple correlation between the two series. The correlation is actually negative in three industries. For all manufacturing, it is .806, and a surprising .969 for durables. The correlation for nondurables is small, only 0.45. The graphs below in Figure 1 show some example comparisons. Both measures have been indexed to equal 100 in 2005.

Figure 1. Comparisons of Inforum and BLS MFP Calculations

Figure 1. Comparisons of Inforum and BLS MFP Calculations (continued)





Issues Relating to the Measurement of MFP

Inforum and BLS are both using equation (10) to calculate MFP. Differences in the calculations shown in the tables and graphs above ultimately relate to differences in the measures of output, inputs, or nominal cost shares. We will touch on some of these issues in this section. More information on the compilation of the Inforum data is in Appendix B.

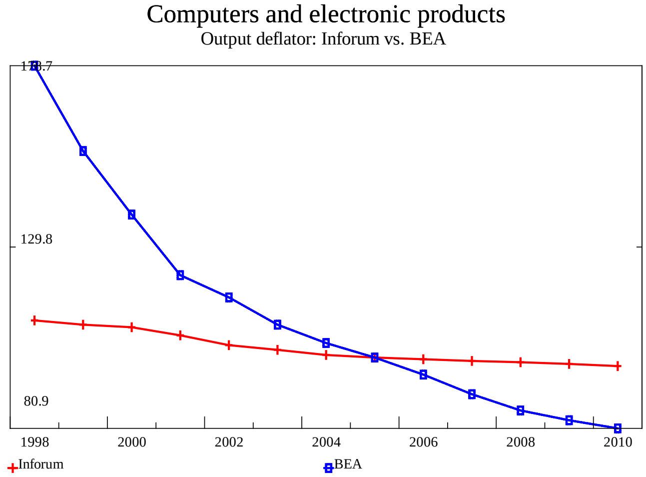
Nominal Output

The Inforum series on nominal output is based on the benchmark IO table, the annual IO tables, and the detailed gross output series published by BEA. BLS constructs its own measures of industry output based on data from the economic censuses and annual surveys from the Bureau of the Census and other sources. BLS also prefers to use a concept known as 'sectoral' output, in which the diagonal component of intermediate has been removed from both output and inputs. Inforum has used gross output, and we have found that removing the diagonal does not affect the growth rate of output substantially.

Output Price

The Inforum output prices are based on those compiled by BEA as part of its gross output series, except that Inforum has chosen not to use the rapidly declining hedonic deflators for Computers (NAICS 334111), Computer storage (334112) and Semiconductors (334413). The Inforum deflator for Computer and electronic products still declines in the period 1998-2010, but not as rapidly as the BEA deflator.

Figure 2. Computer Deflator



Note that the different treatment of the computer deflator results in slower real growth of computer output, as evidenced by the vastly different growth in MFP between Inforum and BLS shown in table 5. This contributes significantly to the different rate of growth of durable manufacturing MFP as well. Since computers are also an important share of capital equipment investment, the Inforum computer deflator leads to a slower measured growth in real capital stock than BLS or BEA.[17]

Capital

Capital input is ideally measured as a flow of capital services. One issue in the measurement of capital is to decide which types of capital to include. BLS includes equipment, structures, land and inventories. Inforum at present includes only equipment and structures. BLS assumes that real capital input is proportional to stocks, and maintains stocks at a detailed asset level for each industry. Since each type of asset has a different average service life, the service flow to stock ratio is different for each asset. The net stock and the service flow are both based on fixed "efficiency schedules" adopted for each type of asset. Inforum calculates an average service life for each industry, based on the average composition of assets of each type, and then uses this average service flow to calculate "spill" out of the stock and to derive the net stock.

BEA's measure of net stock aims to measure the value of capital goods, as the net present discounted value of future services. They use a pattern similar to exponential depreciation where a large share of the value of each asset is lost in the first few periods. BLS aims to capture a measure of "productive capital stock" in its efficiency schedules, where a slower initial depreciation reflects the fact that new capital goods lose their efficiency slowly at first. Inforum by using a "two-bucket" system for estimating depreciation and capital stock, is closer to the BLS. Figure 3 shows the difference in constructing a "one-bucket" (exponential) vs. "two bucket" capital stock in G7, based on a one dollar initial investment in 1980.

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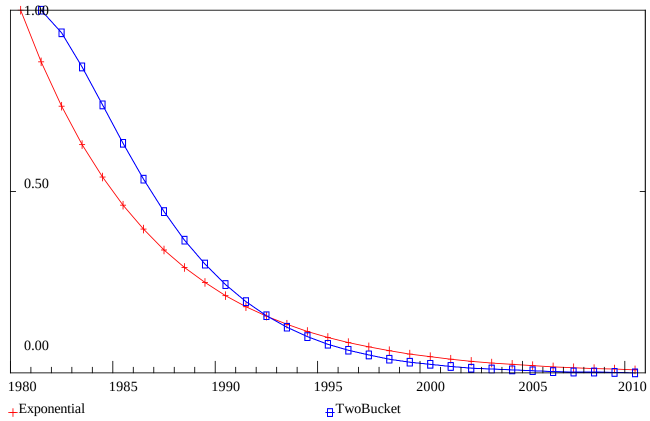
[17] Meade (2001), pp. 165-167 presents the several of the main arguments against using the BEA/BLS computer deflators. See also Almon (2012), pp 25-26 for a discussion of the problems of using the hedonic computer deflator in economic model building.

Figure 3.

Exponential vs. Two-Bucket Capital Stocks
Initial investment of $1 in 1980



BLS uses the BEA investment deflators to deflate new gross investment. Inforum uses a set of Inforum-derived deflators that are based on the IO commodity prices and a capital flow or "**B-**matrix" that shows the composition of investment by asset for each industry over time.

Jorgenson and Griliches (1967) suggest adjusting the capital input measure by an estimate of capital utilization, and use electricity consumption as an indicator of utilization. They find that this adjustment reduces the residual and attributes a larger part of output growth to changes in capital input. BLS has chosen not to adjust for utilization, and Inforum is consistent with BLS in this regard.

Labor

Labor input in the BLS KLEMS-based MFP estimates consists of total hours worked, unadjusted for skill or wage levels. The BLS Current Employment Statistics and Current Population Survey are used to combine data on production and supervisory workers hours. Inforum current derives its data on employment and hours from the BEA data which are published as part of the National Income and Product Accounts (NIPA). Note that BEA includes, but BLS excludes an adjustment of misreporting for tax purposes. This can be an important factor in industries such as Retail trade or Construction. The BLS measure includes estimates by industry for self-employed and family workers, whereas the BEA does not. However, Inforum has made use of BLS data to estimate this component of total hours to add to the BEA-based data. Inforum is using BEA derived labor compensation from the NIPA to estimate the labor cost share. BLS uses an hourly wage index constructed from BLS surveys.

Energy, Materials and Services

Inforum has constructed a set of energy, materials and services aggregates from a set of detailed balanced IO tables in current and constant prices, now available from 1998 to 2010. We have compared our estimates to those constructed by BEA, and found some differences may be due to the following:

1. Inforum constructs a purified "product-to-product" table at the 399 sector level in current prices. In the *LIFT* model, this has been aggregated to a 110 by 65 commodity by industry "New Use" matrix. This will differ from the BEA Use matrix used to construct the BEA KLEMS data.

2. The BEA KLEMS data are based on unpublished detailed tables that underlie the published annual IO make and use tables. These of course may differ from the parallel tables estimated independently by Inforum.

3. The deflation of the BEA KLEMS to constant prices is not documented by reference to a published set of constant price IO tables. The constant price estimates differ more than the current price estimates of E, M and S between Inforum and BEA.

4. BEA aggregates the inputs in purchasers' prices, whereas Inforum uses producers' prices. Inforum's choice leads to a larger "service" component for each industry, as this is where wholesale and retail trade and the various transportation margins are classified.

BLS makes its own estimates of energy, materials and services, from yet another IO database. This IO framework is developed by the BLS Office of Economic Projections, and consists of a time series of current and constant price tables at about 190 sectors, based on the BEA data, but using BLS methodologies to estimate a time-series from 1993 to 2010[18]. The BLS E, M & S estimates are further adjusted to bring them into consistency with other data BLS has compiled for the MFP project. We have not yet made an exhaustive comparison of the Inforum and BLS EMS estimates.

Aggregation

Both the BLS and BEA make extensive use of chained index number techniques to aggregate the detailed inputs and outputs. BEA generally uses the Fisher chained index, whereas BLS has chosen the Tornqvist aggregation formula for almost all of its needs. The data that Inforum has used for this project is aggregated by simple adding up. While this may lead to substitution bias, we have found that it is simpler to check the aggregates using this method. A comparison of the aggregation techniques would highlight how important this issue actually is.

Projections of MFP

The new version of the *LIFT* model has an MFP function added, that forms the KLEMS components and moves forward the historical estimates of MFP, using the same data and techniques that were used to calculate MFP in the historical period. The MFP function simply reports the calculated MFP by industry, based on the forecasted *LIFT* inputs and outputs, including labor hours worked and capital stock.

The development of this modeling capability was motivated by work Inforum has been contracted to do for the Center for Medicare and Medicaid Services (CMS), and the U.S. Federal Aviation Administration (FAA). CMS is interested in historical and forecast rates of MFP growth to assist it in calculating allowable increases in the cost of services by health care providers, which is an element of the Patient Protection and Affordable Care Act passed in March 2010. The FAA is interested in studying how increases in air transportation MFP affect the costs and productivity of industries that use air transportation.

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[18] These data can be accessed at http://www.bls.gov/emp/ep_data_input_output_matrix.htm.

Including the module within *LIFT* is useful in the following ways:

1. Alternative scenarios can be studied to analyze the effect of exogenous changes in other variables on MFP, or to examine what changes in labor, capital and other factors would be necessary to achieve a certain rate of MFP growth.
2. Forecasts of labor, capital and other factors can be examined for reasonableness by comparing projected MFP growth rates with historical growth rates. This provides an independent check on both the labor productivity and the capital investment equations.
3. By assuming fixed or constant pre-specified rates of future MFP growth, we could impose a direct link between capital investment and labor productivity, which is difficult to establish empirically using industry time-series data.
4. The effects on MFP of alternative trends in the efficiency of energy use or the use of other intermediate inputs can be traced.
5. Since *LIFT* calculates prices endogenously, from the bottom-up, the impacts of alternative growth rates of MFP on industry price growth or aggregate inflation can be determined.

The *LIFT* model with MFP was run to 2030 using the current Inforum Summer 2012 Outlook forecast. Table 6 summarizes the growth rates of MFP for 61 private industries in the forecast, comparing the 2010 to 2020 and 2020 to 2030 growth rates with the historical growth from 1998 to 2010. For some 20 industries, the projected MFP growth rates show a smooth transition from history, with either a gradual rise or decline from the historical rate.[19] Other industries show significant changes. For example, MFP in all of the mining industries had negative growth between 1998 and 2010, but has positive growth of over 1 percent in the forecast. About 20 industries display this switch from negative to positive MFP growth. For the remaining 20 industries, the results are somewhat in between, with projected growth generally increasing between 0.5 and 1.0 percent from the 1998-2010 historical period.

These differences could be due to the fact that the historical period we are using is relatively short, and includes 3 years of significant economic slowdown, whereas the forecast is generally smoother and does not include any deep recessions.

[19] This includes industries 11-13, 16, 20, 24, 26-27, 29-30, 35, 40-42, 49, 59 and 60.

Table 6. Historical and Forecast MFP by Industry
Average Annual Growth Rates

	1998-2010	2010-2020	2020-2030
1 Farms	-0.4	0.4	0.4
2 Forestry, fishing, and related activities	-0.3	0.6	0.6
3 Oil and gas extraction	-6.4	1.1	1.2
4 Mining, except oil and gas	-2.0	1.2	1.2
5 Support activities for mining	-0.6	2.7	1.0
6 Utilities	-2.1	1.3	1.1
7 Construction	-1.6	2.2	1.0
8 Food and beverage and tobacco products	-0.6	-0.2	0.0
9 Textile mills and textile product mills	2.1	0.7	0.2
10 Apparel and leather and allied products	0.4	3.3	0.8
11 Wood products	1.1	0.9	0.5
12 Paper products	1.1	0.8	0.8
13 Printing and related support activities	0.9	1.2	1.0
14 Petroleum and coal products	0.8	-0.3	-0.2
15 Chemical products	-0.2	0.1	0.3
16 Plastics and rubber products	0.3	0.3	0.1
17 Nonmetallic mineral products	0.1	1.5	1.1
18 Primary metals	-0.9	0.6	0.5
19 Fabricated metal products	0.3	0.8	0.7
20 Machinery	1.4	0.9	0.8
21 Computer and electronic products	2.3	0.5	0.2
22 Electrical equipment, appliances, and components	1.2	0.3	0.3
23 Motor vehicles, bodies and trailers, and parts	1.6	0.6	0.5
24 Other transportation equipment	0.6	0.8	0.9
25 Furniture and related products	1.6	0.9	0.4
26 Miscellaneous manufacturing	1.7	1.1	0.9
27 Wholesale trade	2.7	2.7	2.1
28 Retail trade	0.9	2.0	1.1
29 Air transportation	0.7	0.8	0.6
30 Rail transportation	0.4	0.7	0.8
31 Water transportation	0.6	1.3	1.1
32 Truck transportation	0.4	1.0	0.7
33 Transit and ground passenger transportation	-1.1	-0.3	-0.4
34 Pipeline transportation	1.7	-0.4	-0.5
35 Other transportation and support activities	1.1	1.2	1.2
36 Warehousing and storage	1.2	1.8	1.6
37 Publishing industries (includes software)	-0.7	2.0	1.7
38 Motion picture and sound recording industries	0.7	1.7	1.1
39 Broadcasting and telecommunications	2.7	1.8	1.7
40 Information and data processing services	4.1	3.3	2.2
41 Federal Reserve banks, credit intermediation	1.5	1.5	1.5
42 Securities, commodity contracts, and investments	2.7	2.0	1.4
43 Insurance carriers and related activities	-0.8	1.6	1.5
44 Funds, trusts, and other financial vehicles	0.4	1.9	1.4
45 Real estate	-0.7	2.3	1.7
46 Rental and leasing services and lessors of intangibles	-0.2	2.9	2.9
47 Legal services	-3.0	1.9	1.9
48 Miscellaneous professional, scientific and technical services	-0.6	1.8	1.8
49 Computer systems design and related services	2.2	3.1	2.5
50 Management of companies and enterprises	-0.3	2.3	1.9
51 Administrative and support services	-0.3	1.7	1.6
52 Waste management and remediation services	-0.8	0.9	1.0
53 Educational services	-1.4	0.7	1.2
54 Ambulatory health care services	0.2	1.7	1.8
55 Hospitals and nursing and residential care facilities	-0.2	1.3	2.0
56 Social assistance	0.3	1.6	1.3
57 Performing arts, spectator sports, museums	0.5	1.6	1.4
58 Amusements, gambling, and recreation	-0.9	1.7	1.4
59 Accommodation	1.7	1.6	1.2
60 Food services and drinking places	0.8	0.9	0.8
61 Other services, except government	-1.8	1.5	1.3

Conclusions and Extensions

The goal of this project has been to create a comprehensive and internally consistent modeling framework for multifactor productivity. This modeling framework is integrated within the database of the Inforum *LIFT* model of the U.S. which forecasts output, hours worked, investment, capital stocks and intermediate purchases in current and constant prices. In many respects, this database satisfies the underlying requirements of a set of "production accounts", as defined in Fraumeini (2006). A consistent set of such accounts allows for the analysis of the interrelationships of structural change, outsourcing, changes in import and export patterns, labor and multifactor productivity and wage and price changes. A serious difficulty with the U.S. data, which is also described in the Fraumeini paper and the comments by Corrado, is that there are two large government agencies (BEA and BLS) producing statistics and components necessary for building this framework, but that there are differences in methodology, definition, coverage and approach that create inconsistencies. For the most part, Inforum has adhered to the BEA data for IO tables, output, investment, employment, value added and prices. BEA does not publish a constant price IO framework, although they must generate one internally to derive the (KL)EMS estimates in real terms. Inforum has traditionally built its models using constant price IO tables, but only recently has BEA provided enough source data to attempt to build a balanced time series of tables in current and constant prices. Inforum is probably the only organization that compiles a time series of product-to-product tables for the U.S., and intermediate estimates derived from such a "recipe" matrix will differ from those derived by BEA or BLS.

To extend and improved what has been developed so far, we anticipate that we will:

1. Derive detailed matrices of capital stock by industry by asset for equipment and structures, and experiment with Tornqvist or Fisher chain-aggregation (using asset-specific user cost weights) to obtain a better measure of capital service flows.

2. Identify and try to resolve important differences in labor and intermediate inputs between the Inforum database and the BLS MFP database.

3. Use scenario analysis to understand the implications of faster or slower MFP growth on labor productivity, prices and capital investment.

4. Use the database developed for this project to develop improved equations for capital investment and labor demand, and prices.

5. Focus more detailed attention on the health care and air transportation sector to understand the impact of differing assumptions about deflators, capital stock and output measures on MFP.

The MFP model in LIFT, while still in its early stages, is already a useful tool for understanding productivity growth of the U.S. economy in a consistent and comprehensive way.

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Appendix A. *LIFT* Sectoring Schemes

A-1. Industry Sectors in *LIFT*

Sec #	Title	NAICS
1	Farms	111, 112
2	Forestry, fishing, and related activities	113, 114, 115
3	Oil and gas extraction	211
4	Mining, except oil and gas	212
5	Support activities for mining	213
6	Utilities	22
7	Construction	23
8	Food and beverage and tobacco products	311, 312
9	Textile mills and textile product mills	313, 314
10	Apparel and leather and allied products	315, 316
11	Wood products	321
12	Paper products	322
13	Printing and related support activities	323
14	Petroleum and coal products	324
15	Chemical products	325
16	Plastics and rubber products	326
17	Nonmetallic mineral products	327
18	Primary metals	331
19	Fabricated metal products	332
20	Machinery	333
21	Computer and electronic products	334
22	Electrical equipment, appliances, and components	335
23	Motor vehicles, bodies and trailers, and parts	3361, 3362, 3363
24	Other transportation equipment	3364, 3365, 3366, 3369
25	Furniture and related products	337
26	Miscellaneous manufacturing	339
27	Wholesale trade	42
28	Retail trade	44, 45
29	Air transportation	481
30	Rail transportation	482
31	Water transportation	483
32	Truck transportation	484
33	Transit and ground passenger transportation	485
34	Pipeline transportation	486
35	Other transportation and support activities	487, 488, 492
36	Warehousing and storage	493
37	Publishing industries (includes software)	511
38	Motion picture and sound recording industries	512
39	Broadcasting and telecommunications	513
40	Information and data processing services	514
41	Federal Reserve banks, credit intermediation, and related activities	521, 522
42	Securities, commodity contracts, and investments	523
43	Insurance carriers and related activities	524
44	Funds, trusts, and other financial vehicles	525
45	Real estate	531
46	Rental and leasing services and lessors of intangible assets	532, 533
47	Legal services	5411
48	Miscellaneous professional, scientific and technical services	5412-5414, 5416-5419
49	Computer systems design and related services	5415
50	Management of companies and enterprises	55
51	Administrative and support services	561
52	Waste management and remediation services	562
53	Educational services	61
54	Ambulatory health care services	621
55	Hospitals and nursing and residential care facilities	622, 623
56	Social assistance	624
57	Performing arts, spectator sports, museums, and related activities	711, 712
58	Amusements, gambling, and recreation industries	713
59	Accommodation	721
60	Food services and drinking places	722
61	Other services, except government	81
62	Federal government enterprises	n.a
63	Federal general government	n.a
64	State and local government enterprises	n.a
65	State and local general government	n.a

A-2. Commodity Sectors in *LIFT*

#	Commodity Title	NAICS
1	Crop production	111
2	Animal production	112
3	Forestry, fishing and agriculture support activities	113, 114, 115
4	Crude oil extraction	211 pt.
5	Natural gas extraction	211 pt.
6	Coal mining	2121
7	Metal ore mining	2122
8	Nonmetallic mineral mining	2123
9	Support activities for mining	2131
10	Electric utilities	2211
11	Natural gas distribution	2212
12	Water, sewage and other systems	2213
13	New construction	2301, 2302
14	Maintenance and repair construction	2303
15	Dairy products, meat and seafood	3115, 3116, 3117
16	Other foods	3111, 3112, 3113, 3114, 3118, 3119
17	Beverages	3121
18	Tobacco	3122
19	Textiles and textile products	313, 314
20	Apparel	315
21	Leather products	316
22	Wood products	321
23	Paper	322
24	Printing	323
25	Petroleum and coal products	324
26	Resin, synthetic rubber and fibers	3252
27	Pharmaceuticals	3254
28	Other chemicals	3251,3253,3255,3256,3259
29	Plastic products	3261
30	Rubber products	3262
31	Nonmetallic mineral products	327
32	Iron and steel	3311,3312,33151
33	Nonferrous metals	3313,3314,33152
34	Fabricated metal products	332
35	Agriculture, construction and mining machinery	3331
36	Industrial machinery	3332
37	Commercial and service industry machinery	3333
38	Ventilation, heating, air-conditioning and ventilation equipm	3334
39	Metalworking machinery	3335
40	Engine, turbine and power transmission equipment	3336
41	Other general purpose machinery	3339
42	Computers and peripheral equipment	3341
43	Communications and audio-video equipment	3342, 3343
44	Semiconductors and other electronic components	3344
45	Electromedical and electrotherapeutic apparatusw	334510, 334517
46	Search, detection and navigation equipment	334511
47	Measuring and control instruments	334512,3,4,5,7,8,9
48	Magnetic and optical media	3346
49	Household appliances	3352
50	Electrical equipment	3353
51	Other electrical equipment and components	3351,3359
52	Motor vehicles	3361,3362
53	Motor vehicle parts	3363
54	Aerospace products and parts	3364
55	Ship and boat building	3366

A-2. Commodity Sectors in *LIFT* (continued)

#	Commodity Title	NAICS
56	Other transportation equipment	3365,3369
57	Furniture	337
58	Medical equipment and supplies, dental labs	3391, exc. 339115
59	Ophthalmic goods	339115
60	Miscellaneous manufacturing	3399
61	Wholesale trade	42
62	Retail trade	44,45
63	Air transportation	481
64	Rail transportation	482
65	Water transportation	483
66	Truck transportation	484
67	Transit and ground passenger transportation	484, S00201
68	Pipeline transportation	486
69	Transportation support, sightseeing, couriers	487,488,492
70	Warehousing and storage	493
71	Publishing, except software	511, exc. 5112
72	Software	5112
73	Motion picture and sound recording	512
74	Broadcasting: Cable, TV and radio	5131, 5132
75	Telecommunications	5133
76	Information and data processing	514
77	Banks, credit cards and finance	521,522
78	Securities, investments, funds and trusts	523,525
79	Insurance	524
80	Real estate	531
81	Owner-occupied dwellings	S00800
82	Rental and leasing of goods	532
83	Royalties	533
84	Legal services	5411
85	Professional, scientific and technical services	541, exc. 5415
86	Computer systems design and related services	5415
87	Management of companies and enterprices	55
88	Administrative and support services	561
89	Waste management and remediation	562
90	Educational services	611
91	Home health care services	6216
92	Offices of physicians, dentists, and other health practioner	6211, 6212, 6213
93	Other ambulatory health care services	6214, 6215, 6219
94	Hospitals	622
95	Nursing and residential care facilities	623
96	Child care and social assistance	624
97	Performing arts, spectator sports and museums	711,712
98	Amusements, gambling and recreation	713
99	Accomodation	721
100	Food services and drinking places	722
101	Automotive repair and maintenance	8111
102	Other repair and maintenance, personal services	8112,-3,-4, 812
103	Religious, grantmaking and other organizations	813
104	Private households	814
105	Postal service and federal government enterprises	491, S00102
106	State and local government enterprises	S00203
107	General government industry	S00500
108	Noncomparable imports	S00300
109	Scrap, used and secondhand	S00401, S00402
110	Rest of the world adjustment to final uses	S00600

Appendix B. Data Sources

This appendix describes the data used for this paper. Unless otherwise noted, all series used in the paper are annual and cover the period from 1998 to 2010.

A. Nominal Output by Industry

The nominal output data are derived from the 2002 benchmark input-output table, the series of annual IO tables from 1998 to 2010, and the BEA gross output series, which includes current and constant prices industry output (before redefinitions). The Inforum concept of industry output is closest to the BEA series "industry output after redefinitions" from the annual IO tables.

B. Output Price

To deflate industry output, we have compiled a series of make tables in current prices. We use commodity deflators to deflate the make tables down the column, and form the real industry output as the row sum of the deflated make table. The industry output price is formed as the ratio of nominal industry output over real industry output.

C. Labor Hours

The NIPA table 6.9 "Hours worked by full-time and part-time employees" is used as the control totals for hours worked for employees. The distribution to more detailed industries is achieved by sharing the hours worked by shares of employment in each industry. Finally, hours for self-employed and family workers are added by adjusting hours by the share of employment of self-employed and family workers to full-time and part-time employment.

D. Labor Compensation

Labor compensation includes wages and salaries plus supplements. Inforum uses the NIPA data directly. The average "wage" per hour is defined as the total labor compensation divided by total hours worked, for each industry.

E. Investment and Capital Stocks

Data on nominal investment series by owning industry is taken from the BEA *Fixed Assets* data. Fixed ratios are used to convert these series to a user basis, as defined by the 1997 Capital Flow Table published by BEA as part of the 1997 U.S. Benchmark IO table. Average service lives by industry are used to derive time series of real capital stocks. The LIFT model also includes its own time-series of capital flow tables, estimated and balanced by Inforum, for the period 1998 to 2010. There are in nominal and constant 2005 dollars.

F. Intermediate Purchases, Aggregated as Energy, Materials and Services

The intermediate aggregates used for the Inforum KLEMS data are drawn from the IO database used for the *LIFT* model. This database uses detail from the 2002 Benchmark U.S. IO table and the series of U.S. annual IO tables, combined with detailed data on imports, exports and industry output to create a time series of detailed make and use matrices from 1998 to 2010. These are then converted annually to a product-to-product table, based on commodity technology The entire framework is converted to constant prices by deflating output by domestic output deflators, deflating imports by imports deflators, and deflating the rest of each row implicitly in a way that preserves the row sum in constant prices.