Backcasting the BEA/BLS Integrated Industry-level Production Account and the Sources of U.S. Economic Growth between 1987 and 2016

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I. Introduction

This paper describes forthcoming experimental historical statistics for the integrated industry-level production account covering the period 1986-1996 that will be released to the public in June 2018. Release of this new dataset will add more than a decade of historical data to this time series and enhance the usefulness of the production account by allowing analysis of economic trends over a longer period. These statistics are being prepared as part of an ongoing collaboration between the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS).

These new historical data provide a view of the sources of economic growth over roughly three decades of economic history. The data reveal that about half of economic growth over this period was due to the accumulation of capital inputs. About thirty percent was due to growth in labor input, while the remainder (about 20%) was due to growth in multifactor productivity (MFP). The industry dataset shows that the aggregate growth in capital input was driven by capital services growth employed in the trade; information; and finance, insurance, and real estate sectors. The preponderance of the contribution of labor input was due to an increase of labor services in the services industries, while the large majority of aggregate MFP growth was accounted for by MFP growth in the computer and electronic manufacturing and trade sectors.

In addition to the new historical data, this forthcoming dataset will also include revised data for 1997-2015 and new estimates for 2016. Minor revisions throughout this period are due to the incorporation of updated data on capital and labor inputs from the BLS productivity program published on March 21, 2018.

[1] The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis or the Bureau of Labor Statistics. Garner and Russell are with the BLS Office on Productivity and Technology. Harper, Howells, and Samuels are with the Bureau of Economic Analysis Industry Economic Accounts. We are grateful to Matt Calby, Eugene Njinkeu, Ethan Schein, Randy Kinoshita, and Corey Holman for their work on the estimates, and to Kim Bayard for providing her NAICS-SIC concordance.

In addition, revisions in 2014 and 2015 reflect new data from BEA's most recent annual update to the industry accounts published on November 2, 2017.

The conceptual framework that underpins the estimates is identical throughout the time series. However, more limited data availability requires that different techniques be employed to prepare estimates in the earlier periods. The primary purpose of this paper is to describe the insights gained from the new data for 1986-1996 and the methodology underpinning these results. See Fleck et al. for a more detailed discussion of the methodologies and source data that underpin statistics for the more recent period.[2]

The remainder of the paper is divided into four main sections. Section II describes the conceptual estimation framework that underpins the full set of statistics. Section III describes the source data and methodologies used to prepare the data inputs for the period prior to 1997. Section IV describes the results. Section V concludes.

II. Conceptual Framework

To prepare these statistics, we assume a production function relating industry gross output to five factor inputs using the function Q = F(K, L, E, M, S, t). Assuming constant returns to scale, perfect competition, and factor payments equal to marginal product, the gross-output growth model can be written as:

Eq 1. $$\frac{dlnQ}{dt} = \left(\frac{\partial lnQ}{\partial lnK} \cdot \frac{dlnK}{dt}\right) + \left(\frac{\partial lnQ}{\partial lnL} \cdot \frac{dlnL}{dt}\right) + \left(\frac{\partial lnQ}{\partial lnE} \cdot \frac{dlnE}{dt}\right) + \left(\frac{\partial lnQ}{\partial lnM} \cdot \frac{dlnM}{dt}\right) + \left(\frac{\partial lnQ}{\partial lnS} \cdot \frac{dlnS}{dt}\right) + \left(\frac{\partial lnQ}{\partial t}\right)$$

where

Q = Gross Output
K = Capital Input
L = Labor Input
E = Intermediate Energy Inputs
M = Intermediate Material Inputs
S = Intermediate Purchased Services Inputs
t = Time

Which can be rearranged in terms of multifactor productivity growth as follows:

Eq 2. $$\left(\frac{\partial lnQ}{\partial t}\right) = \frac{dlnQ}{dt} - \left(\frac{\partial lnQ}{\partial lnK} \cdot \frac{dlnK}{dt}\right) - \left(\frac{\partial lnQ}{\partial lnL} \cdot \frac{dlnL}{dt}\right) - \left(\frac{\partial lnQ}{\partial lnE} \cdot \frac{dlnE}{dt}\right) - \left(\frac{\partial lnQ}{\partial lnM} \cdot \frac{dlnM}{dt}\right) - \left(\frac{\partial lnQ}{\partial lnS} \cdot \frac{dlnS}{dt}\right)$$

With the above assumptions, the unknown elasticities can be replaced with the observable factor share, v_i, for each input. Shown below is the factor share for capital input:

Eq 3. $$\frac{\partial lnQ}{\partial lnK} = \frac{P_K K}{P_K K + P_L L + P_E E + P_M M + P_S S} = \frac{Capital\ Compensation}{Total\ Compensation} = v_K$$

where

P_K = Price of Capital

[2] Fleck, Susan, Steven Rosenthal, Matthew Russell, Erich H. Strassner, and Lisa Usher, 2012. "A Prototype BEA/BLS Industry-Level Production Account for the United States," in Measuring Economic Sustainability and Progress, edited by Dale W. Jorgenson, J. Steven Landefeld, and Paul Schreyer (Chicago: University of Chicago Press, for the National Bureau of Economic Research, 2014).

P_L = Price of Labor
P_E= Price of Intermediate Energy Inputs
P_M= Price of Intermediate Materials Inputs
P_S= Price of Intermediate Purchased Services Inputs

The assumption of constant returns to scale ensures that the factor shares for all inputs sum to one:

Eq 4. $v_K + v_L + v_E + v_M + v_S = 1$

In discrete time, the input weights are two-year averages of the cost shares for each input in years t and t-1, where $\tilde{v}_i = \frac{1}{2} v_{i,t} + \frac{1}{2} v_{i,t-1}$.

All of this information can be combined to rewrite MFP growth for an industry as the residual difference between growth in output and growth in the combined inputs:

Eq 5. $\Delta MFP = \Delta lnQ - \tilde{v}_K \Delta lnK - \tilde{v}_L \Delta lnL - \tilde{v}_E \Delta lnE - \tilde{v}_M \Delta lnM - \tilde{v}_S \Delta lnS$

Finally, it is worth noting that there are no assumptions restricting individual industries in this analysis of MFP. Each industry faces the above production function individually and without regard to any other industry.

The MFP index is computed by dividing an index of real gross output by an index of combined real inputs. The combined index of real inputs is computed using a Tornqvist index number formula to aggregate real intermediate inputs by industry for energy, materials, and purchased services, real labor input, and real capital input weighted by average cost shares.

III. Data

In the framework described above, the four key datasets are gross output, intermediate inputs, capital, and labor. Data on gross output and intermediate inputs by industry are drawn from BEA's GDP by Industry statistics while data on capital and labor inputs come primarily from the BLS Productivity Program. Total capital and labor compensation by industry are controlled to match value added by industry estimates from BEA. As described below, labor, capital, and intermediate inputs are adjusted to account for changes in composition over time.

Gross Output and Intermediate Inputs

BEA's GDP by Industry statistics provide a time series of nominal and real gross output, intermediate inputs (including a decomposition of energy, materials, and purchased services inputs), and value added by industry, prepared based on the 2007 North American Industry Classification System (NAICS). These data are fully integrated with expenditure-based GDP estimates from the National Income and Product Accounts (NIPAs). In addition, the data are prepared within a balanced supply-use framework that allows for simultaneous and consistent analysis of industry output, inputs, value added, and final demand. These

fully integrated statistics were first released in January, 2014, and covered the period 1997-2012. They have subsequently been updated and extended to cover the period 1997-2016.[3]

While certain series in the GDP by Industry dataset extended further back in time, the full suite of integrated make-use tables and GDP by industry statistics extended back only to 1998 prior to the release in early 2014. As a result, the initial version of the industry-level production account was also limited to the time period beginning in 1998. However, in February 2016, BEA released integrated make-use tables and GDP by Industry statistics extending back to 1947, adding a half century of historical data to this time series. The availability of these new historical data opened the possibility of extending the industry-level production account back in time as well.[4]

Gross Output and Intermediate Inputs: Backcasting

Preparation of the historical make-use tables and GDP by Industry statistics relied heavily on a series of benchmark input-output tables prepared by BEA from 1947 to 1992[5]. These tables provide valuable information about the structure of the U.S. economy at various points in history; however, the tables as initially published were designed as standalone snapshots of the economy and could not be treated as a time series. Among other things, earlier tables were not updated to incorporate definitional and conceptual changes introduced in later tables, and the tables were not prepared using a consistent industry classification structure. Transformation of these disconnected benchmark tables into a consistent annual time series took place in four major steps.

First, the tables were updated to incorporate major definitional changes introduced into the NIPAs since the initial publication of each table. Major changes incorporated as part of this step include statistical revisions to autos and trucks, housing and housing services, and non-profits; changes to the treatment of output for insurance and banking; introduction of the "government as producer" treatment; and capitalization of software.

Second, the tables were updated to reflect the 2002 NAICS structure, consistent with data available as of May 2010. Benchmark tables in the historical period were initially published using whichever version of the Standard Industrial Classification (SIC) system was current at the time of preparation. The SIC-to-NAICS concordance that was used for the initial conversion of these tables to NAICS was based on fixed weights from 1997. This 1997 fixed-weight concordance was updated by aggregating SIC-based benchmark data up to roughly a 3-digit NAICS level of detail. The resulting concordance was used to convert both make

[3] Kim, Donald, Erich H. Strassner, and David B. Wasshausen, "Industry Economic Accounts, Results of the Comprehensive Revision, Revised Statistics for 1997-2012." *Survey of Current Business*, February 2014 and Barefoot, Kevin, Teresa L. Gilmore, and Chelsea K. Nelson, "The 2017 Annual Update of the Industry Economic Accounts, Initial Statistics for the Second Quarter of 2017, Revised Statistics for 2014-2016 and the First Quarter of 2017." *Survey of Current Business*, December, 2017.

[4] Lyndaker, Amanda S., Thomas F. Howells III, Erich H. Strassner, and David B. Wasshausen, "BEA Briefing, Integrated Historical Input-Output and GDP by Industry Accounts, 1947-1996," *Survey of Current Business*, February 2016.

[5] Benchmark tables in this period were prepared for the following years: 1947, 1958, 1963, 1967, 1972, 1977, 1982, 1987, and 1992.

and use tables to a 2002 NAICS basis. The converted tables were then re-balanced using a RAS balancing technique.

Third, annual tables were prepared for the inter-benchmark periods. To begin, make tables and unbalanced use tables were prepared by interpolating between benchmark tables. A variety of data were used as indicators for the interpolation process, including Census survey data, annual make-use tables and gross output by industry statistics published by BEA, and personal consumption and private investment data from the NIPAs. Each of these tables was then controlled to be consistent with historical GDP data using RAS balancing.

Fourth, the time series was updated to reflect the 2007 NAICS structure, and definitional and statistical improvements from BEA's 2013 comprehensive update were incorporated into the dataset. Major changes incorporated at this stage include the capitalization of R&D expenditures, own account entertainment originals, and residential housing transfer costs as well as the adjustment of defined pension plans from a cash-accounting basis to an accrual-accounting basis.

For the industry-level production account, intermediate inputs in the historical time series also needed to be decomposed into energy, materials, and purchased services (EMS) components. The time series of make-use tables for 1963-1996 includes a decomposition of intermediate inputs into 75 commodities; however, this level of detail was not sufficient to allow a one-to-one assignment of each commodity to an EMS category. We addressed this using unpublished data from the 1997 use table. The working level of detail for tables beginning in 1997 includes about 5,000 goods and services and about 800 industries. At this level of detail, it is possible to make a direct EMS assignment to each cell in the use matrix. By aggregating these data up to the same level of detail as the historical use tables (about 75 goods and services and 65 industries), we were able to calculate EMS ratios for each cell in the matrix. These fixed ratios were applied to the historical use tables to generate estimates of EMS inputs for each industry for 1987-1996.

With the nominal data available in the make-use framework, estimates of real GDP by industry were prepared using a double deflation methodology in which gross output and intermediate inputs are deflated separately and real value added is computed as the residual, as is standard in the published GDP by industry statistics. Real gross output by industry was derived by deflating the commodities produced by each industry as reflected in the make table.[6] Similarly, real intermediate inputs were derived by deflating the commodities consumed by each industry as reflected in the use table. Prices used for deflation were developed by Dale W. Jorgenson, Mun Ho, and Jon D. Samuels and are described in more detail in the article that accompanied the initial publication of the historical GDP by industry statistics (Lyndaker, Howells III, Strassner, Wasshausen 2016).

As in the post-1996 period, the domestic and imported portions of intermediate inputs are deflated separately to account for potential differences in price between commodities purchased from domestic versus foreign sources. Intermediate inputs are disaggregated into domestic and imported components based on the proportionality assumption. More specifically, for each detailed commodity used by an

[6] This differs from the BLS Productivity Program's use of a sectoral output measure which removes the double counting of the intrasectoral sales between establishments within the same sector.

industry, the portion attributable to imports is calculated as the ratio of total imports of the commodity over total domestic supply of the commodity.

Gross Output and Intermediate Inputs: Revisions

This 2017 annual update to BEA's GDP by industry statistics incorporated the Census Bureau's latest Service Annual Survey (SAS) tabulations, which revised statistics for 2014 and 2015. In addition, newly available data for 2016 from SAS replaced estimates based on the Census Bureau's Quarterly Services Survey (QSS). Similarly, revised and newly available data from the Department of Treasury's Statistics of Income (SOI) Division led to revisions to underlying components of the current-dollar estimates of value added by industry, including corporate profits, nonfarm proprietors' income, and net interest for 2014 and 2015. In addition, the annual update incorporated newly available Census Bureau data from the 2015 Annual Survey of Manufactures, the 2015 Annual Retail Trade Survey, and the 2015 Annual Wholesale Trade Survey.

Capital Services Inputs

Capital services are expressed in accordance with a service flow concept of physical assets. A central notion in the construction of capital measures is the concept of "productive" capital stock, or the stock measured as "efficiency units." Conceptually, productive stock represents the amount of new investment required to produce the same capital services actually produced by existing assets of all vintages. Thus, capital services are assumed to be proportional to productive stock.

Capital Input: Backcasting

By definition, a capital asset is one that lasts more than a year. Therefore, the service flows received from a producing industry or firm are employed over a longer period than the original investment conveys. As a practical matter, real stocks are constructed as vintage aggregates of real historical investments in accordance with an "efficiency" or service flow concept using the perpetual inventory method outlined in the initial release of the BEA/BLS production account. This implies that the hard work of backcasting historical stocks had, in effect, already been accomplished by the BLS with the original release of the account.

The current-dollar value added components by industry needed to calculate rental prices used to construct capital services were the missing link that BEA's release of historical make-use tables was able to bridge. These new historical measures allowed the BLS to incorporate capital services estimates back to 1987. With the release of the 2016 Multifactor Productivity trends[7] news release, BLS incorporated these integrated and improved data into their official measures. Thus, this release makes use of all the available historical data from the most recent BLS multifactor productivity update to produce its capital service measure back to 1987 on a national accounts basis.[8]

[7] See https://www.bls.gov/news.release/archives/prod3_03302017.pdf
[8] See https://www.bls.gov/mfp/mprdload.htm

Capital Input: Revisions

With this update of the account, the capital measures for the finance and insurance industries were revised to more fully integrate the BEA/BLS production account into the national accounts. Previously, in the finance and insurance sectors, controls for capital compensation were not constrained to BEA income estimates because of concerns for some of the features of the more detailed estimates.

More recently, BEA has made a number of improvements to the finance and insurance sectors that made constraining the BLS construction of capital measures to the income pieces available from BEA beneficial from both a consistency standpoint as well as a methodological standpoint. Specifically, BEA improved the insurance and banking estimates with the 2013 Comprehensive Revision.[9] These improvements have made constraining to BEA, as is done with all other industries in the BEA/BLS production accounts, a logical next step.[10] This change follows publication of the BLS Multifactor Productivity Trends 2017[11] release in which this consistent treatment was also adopted by BLS in the finance and insurance sectors. On a real basis, the revisions to the capital input measures were small.

In addition to these improvements to the finance industries, a small correction to the constant-dollar investment of the aircraft asset in the finance industries was made to align with the BEA Fixed Asset accounts. These corrections were small and localized to the already adjusted finance industries.

The final revision to the methods for capital service estimates involves an update to how inventories are distributed among most nonmanufacturing industries. For all non-manufacturing industries except mining, utilities, and construction, BEA inventories are grouped into an "other" category. BLS uses IRS book value data to distribute "other" inventories to the remaining non-manufacturing industries after moving the data from a company to an establishment basis via establishment-company ratios. Additionally, BLS employed a three-year smoothing of the IRS book values for the data processing, internet publishing industry. Previously BLS only smoothed the data for the years 1999-2008. BLS now smooths the data from 1999 through the last year available. Because the IRS data are used to determine the share of "other" inventories allocated to each non-manufacturing industry, this change affected the inventory values of all the other non-manufacturing industries as well.

Labor Input

Labor Hours

As in the previous set of accounts, BLS prepares a time series of labor hours reflecting annual hours worked and are aggregated from estimates of more detailed industries. BLS estimates labor hours using payroll employment and hours from the Current Employment Statistics (CES) survey and are supplemented with data for the self-employed and average weekly hours for nonproduction and supervisory workers from the Current Population Survey (CPS).[12] The BLS National Compensation Survey

[9] See March 2013 Survey of Current Business "Preview of the 2013 Comprehensive Revision of the National Income and Product Accounts."
https://www.bea.gov/scb/pdf/2013/03%20March/0313_nipa_comprehensive_revision_preview.pdf
[10] See https://www.bea.gov/scb/pdf/2013/06%20June/0613_preview_comprehensive_iea_revision.pdf also:
https://www.bea.gov/scb/pdf/2013/02%20February/0213_nipa-rev.pdf
[11] See https://www.bls.gov/news.release/archives/prod3_03212018.pdf
[12] See http://www.nber.org/chapters/c13005

is also used to convert the hours of payrolled workers from a paid to a worked basis when constructing the initial set of employment and hours estimates for the BEA/BLS production account.[13] Sources for industries that are not covered by CES or where data are missing include the Department of Agriculture, BLS Quarterly Census of Employment and Wages (QCEW), and Mine Safety and Health Administration.[14] These estimates are subsequently controlled to BEA National Accounts estimates of hours worked at a more aggregate level before being distributed to demographic groups as outlined in the labor composition section.

Labor Hours: Backcasting

In 2003, the BLS CES program released historical employment and average weekly hours data for detailed industries on a North American Industrial Classification system back to 1990. In addition to the historical data, the BLS CES program made available the bridge ratios used in converting the measures. These data serve as the basis for the estimates of the BEA/BLS Production account prior to 1997 and are consistent with the data after 1997.

For the period prior to 1990, the BLS CES provides reconstructed historical measures for 2-digit NAICS sectors back to 1939. Reconstructed historical measures for years before 1990 are also available for selected 3-, 4-, 5-, and 6-digit NAICS industries.

Where available, complete NAICS-based payrolled employment and hours from the BLS CES series were used in the BEA/BLS production account. For the industries that were not available from BLS CES, employment estimates were developed using historical Standard Industrial Classification (SIC)-based measures and conversion factors published by the BLS CES program to reconstruct NAICS-based series back to 1987. This conversion was carried out at the most detailed industry level for which conversion factors were available by the BLS, that is, using a 4-digit SIC to 6-digit NAICS CES bridge. The resulting converted employment estimates were historically linked to the published CES employment data series in 1990.

Hours for 1987-89 were derived using an approach similar to that used to develop the employment estimates. Total hours residuals were constructed from the available NAICS-based aggregates and the available NAICS-based detail from BLS CES. The residual total hours were then distributed to the detail using proportions derived from the initially converted set of NAICS-based employment estimates, to create total payrolled hours estimates for the remaining component industries at all levels of industry detail.

The CPS assigns respondents to industries using the Census Bureau's Industry Classification System (ICS). There are two different classification systems across the time period of 1987-1996. For the years 1987-1991, the ICS is based on the 1980 Census codes, which uses the 1972 SIC classification, as modified in 1977. The ICS for the 1992-2002 interval is based on the 1990 Census which uses the 1987 SIC classification. The CPS data from 2000-2002 were dual-coded on both an SIC and a NAICS basis.

[13] See https://www.bea.gov/scb/pdf/2014/08%20August/0814_industry-level_production_account.pdf
[14] Ibid.

To estimate consistent historical NAICS-based self-employed and supervisory average weekly hour estimates back to 1987, a multi-step process was followed to convert the historical CPS data from an SIC-based code to a NAICS-based industry code used in the BEA/BLS production account. First, a 3-year average SIC-to-NAICS conversion bridge was derived from the dual coded CPS data from 2000-2002. Adjustments to the initial conversion ratios were later made based on a comparison of the NAICS industry employment levels for 2000-2002 generated by applying the bridge with the employment estimates from the CPS data provided on a NAICS basis. NAICS final employment and hours estimates for 1987-2002 were derived by applying the adjusted conversion ratios to the historical SIC-based employment and hours series.

With the annual release of the 2016data, the BLS instituted an improvement to the hours worked to hours paid ratios necessary to convert the BLS CES data for payrolled workers to the theoretically preferred hours worked basis[15]. From 2005-onward, fourth-quarter NCS data at the 3-digit NAICS level are used as a proxy for each annual ratio value. During these years, more than 98 percent of the sample rotation is isolated to the fourth quarter of each year. These new observations, which represent around 20 percent of the overall respondents in this quarter, provide a refreshed source of response relative to the three prior quarters of the year, in which carried-over responses are generally held the same as the initial survey response.

From 1996 through 2004, however, an average of the four quarterly NCS ratios is used as the NCS sample rotation was intermittent throughout the year and was not regularly scheduled as the 2005-onward period had been. In order to estimate three-digit ratios for 1990-1996, the 1996 NCS ratio values are carried backwards using the BLS Hours At Work Survey (HWS) as an extrapolator series. For 1987-1989, ratios for 14 super sectors from the HWS are utilized to move more detailed industry hour worked to hours paid data backwards.

Labor Hours: Revisions

This update of the BEA/BLS production accounts uses the same source for labor hours as the original release, but includes a number of improvements. The BLS CES made an improvement in Educational services, health care and social assistance that has been incorporated into this update the BEA/BLS production accounts.[16] In addition, there has been a revision to incorporate the all-employee hours measure for couriers and messengers within other transportation and support activities which revises the series across the time series.

Labor Composition

In order to create a constant quality index of labor input, hours worked are weighted to account for substitution between heterogeneous types of labor. The need for this adjustment reflects the assumption that the marginal product of a skilled worker is higher than that of an unskilled worker, implying that replacing hours worked by an unskilled worker with an equal number of hours worked by a skilled worker will increase economic output. This change in labor input due to shifts in worker characteristics is referred to as the labor composition effect. For this set of accounts, workers are disaggregated by sex, eight age

[15] https://www.bls.gov/lpc/hwhpnew.htm
[16] https://www.bls.gov/ces/cesbmart13.pdf

groups, six education groups, and employment class (payrolled vs. self-employed) for a total of 192 demographic categories. In addition, workers are categorized into one of 63 industries resulting in a total of 12,096 cells in the labor composition matrices for each period.

The estimation process begins by filling out information on employment, hours, and compensation for each cell in these matrices. For 1990 and 2000, the matrices are initialized using the U.S. Census 1990 and 2000 1-Percent Public Use Microdata Sample (PUMS) files. Initial estimates are generated for 1991-1999 by linear interpolation at the cell level. These initial estimates are iteratively adjusted using the RAS balancing technique to match a series of marginal controls developed from the March supplement to the CPS. [17] For years before 1990 the t+1 balanced matrices are used as the initial cell estimates, and for years after 2000 the t-1 balanced matrices are used. As with the periods 1990-2000, these initial matrices are iteratively adjusted to match controls from the CPS.

After balancing, the matrices are scaled in sequence (1) to employment controls from BEA's National Income and Product Accounts (NIPAs) for 63 industries by employment class, (2) to BLS hours for 63 industries by employment class, (3) to NIPA hours for payrolled workers by 17 aggregate industries, and (4) to NIPA compensation for payrolled workers by 63 industries. In the final step, the hourly compensation of self-employed workers is replaced by the rate for payrolled workers in the same cell. This step is taken because reported compensation of self-employed workers cannot be disentangled from compensation accruing to their capital assets. Additional methodological information is described in Fleck, et al (2014) with updates in Rosenthal, et al (2014).

Labor Composition: Backcasting

Previous publications of these accounts made use of an SIC-to-NAICS bridge from the BLS CES program to convert SIC-based labor measures beginning in 2003 to NAICS industries. In preparing the new historical period covered by these accounts, a modified SIC-to-NAICS bridge was constructed to incorporate time-varying weights for manufacturing industries. These dynamic, employment-based weights were supplied by the Federal Reserve Board based on research from Bayard (2003) which made use of establishment-level microdata from the Census of Manufacturing and the Annual Survey of Manufactures spanning the period from 1963 to 1997. The time-varying weights replaced static weights where available, but were scaled to leave unchanged any weights linking portions of SIC manufacturing industries to NAICS non-manufacturing industries. For the period between 1997 and 2000, all updated manufacturing weights were interpolated to the static weights from the previous bridge.

The modified SIC-to-NAICS bridge was applied to the U.S. Census 1990 PUMS files to develop the initial 1990 labor composition matrix as well as to the 1987-2002 CPS marginal controls. The bridge was also applied to the SIC-based NIPA employment, hours, and compensation scaling controls for 1987-1997; however, these converted results were not used directly. In order to mitigate the possibility of time series breaks, the converted series were used as indicators to backcast a time series beginning with the 1998 levels in the published NAICS-based NIPA tables. Finally, these new NAICS-based employment, hours, and compensation levels were scaled to the SIC-based totals for all industries to ensure that this conversion process left totals unchanged.

[17] Labor composition estimates for the published BLS MFP data are constructed using the Basic Monthly CPS data. BLS and BEA are collaborating to reconcile the labor composition measures produced by BLS for the official MFP estimates and those produced by BEA for the account presented in this paper.

In addition to the modified bridge, the 1987-1991 March Supplement of the CPS required special handling for the reported level of educational attainment. The current questionnaire allows respondents to select their highest degree attained, which aligns well with the education categories chosen for these accounts. However, prior to 1992, respondents were instead asked for the number of years of schooling as well as whether the last year of schooling was completed. This inconsistency was addressed by converting the number of years of schooling to an estimated highest degree attained via a frequency matrix described in Jaeger 1997. That work matched CPS respondents who had reported educational attainment under both versions of the questionnaire, and cross tabulated pairs of responses to create conversion weights.

Labor Composition: Revisions

Revisions to the period 1998-2000 are a result of the interpolated Census PUMs matrices. The process of controlling to the CPS redistributed the marginal matrices based on the shares that resulted from the iterative proportional scaling procedure. Beyond that, revisions reflect updates to incorporate the latest data with hours and compensation estimates and are typically confined to the 2014 forward period.

IV. Results

The major advantage of the longer time series of integrated KLEMS data is that it permits analysis of longer-term economic trends. Over the last three decades, this includes the Information Technology revolution and increased globalization of the production process. The dataset that we have described above is an important tool for identifying the structural change that has taken place between 1987 and 2015, particularly at the industry level. In this section, we focus on two aspects of economic growth for the period that our new dataset covers. The first is the industry-level sources of growth, including the industry-level contributions of capital, labor, and productivity to economic growth, and the second is to use the new, longer time series to describe some aspects of structural change over this period. To address these two related questions, we focus on an industry classification more condensed than the 63 industries described above. In particular, we use a group of nine sectors that reflect major industry groupings.[18]

We start with standard growth accounting to describe the industry-level sources of growth. Table 1 includes the sources of output growth at the industry level between 1987 and 2016. Over this period, the three fastest growing industries were Information Technology-related: computer systems design; data processing, internet publishing, and other information services; and computer and electronic products manufacturing, reflecting not only the importance of IT hardware, but also the related systems and development, and the shift towards cloud computing. The textile; apparel and leather; and paper manufacturing industries all contracted over the period, likely reflecting increased competition from foreign products and other shifts in demand toward cheaper substitutes. Relatively strong growth in rental and leasing; broadcasting and telecommunications; and data processing was driven by capital investments, while growth in computer systems design; social assistance; and warehousing and storage was driven by growth in labor inputs, reinforcing the importance of looking at the input side when analyzing the sources of growth. Between 1987 and 2016, the computer and electronic products; securities, commodity contracts, and investments; and warehousing and storage had the largest growth in multi-factor productivity (MFP).

[18] This is the same industry classification used by (Jorgenson & Schreyer, 2013)

Table 2 presents sector contributions to aggregate value added growth and shows many familiar facets of economic growth over the last thirty years. Between 1987 and 2016, manufacturing contributed 0.34 percentage point (pp) to aggregate value added growth of 2.38 percent per year on average. However, this contribution was skewed heavily towards the first part of the period (0.45pp between 1987-1995 and 0.84pp during the IT-Investment boom of 1995-2000), and has fallen off since. Between 2000 and 2007 manufacturing contributed 0.32pp to aggregate growth and -0.01 between 2007 and 2016. Importantly, the manufacturing sector includes the relatively rapidly growing computer and electronic industry; excluding this industry the contribution of manufacturing to aggregate growth was 0.20pp in 1987-1995 and -0.08 in 2007-2016. Over the same period value added generated by services industries increased in importance. In particular: the information industries; finance, insurance, real estate, rental and leasing; and other services accounted for about 46% of real economic growth in the 1987-1995 period and 74% of real growth in the 2007-2016 period.

The bottom portion of the table includes the nominal value added shares of each of the major sectors and conveys a similar story. The nominal value added share encompasses payments to labor and capital services and shows how income is distributed throughout the economy. Factors of production in the manufacturing sectors earned 16.7% of aggregate income in 1987-1995, but only 11.6% of income in 2009-2016, reflecting the overall decline in the share of manufacturing in the economy. Other services produced 20.8% of income between 1987 and 1995, but this increased to 24.8% over the 2009-2016 period. The value added share in finance, insurance, real estate, rental and leasing also increased, from 17.5% in the early periods to about 19.0% in the later period.

Table 3 shows the sector-level sources of growth. Over the entire period, growth in capital input was the predominant source of economic growth, followed by growth of labor input, and then growth in MFP. Growth in capital input in the finance and trade industries accounted for about half of the total contribution of capital input. However, breaking down the shares of capital growth across the different time periods reveals the effect of the 2007 housing crisis. The more recent 2007-2016 period saw the finance, insurance, real estate and rental and leasing sector's contribution to capital cut in half with the financial crisis from 39% in the earlier period to 19% in the 2007-2016 period. More than half of the contribution of labor input was accounted for by growth in labor input in the other services industries, and growth in MFP was dominated by MFP growth in manufacturing (mostly computers and electronic products) and the trade sectors.

It is worth summarizing a few of the main trends that the 1987-2016 KLEMS data reveal. Over this period, output growth shifted from manufacturing to services, and income shares shifted as well. Economic growth during the period of the ongoing recovery from 2009-2016 was significantly slower than the 1987-1995 period before the IT boom; this was driven mostly by slower capital and labor input growth. MFP growth was actually faster in the 2009-2016 period in comparison to the 1987-1995 period. The growth in other services was driven mostly by labor input growth and a recovery of MFP from negative early in the period to slightly positive towards the end of the period.

In the second part of this section, we focus on one particular component of structural change over the last thirty years: the industry sources in the change in the distribution of income. It is relatively well known that the share of value added accruing to labor has been in decline. In this part, we present new information on the industry sources of this decline.

Figure 1 shows the change in the share of aggregate value added of capital and labor by sector. Over this period, the capital share increased from 38.6% of income in 1987 to 45.5% of income in 2016. Figure 1 indicates that this shift was not proportionate across sectors. For example, while the income share paid to labor generated in the manufacturing sector fell by a significant margin, it increased by almost as much in the other services sector. Thus, the shift in output from manufacturing to other services actually counterbalanced the trend of a falling labor share. In the trade sector, the share of income accruing to capital increased, while that accruing to labor actually fell, providing evidence that an industry's expansion does not necessarily produce proportional gains for labor and the owners of capital.

Figures 2 and 3 provide more information on the changes in the aggregate labor share by industry. Figure 2 shows that even though the aggregate labor share fell over the period, the share of income accruing to college-educated labor (those with a BA degree or above) increased significantly over the period, so that the decline in the aggregate labor share was entirely due to a decline in the share of income paid to workers without a college degree. Figure 3 presents the decomposition by gender. Over the period, the share of income accruing to men fell from 44.2% to 36.6% between 1987 and 2016. This was driven mainly by large declines (relative to women) in the manufacturing, trade, and government sectors. With the shift towards services, the shares of income paid to both men and women in the services sector increased, and the service sector was the largest driver of increase in the aggregate share of income paid to female workers. This is interesting in light of the findings in (Ngai & Petrongolo, 2017) that the shift to services has narrowed the gender pay gap.[19]

The change in the capital share was not proportionate across industries and types of capital. Figure 4 shows that large changes to the share of income paid to capital occurred in the agriculture, forestry, fishing, hunting, mining, finance, and other services sectors. Within the other services sector, a significant portion of the increase was attributed to the share of Information Technology capital, while in the agriculture, forestry, fishing, hunting, mining sectors, other capital accounted for almost all of the increase in the aggregate capital share. Interestingly, the increase in the capital share in the manufacturing industry was mostly driven by an increase in the share of income accruing to Research and development.

V. Conclusion

The main purpose of this paper has been to present an extended time series of integrated KLEMS-based production accounts for the U.S. The account, produced in a collaboration between the BEA and BLS now covers 1987-2016, in contrast to the 1998-2015 time period covered in the previous vintage of the account released in July 2017. The integrated nature of the account reflects that the capital (K) and labor (L) estimates are constructed to be consistent with GDP by industry accounts produced by the BEA, while the methods to produce the capital and labor are consistent with the methods used by the official productivity statistics produced by the BLS. The account yields industry level sources of growth estimates that are consistent with official GDP measures.

[19] The (Ngai & Petrongolo, 2017) finding focuses on wage rates, while the information that we have presented is about aggregate income shares. While they are not directly comparable, both suggest that shift to services is an important component in how wages and income have evolved.

The longer time series yields important data on the evolution of U.S. economic growth over the least three decades. The account shows the shift from manufacturing towards services and the importance of isolating the effects of the computer and electronics product industry when studying the overall manufacturing sector (Houseman, 2018). The KLEMS approach shows not only which industries are contributing to growth, but the industry-level sources of growth. The most important source of economic growth over the period was the accumulation of capital input. Of the 1.19 percentage points that capital input contributed to growth over the period, the services industries account for 0.89 percentage points. Aggregate labor input accounted for another 0.76pp of economic growth between 1987 and 2016. Of this, the other services industries sector alone accounted for 0.48pp, demonstrating the relative importance of labor in service producing industries. Finally, MFP growth accounted for 0.43pp of aggregate economic growth. Almost all of this was accounted for by MFP growth in the manufacturing and trade sectors; within manufacturing almost all of the MFP growth was due to growth in MFP of the computer electronic products industry.

The account demonstrates the importance of structural change at the industry level in evolution of the allocation of income between capital and labor. The share of income accruing to labor in the manufacturing sector shrank substantially over the period, while the share of income accruing to labor increased substantially in the services industries. In the manufacturing sector this was mostly due a decline in the share of income paid to workers without a college degree, while workers with a college degree accounted for the large majority of the increase in the income paid to labor in the service sectors.

The new estimates presented in this paper are important milestone because extending the account to cover 1987-1997 involved overcoming significant obstacles including the change in industrial classification between NAICS and SIC and changes in the reporting of educational attainment from years of school to attainment measures. But, this is not the final step in the development of the account. Important next steps could include extending the account even further back in time to span the entire period covered by BEA's GDP by industry accounts (1947) and resolving existing difference in the measures of labor composition produced by BLS for the official MFP estimates and those produced by BEA for the account presented in this paper.

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Table 1: Sources of Industry Output Growth 1987-2016

	Output Growth	Capital Contribution	Labor Contribution	Intermediate Contribution	MFP Growth
Farms	1.69	0.09	-0.18	0.37	1.42
Forestry, fishing, and related activities	0.11	0.42	0.99	-0.49	-0.81
Oil and gas extraction	1.29	-0.08	-0.08	0.06	1.40
Mining, except oil and gas	0.39	0.39	-0.25	-0.51	0.77
Support activities for mining	1.46	0.21	0.45	-0.56	1.36
Utilities	0.31	0.74	0.03	0.05	-0.50
Construction	0.39	0.21	0.52	0.34	-0.68
Wood products	0.15	0.06	-0.24	0.58	-0.24
Nonmetallic mineral products	0.20	0.14	-0.07	0.05	0.08
Primary metals	0.49	-0.07	-0.30	0.18	0.68
Fabricated metal products	1.18	0.18	0.05	0.99	-0.04
Machinery	1.09	0.30	-0.04	1.00	-0.18
Computer and electronic products	6.56	0.56	-0.49	0.53	5.96
Electrical equipment, appliances, and components	0.14	0.17	-0.39	0.13	0.23
Motor vehicles, bodies and trailers, and parts	2.55	0.24	0.02	1.76	0.52
Other transportation equipment	1.04	0.23	-0.28	1.37	-0.28
Furniture and related products	0.16	0.16	-0.33	0.33	0.00
Miscellaneous manufacturing	1.75	0.46	0.21	0.41	0.67
Food and beverage and tobacco products	1.10	0.25	0.09	0.93	-0.17
Textile mills and textile product mills	-1.90	-0.10	-0.85	-1.44	0.49
Apparel and leather and allied products	-2.95	0.00	-1.74	-1.75	0.54
Paper products	-0.25	0.09	-0.29	0.17	-0.21
Printing and related support activities	-0.77	0.01	-0.53	-0.75	0.51
Petroleum and coal products	0.85	0.10	-0.07	0.00	0.81
Chemical products	1.29	1.12	-0.01	0.71	-0.53
Plastics and rubber products	1.37	0.29	0.02	0.71	0.35
Wholesale trade	3.31	1.12	0.43	0.82	0.94
Retail trade	2.93	0.86	0.37	0.78	0.91
Air transportation	0.99	0.40	0.05	-0.03	0.57
Rail transportation	1.04	0.07	-0.73	0.60	1.10
Water transportation	2.58	0.04	0.33	1.13	1.08
Truck transportation	2.89	0.35	0.49	1.73	0.31
Transit and ground passenger transportation	1.60	0.41	1.05	0.57	-0.42
Pipeline transportation	-0.44	1.12	0.03	-2.43	0.84
Other transportation and support activities	2.85	0.02	1.35	2.04	-0.56
Warehousing and storage	5.91	0.30	2.03	2.15	1.44
Publishing industries, except internet (includes software)	3.31	0.90	0.07	0.95	1.38
Motion picture and sound recording industries	2.45	1.40	0.57	0.68	-0.19
Broadcasting and telecommunications	4.77	1.90	0.00	2.29	0.58
Data processing, internet publishing, and other information services	7.12	2.58	1.09	3.62	-0.17
Federal Reserve banks, credit intermediation, and related activities	1.52	1.87	0.30	0.68	-1.33
Securities, commodity contracts, and investments	6.49	0.15	1.06	3.19	2.10
Insurance carriers and related activities	2.77	1.27	0.49	0.64	0.37
Funds, trusts, and other financial vehicles	2.78	0.11	0.07	2.35	0.26
Real estate	2.72	1.39	0.06	0.94	0.33
Rental and leasing services and lessors of intangible assets	3.63	3.99	0.18	1.73	-2.27
Legal services	0.92	0.68	0.68	0.78	-1.22
Computer systems design and related services	7.98	0.18	4.53	2.51	0.77
Miscellaneous professional, scientific, and technical services	3.69	0.80	1.38	1.64	-0.13
Management of companies and enterprises	3.06	0.29	1.57	2.27	-1.07
Administrative and support services	4.66	0.76	1.77	2.01	0.12
Waste management and remediation services	2.67	0.32	1.00	1.75	-0.41
Educational services	2.96	0.22	1.45	1.53	-0.23
Ambulatory health care services	3.35	0.22	1.79	1.58	-0.24
Hospitals and Nursing and residential care	2.77	0.26	1.15	1.86	-0.51
Social assistance	3.69	0.10	2.53	1.60	-0.54
Performing arts, spectator sports, museums, and related activities	3.73	0.08	1.19	1.86	0.61
Amusements, gambling, and recreation industries	3.68	0.68	1.03	1.79	0.18
Accommodation	2.11	0.69	0.28	0.84	0.30
Food services and drinking places	2.28	0.18	0.62	1.23	0.25
Other services, except government	1.74	0.43	0.51	1.10	-0.29
Federal	0.72	0.37	-0.17	0.46	0.07
State and local	1.90	0.45	0.64	0.73	0.08

Notes: Average annual percentange growth. A contribution is a share-weighted growth rate.

Table 2: Sector Sources of Value-Added Growth

	1987-2016	1987-1995	1995-2000	2000-2007	2007-2016	2007-2009	2009-2016
			Contributions				
Value-Added	2.38	2.65	4.22	2.34	1.14	-1.56	1.91
Agriculture, Forestry, Fishing, Hunting, Mining	0.08	0.04	0.05	0.06	0.14	0.25	0.11
Transportation, Warehousing, Utilities	0.07	0.16	0.10	0.02	0.02	-0.17	0.08
Construction	0.00	0.03	0.13	-0.04	-0.06	-0.48	0.06
Manufacturing	0.34	0.45	0.84	0.32	-0.01	-0.64	0.18
Computer and electronic products	0.24	0.25	0.62	0.17	0.07	0.09	0.06
Trade	0.41	0.54	0.90	0.33	0.09	-0.61	0.29
Information	0.20	0.17	0.20	0.30	0.14	0.03	0.17
Finance, Insurance, Real Estate, Rental and Leasing	0.50	0.46	0.89	0.57	0.27	0.02	0.34
Other Services	0.57	0.60	0.89	0.49	0.44	-0.12	0.60
Government	0.19	0.20	0.21	0.28	0.11	0.17	0.09
			Shares				
Shares in Nominal Value-Added	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture, Forestry, Fishing, Hunting, Mining	2.7	2.6	2.1	2.4	3.3	3.2	3.3
Transportation, Warehousing, Utilities	4.7	5.3	4.8	4.3	4.3	4.3	4.4
Construction	4.0	3.9	4.1	4.6	3.7	4.0	3.6
Manufacturing	13.9	16.7	15.4	12.7	11.6	11.6	11.6
Computer and electronic products	1.7	1.9	2.1	1.5	1.5	1.5	1.5
Trade	11.9	12.5	12.7	11.8	11.2	11.1	11.2
Information	4.6	4.5	4.7	4.7	4.5	4.7	4.5
Finance, Insurance, Real Estate, Rental and Leasing	18.6	17.5	18.5	19.3	19.0	18.6	19.1
Other Services	23.0	20.8	22.5	23.4	24.8	24.6	24.8
Government	16.7	16.2	15.3	16.9	17.6	17.8	17.5

Notes: Average annual percentages. Aggregate value added growth is the aggregate of share weighed industry value added growth. Sector aggregates are the sum of contributions over the underlying industries.Shares are average nominal shares over the period.

Table 3: Contributions to Aggregate Value-Added Growth

	1987-2016	1987-1995	1995-2000	2000-2007	2007-2016	2007-2009	2009-2016
			Capital Input				
Aggregate	1.19	1.25	1.91	1.35	0.62	0.64	0.61
Agriculture, Forestry, Fishing, Hunting, Mining	0.01	0.00	0.00	0.00	0.03	0.01	0.04
Transportation, Warehousing, Utilities	0.04	0.04	0.05	0.03	0.04	0.03	0.04
Construction	0.02	0.01	0.05	0.05	-0.01	-0.02	-0.01
Manufacturing	0.14	0.17	0.26	0.07	0.11	0.13	0.10
Trade	0.17	0.17	0.31	0.22	0.08	-0.02	0.10
Information	0.14	0.13	0.22	0.13	0.09	0.10	0.09
Finance, Insurance, Real Esate, Rental and Leasing	0.42	0.49	0.70	0.52	0.11	0.12	0.11
Other Services	0.16	0.16	0.24	0.20	0.09	0.15	0.07
Government	0.10	0.09	0.08	0.13	0.09	0.15	0.07
			Labor Input				
Aggregate	0.76	1.09	1.33	0.43	0.40	-1.30	0.88
Agriculture, Forestry, Fishing, Hunting, Mining	0.00	-0.01	-0.01	0.02	0.01	-0.03	0.02
Transportation, Warehousing, Utilities	0.03	0.07	0.04	0.00	0.03	-0.07	0.06
Construction	0.04	0.04	0.16	0.07	-0.04	-0.40	0.06
Manufacturing	-0.04	0.07	0.03	-0.21	-0.04	-0.41	0.06
Trade	0.07	0.13	0.12	0.04	0.02	-0.20	0.08
Information	0.01	0.04	0.11	-0.05	-0.01	-0.08	0.01
Finance, Insurance, Real Esate, Rental and Leasing	0.07	0.07	0.16	0.08	0.02	-0.15	0.07
Other Services	0.48	0.60	0.61	0.39	0.39	-0.06	0.52
Government	0.08	0.09	0.11	0.10	0.03	0.11	0.01
			MFP				
Aggregate	0.43	0.31	0.98	0.55	0.13	-0.90	0.42
Agriculture, Forestry, Fishing, Hunting, Mining	0.07	0.06	0.07	0.04	0.10	0.27	0.05
Transportation, Warehousing, Utilities	0.00	0.05	0.01	0.00	-0.04	-0.13	-0.02
Construction	-0.06	-0.02	-0.09	-0.15	-0.01	-0.06	0.01
Manufacturing	0.24	0.21	0.55	0.46	-0.07	-0.36	0.01
Trade	0.17	0.24	0.47	0.08	0.00	-0.39	0.11
Information	0.05	0.00	-0.13	0.22	0.06	0.02	0.08
Finance, Insurance, Real Esate, Rental and Leasing	0.01	-0.10	0.03	-0.03	0.14	0.05	0.16
Other Services	-0.07	-0.16	0.04	-0.10	-0.04	-0.21	0.01
Government	0.02	0.02	0.02	0.04	-0.01	-0.10	0.01
Aggregate Value Added Growth	2.38	2.65	4.22	2.34	1.14	-1.56	1.91

Notes: Average annual percentages. Aggregate value added growth is the aggregate of share weighed industry value added growth. Sector aggregates are the sum of contributions over the underlying industries.

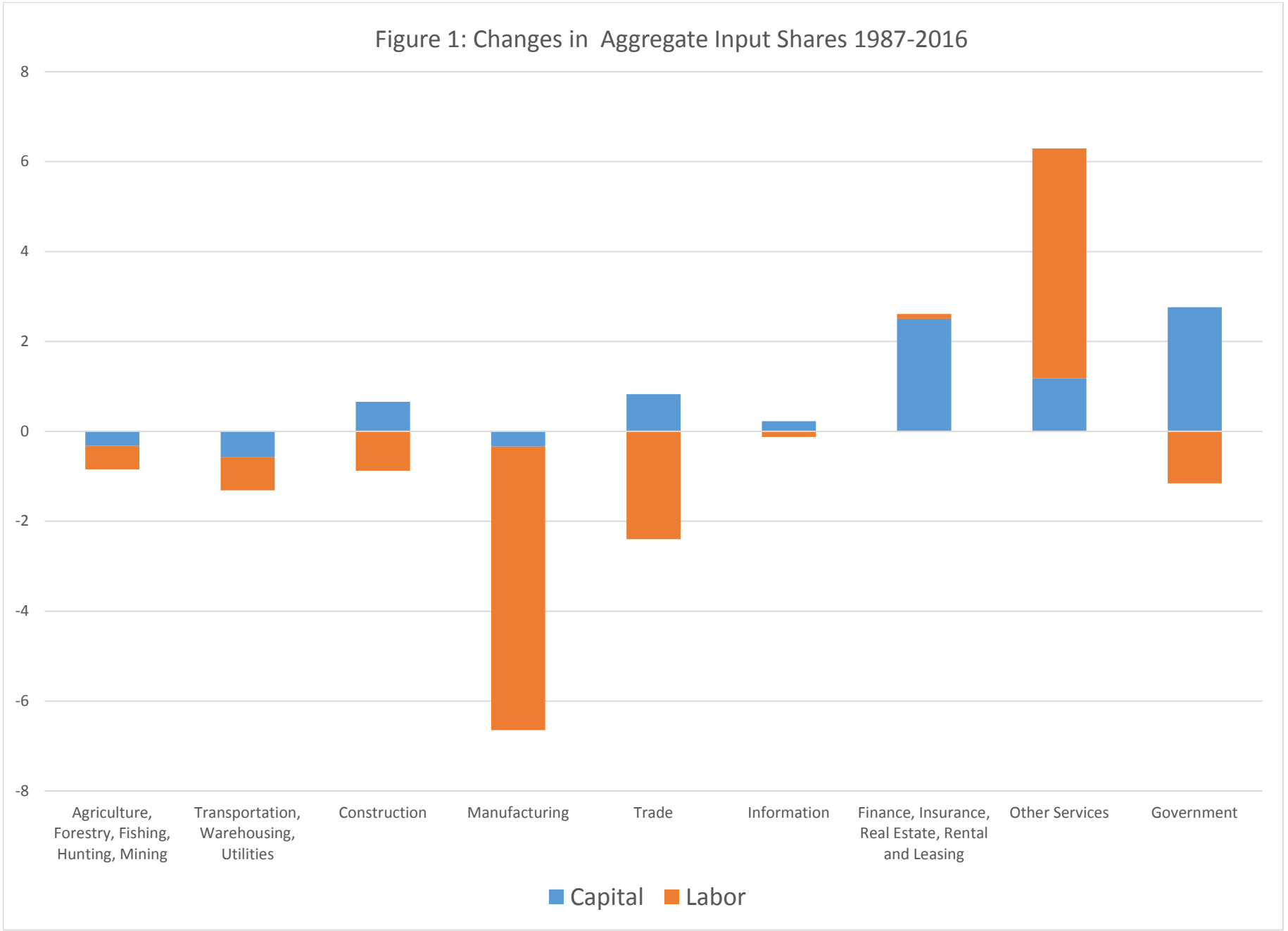
Figure 1: Changes in Aggregate Input Shares 1987-2016
8
6
4
2
0
-2
-4
-6
-8
Agriculture, Forestry, Fishing, Hunting, Mining
Transportation, Warehousing, Utilities
Construction
Manufacturing
Trade
Information
Finance, Insurance, Real Estate, Rental and Leasing
Other Services
Government
Capital
Labor

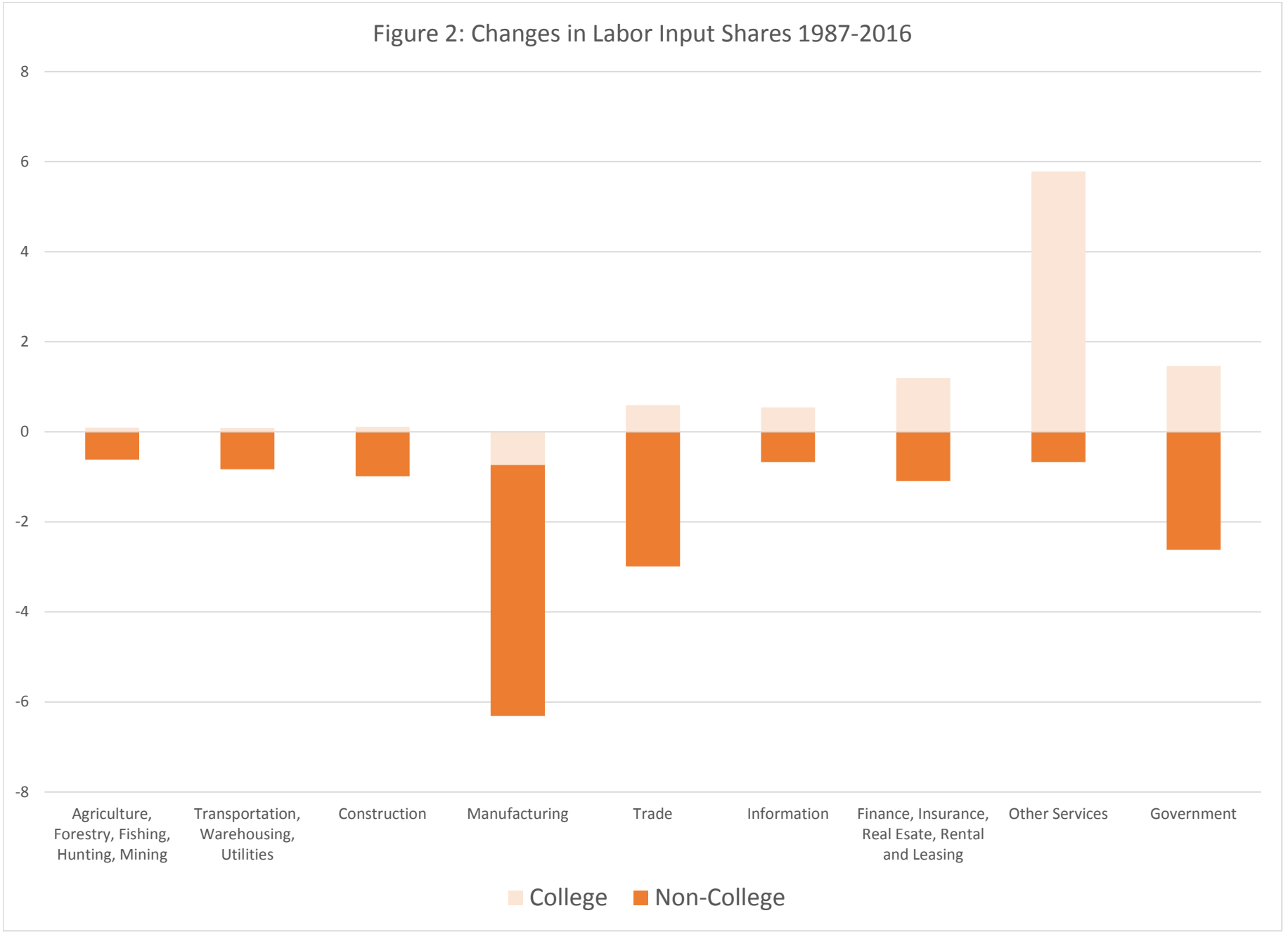
Figure 2: Changes in Labor Input Shares 1987-2016
8
6
4
2
0
-2
-4
-6
-8
Agriculture, Forestry, Fishing, Hunting, Mining
Transportation, Warehousing, Utilities
Construction
Manufacturing
Trade
Information
Finance, Insurance, Real Esate, Rental and Leasing
Other Services
Government
College
Non-College

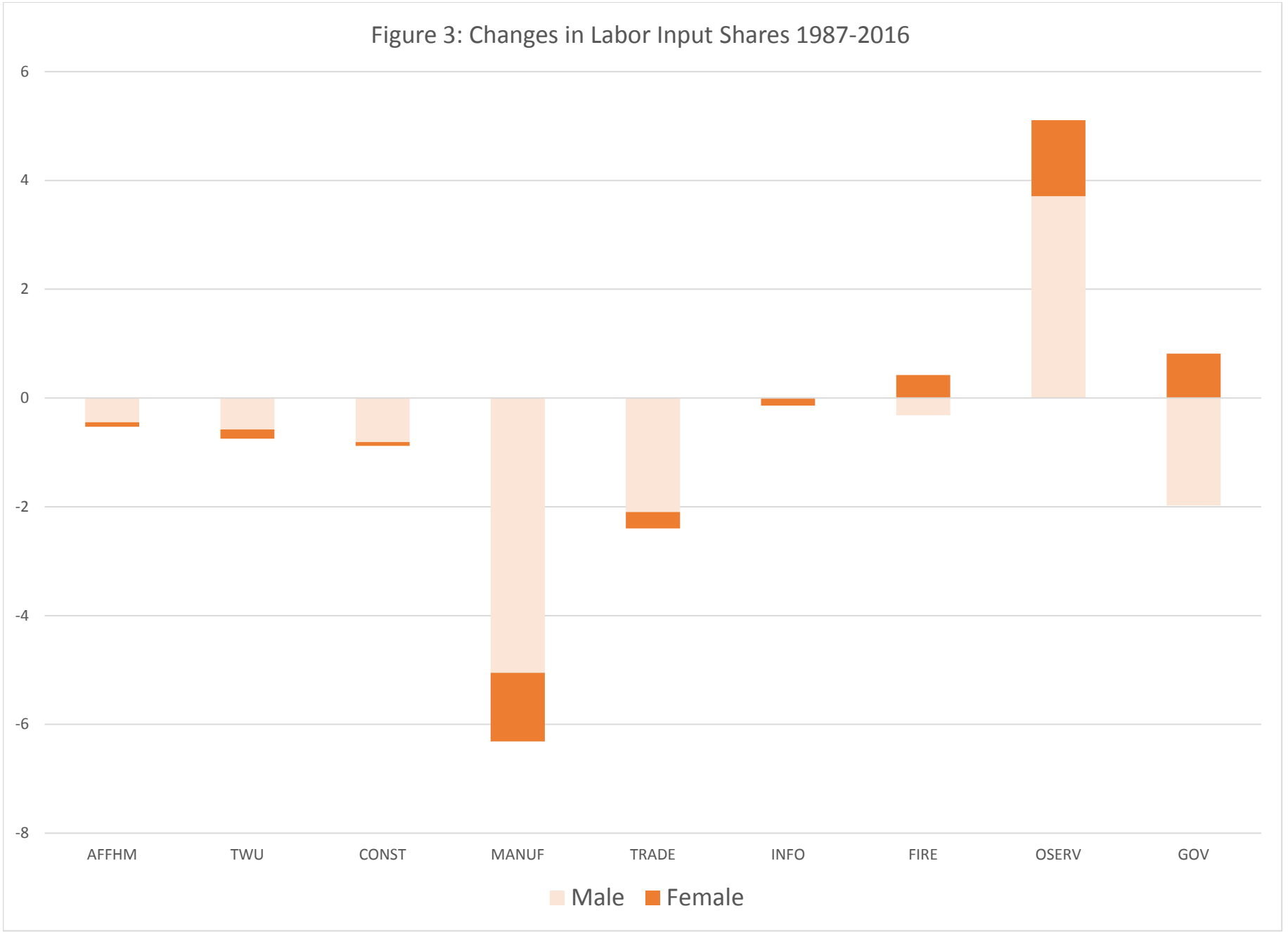
Figure 3: Changes in Labor Input Shares 1987-2016
6
4
2
0
-2
-4
-6
-8
AFFHM
TWU
CONST
MANUF
TRADE
INFO
FIRE
OSERV
GOV
Male
Female

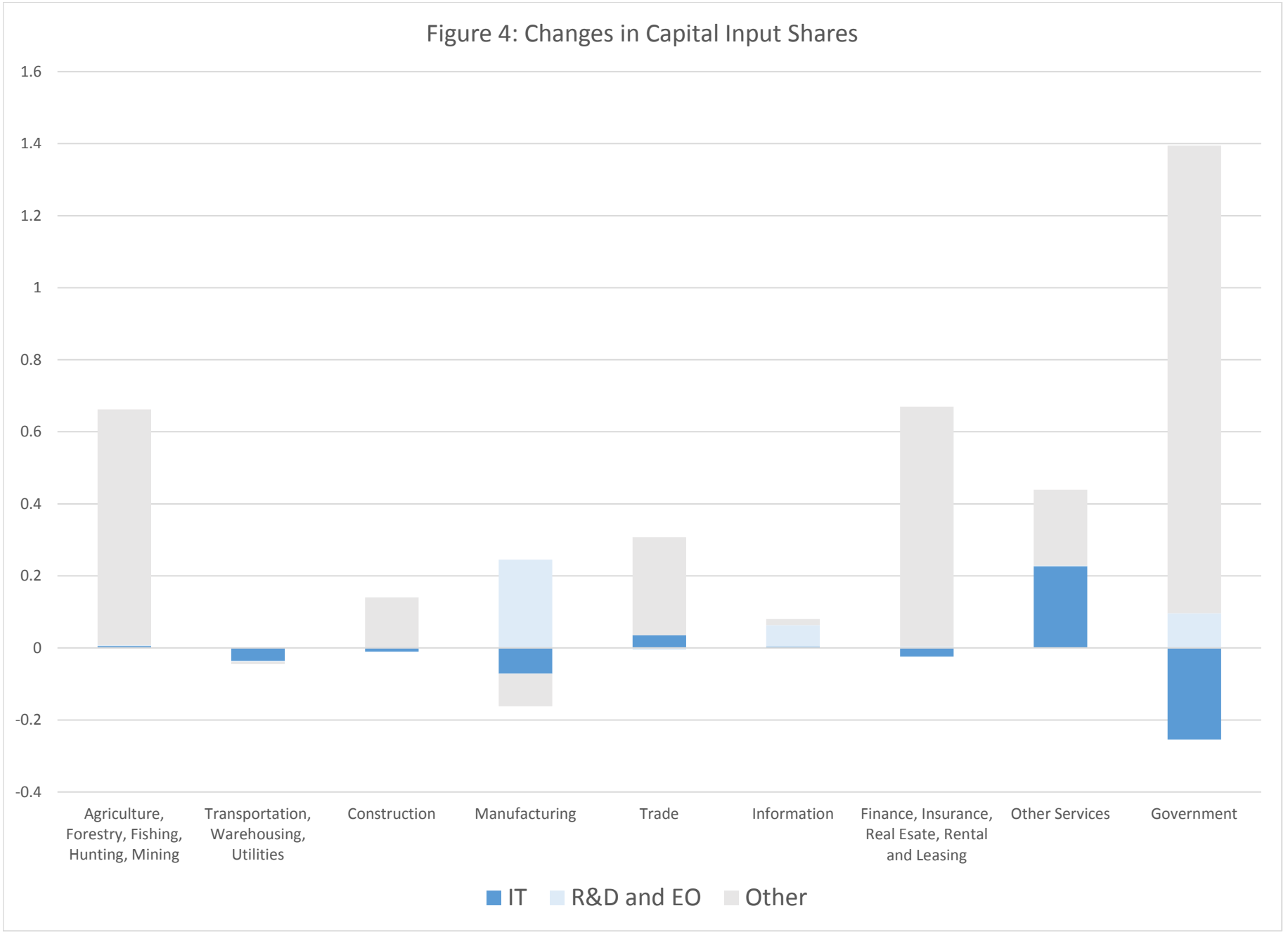
Figure 4: Changes in Capital Input Shares
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Agriculture, Forestry, Fishing, Hunting, Mining
Transportation, Warehousing, Utilities
Construction
Manufacturing
Trade
Information
Finance, Insurance, Real Esate, Rental and Leasing
Other Services
Government
IT
R&D and EO
Other