Toward a BEA-BLS Integrated Industry-level Production Account for 1947-2016

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Abstract

This paper presents new collaborative research work by the BEA and BLS toward an account that covers 1947 to 2016, the entire time span of the GDP by Industry accounts. The prototype estimates that we have constructed reveal that for the past decade and a half, relatively slow input growth (in capital and labor services) has curtailed U.S. economic growth, even relative to the long slump between 1973 and 1995. The low contribution of capital input was concentrated in the Finance, insurance, real estate, rental and leasing and Manufacturing sectors, while the low contribution from labor was spread more equally across sectors.

Keywords: Industry multifactor productivity, industry sources of economic growth, integrated production account, aggregate economic growth, U.S. total factor productivity.

I. Introduction

For students of economic growth, it is important to have complete information on outputs, inputs and productivity across all sectors of the economy. Since 2012, the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS) have maintained a complete integrated industry-level production account for the U.S. that combines output and intermediate inputs data from the BEA GDP by Industry accounts with measures of labor and capital inputs from the BLS Productivity Program. Although agencies throughout the decentralized U.S. statistical system have always worked closely together, this was an innovative effort for BEA and BLS to produce a joint product. The internally-consistent production account includes a complete set of prices and quantities of output produced and inputs consumed by U.S. industries, as well as measures of multifactor productivity (MFP), also referred to as total factor productivity. Because GDP and

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[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. We have written this paper in honor of Dale Jorgenson, whose seminal work on KLEMS measurement has inspired this paper, and whose research agenda on economic measurement and engagement with the U.S. statistical agencies has been an invaluable resource. We are grateful to Matt Calby, Justin Harper, Eugene Njinkeu, and Ethan Schein of BEA and Kendra Asher, Corey Holman, Mike Jadoo, and Randal Kinoshita of BLS for their work on the estimates presented in this paper.

aggregate productivity data begin in 1929 and 1947 respectively, there has been a growing demand to have consistent industry-level data that also span this period. This paper navigates numerous hurdles to extend the BEA/BLS integrated industry-level production accounts over seven decades, from 1947 to 2016.

Dale W. Jorgenson and J. Steven Landefeld (2006) identified an integration of the nation's national accounts and productivity statistics as a high priority of their "new architecture" for the U.S. national accounts.[2] One of the main applications of integrated GDP and productivity statistics is to provide "growth accounting" that is consistent with official GDP accounts. Growth accounting attributes economic growth to its underlying sources across industries and factors of production, including capital, labor, and multifactor productivity. Recently, growth accounting has been applied to identify the role of information technology (as a contributor to aggregate MFP and as a capital input) in economic growth, measure the role of the upgrading of the labor force on economic growth, understand the sources of the slow recovery in the U.S., and for cross country comparisons of why economic growth rates differ. Therefore, having integrated and official statistics is of utmost importance.

In response to customer demand, BEA and BLS developed a conceptual framework for creating an integrated production account in 2006.[3] In 2008, BEA and BLS presented a prototype integrated production account for the private nonfarm business sector that included a reconciliation of the BEA and BLS estimates.[4] The initial focus on the private nonfarm sector was an effort to be consistent with the existing official measures of multifactor productivity produced by BLS. The real output of government, private households, and nonprofit institutions were removed from the output and input sides of the account because direct measures of output are generally not available for these nonmarket sectors.[5] Including nonmarket sectors tends to dampen estimates of aggregate productivity growth because often productivity growth for these sectors is imposed to be zero by construction. Thus, the official multifactor productivity data for the U.S. focus on the private business sector, which constitutes about 74 percent of GDP. Although the initial prototype for the BEA/BLS integrated industry-level production account covered the private nonfarm business sector, the ultimate goal was to have a complete accounting of the entire U.S. economy.[6] Therefore, the BEA/BLS integrated industry-level production account that was released in 2012 covered the entire economy and included data for 63 industries.[7] The completeness of this account allows users to identify sources of growth in output, factor inputs, and productivity at the aggregate level, highlight the performance of individual industries, and identify industry contributions to aggregate output and productivity

[2] This built upon Christensen et al. (1973) research that proposed a set of accounts that incorporate indices of input volume by sector, and Jorgenson et al. (1987) research that extended the accounting system to measures of output by industry.
[3] See Fraumeni et al. (2006) outlined differences in source data and methods that required resolution for a successful account.
[4] See Harper, et al. (2008).
[5] Direct measures of output for government enterprises are available, however subsidies account for a large fraction of government capital income, making it is difficult to estimate reliable measures of capital for the government sector. Capital measures for nonprofit institutions and government are estimated following methodology outlined in Harper et al (2008).
[6] This initial prototype also did not include estimates of labor composition at the industry level.
[7] See Fleck et al. (2014).

growth. This complete account serves as a valuable source of information for assessing the strength of the U.S. economy.[8]

The BEA/BLS integrated industry-level production account originally began with data for 1998 and was based on the North American Industrial Classification System (NAICS). The production account includes data for 63 industries that make up the GDP by Industry data from BEA. The NAICS was adopted in 1997 to replace Standard Industrial Classification system (SIC) to harmonize Canada, Mexico and the U.S. statistical classification systems, as well as account for new and emerging products. To avoid the resource-intensive effort of bridging the SIC/NAICS changes in a consistent manner across all measures of outputs and inputs produced by multiple statistical agencies and to make use of the newly integrated GDP by Industry accounts, the 2012 BEA/BLS integrated production account began with 1998 data. Realizing the value in analyzing past sources of economic growth, BEA and BLS embarked on efforts to extend the dataset back in time. In June 2018, the accounts were extended to include an additional decade of experimental historical data covering 1987-1997.[9] However, because GDP and aggregate productivity data begin in 1929 and 1947 respectively, there was significant demand by data users to have consistent industry-level data that also span this period. Yuskavage (2007) described the conversion of the 1947-1997 Input-Output Tables from an SIC basis to a NAICS basis. That effort has since been extended and integrated with the expenditure side GDP data. This time series of make and use tables is an important component of the integrated industry-level production account that we describe in this paper.

The next section reviews the basic framework for the production account. This is followed by several sections that discuss the construction of the historical data, including necessary estimation assumptions and data limitations. Section III outlines the measures of GDP by Industry and the annual Make and Use Tables that begin in 1947, as well as measures of intermediate inputs of energy, materials and purchased services. Section IV explains the work involve to extend industry-level measures of hours worked back to 1947, and the steps involved in capturing changes in labor composition. Section V presents efforts to create a consistent historical series of capital services at the industry level and explains improvements in the required imputations for capital services in nonmarket industries. Section VI reviews adjustments made to integrate input data with measured output. Sources of growth are presented in Sections VII and VIII. Section IX concludes and provides next steps for the project.

II. Production Account Framework

The purpose of the BEA/BLS integrated industry-level production account is to measure the sources of economic growth from the bottom up. Thus, we start with a description of accounting

[8]MFP growth rates generated from the BEA/BLS integrated production accounts differ from the productivity data published by BLS because BLS excludes non-market sectors and uses a sectoral output concept in the official BLS productivity statistics. Thus, MFP measures from the BEA/BLS integrated accounts presented here will differ from the official MFP measures most noticeably in industries with a high concentration of nonprofit institutions and industries which consume large portions of inputs that are produced within their own industry. Data releases from this BEA/BLS integrated production account typically also include the official productivity data produced by BLS for comparison purposes.

[9] See Garner et al. (2018).

for growth at the industry level. We rely on a long line of literature and begin with the equation that describes the sources of growth of real gross output at the industry level as the weighted sum of the growth in inputs and the growth in multifactor productivity (MFP). For industry j in a given year:

$$\text{(EQN 11.1)}\ \Delta lnQ_j = w_{K_j}\Delta lnK_j + w_{L_j}\Delta lnL_j + w_{E_j}\Delta lnE_j + w_{M_j}\Delta lnM_j + w_{S_j}\Delta lnS_j + \Delta MFP_j$$

where K,L,E,M,S denote capital, labor, energy, materials, and purchased services, and Δ is the difference between periods t and t-1. The growth of KLEMS inputs on the right-hand side and real output on the left-hand side are log growth rates of real constant-quality inputs and output. For each input X, w_x is the associated nominal cost of the input divided by nominal total cost. In discrete time, these cost shares are two-period annual average shares in equation (EQN 11.1), and in the equations below. We assume that the cost shares sum to one. There is a long literature on this assumption and on the relationship between measured MFP growth using (EQN 11.1), and technological change. This discussion is beyond the scope of this paper, but many of the issues are summarized in (OECD, 2001).

In practice, the growth in MFP is unobservable, so it is measured as a residual. MFP growth is the change in output not accounted for by the change in measured inputs. MFP growth is a widely used measure of technological change and innovation and captures quality advances and improvements in the overall production process.

III. Output and Intermediate Inputs including Energy, Materials, and Services

Output and intermediate inputs come directly from the GDP by Industry accounts produced by BEA. BEA's GDP by Industry statistics provide a time series of nominal and real gross output, intermediate 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 GDP by Industry accounts were first released in January 2014, and covered the period 1997-2012. They have subsequently been updated annually and extended to cover the period 1947-2016.

The estimates of intermediate purchases of energy, materials, and services (EMS) that we employ in this paper are new for the 1947-1997 period. That is, while the total intermediate input (price and quantity) by industry is available in the BEA GDP by Industry accounts, information on the price and quantity of energy (E), materials (M), and services (S) for 1947-1997 is not.[10] To describe the approach taken to develop historical energy, materials, and services estimates in this paper, we begin by reviewing the approach taken by (Jorgenson et al. (2005). They constructed EMS by assigning a single energy, materials, or services intermediate input category to each individual commodity within their (44 by 44) Use Table. That is, 100% of the Use Table cell gets allocated to E, M, or S. The commodities within the E, M, S categories are aggregated by industry using Tornqvist indexes. This creates a price and quantity of E, M, and S that is consistent with the

[10] EMS estimates (price and quantity) are available in the GDP by Industry data for 1997 forward.

industry level intermediate input price and quantity. Because the BEA industry accounts have more detailed underlying information than the published Use Tables, we are able to take advantage of this data to make refined assignments to E, M, or S.

In the account we present here, our E, M, S assignment for the 1947-1997 period is related to the method used for 1997 forward in the official GDP by Industry accounts. In the official accounts for 1997 forward, E, M, S assignments are made using the underlying Use Table at the "working level." 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 directly assign each cell in the use matrix to an E, M, S category (that is, for each detailed commodity and each industry). For 1947-1997, "working level" information is not available, and only information at the "summary level" is available. The "summary level" includes a Use Table on the order of about 63 commodities and 63 industries.

The methodology that we use in this paper for 1947-1996 allows us to deviate from the assumption that the entire cell of the Use Table published at the summary level gets allocated to a single E, M, or S category. In particular, we assign Use Table cells between 1947 and 1996 using cell-specific E, M, and S ratios at the summary level (but based on "working level") table in 1997. To be clear, we *are not* using industry-level E, M, S ratios in 1997 and bringing these all the way back in time to 1947. We *are* assuming that within a particular cell of the use table, the same E, M, S ratio holds in 1947 as in 1997. For example, suppose that the working level table in 1997 allows us to estimate that at the summary level 90% of the Oil and gas extraction commodity purchased by the Farm industry was Energy and 10% was Services (like installation services). In our historical data between 1947 and 1997, we assume that this same 90%-10% split applies to purchases of Oil and gas by the Farm industry. We reproduce this methodology for every cell in the Use Table, allowing us to improve on the assumption that 100% of the Oil and gas by the Farm industry is an Energy purchase, and ensuring consistency with the data from 1997 forward that underlies the official EMS estimates in the GDP by Industry accounts.[11]

An alternative way to gain intuition for our approach is that we basically assign each cell in the 1947-1996 Use Table to an E, M, S category, just as in Jorgenson et al. and just as we do at the "working level" in the 1997-2016. But, then we further divide the cells to allow a portion of each cell to be reapportioned as in the 1997 detailed data. While we think that this is an improvement over previous studies that assigned each cell of the use table at the summary level in its entirety to an E, M, S category, we do note that this assumes that *within* each cell of the summary-level use table, there was no structural change across E, M, and S categories between 1947 and 1996. Of course, our method does capture structural change in energy, materials, and services *across* cells in the use table. For example, if the Farm industry has a higher cost share of Oil and gas in 1947 than in 1997, the overall energy share in Farms would be higher in 1947 than in 1997, assuming similar structures for the other intermediate inputs. In summary, this dataset provides the estimates of gross output, and intermediate inputs in current and constant dollars, including energy, materials, and purchased services that we use to implement equation (EQN 11.1).

[11] We apply the same price deflator to E, M, and S at the cell level, ensuring that our E, M, and S splits do not impact the GDP by Industry estimates via double deflation.

We note that the framework described in equation (EQN 11.1) is based on the concept of industry gross output that underlies BEA's GDP by Industry accounts. The official BLS MFP measures are based on the concept of sectoral output. Sectoral output is equal to gross output less only those intermediate inputs that are produced within that industry or sector; intermediate inputs used in production from outside the industry are not removed. Thus, sectoral output represents the value of output leaving the sector or industry. For detailed industries, sectoral output is very close to gross output because very few industry outputs are used as intermediate inputs in the same industry.

IV. Labor Input

The measure of labor input that we use accounts for both the change in hours worked by industry, as well as the change in the composition of industry workers. Measuring labor composition is important because an improvement in the composition of the workforce, for example due to a higher level of educational attainment, represents movement along the production function, not a shift in the production function. If labor composition was not accounted for in the measure of labor input, the contribution of MFP would be confounded with contributions from changes in the characteristics of the workforce. The BLS productivity program regularly publishes measures of hours worked and labor composition for NIPA level industries from 1987 forward.[12] The next two subsections divide the discussion of labor input into hours worked and labor composition.

Hours Worked

Measures of hours worked are developed by the BLS primarily using data on employment and average weekly hours from the BLS Current Employment Statistics (CES) program and supplemented with data from the Current Populations survey (CPS) and the National Compensation Survey (NCS).[13] Hours worked for employees are calculated as the product of employment and average weekly hours paid and adjusted to remove paid leave using an adjustment ratio of hours worked to hours paid. We want to capture the total hours actually worked and available for production activities. Hours worked for the self-employed are estimated directly from the CPS. The earliest hours series for sub-aggregates of the economy published by BLS begin in 1964 and cover 13 economic sectors.[14] The data become more detailed in 1979 when wholesale trade, retail trade, transportation and warehousing and utilities are available as individual industry groups. Complete 4-digit NAICS industry coverage begins in 1990. To estimate the historical series of hours worked for employees, components of employment and an adjustment ratio of hours worked to hours paid are created separately.

The CES began collecting data on employment for all workers and hours for production workers in 1947 with the primary interest in understanding the goods-producing economy. Therefore,

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[12] https://www.bls.gov/mfp/ Accessed December 1, 2018.
[13] BLS Handbook of Methods: Industry Productivity Measures, https://www.bls.gov/opub/hom/inp/pdf/inp.pdf Accessed December 1, 2018.
[14] Natural resources, construction, durable and nondurable manufacturing, transportation, trade and utilities, information, financial activities, professional business services, education and health, leisure and hospitality, other services, and government. See nonfarm hours in table "U.S. Nonfarm Economy by Sector - employees only" and farm data in "Total U.S. Economy - all workers" at bls.gov/lpc

employment and hours data beginning in 1947 only cover durable and nondurable manufacturing, mining, construction, the aggregate service sector, and a few select industries. Coverage of employment expanded in 1958, and additional hours became available in 1964. CES employment data for most 3-digit SIC sub-sectors begin in 1972 with continual expansion in service-producing industries through 1990. To fill in the industry gaps in earlier years, data for the first available year that an industry is published is used to determine an industry's size relative to its next larger available parent sector and this share is held constant going back in time.[15] To estimate hours a similar approach is taken, using the available production worker hours and assuming that nonproduction and production workers work similar average weekly hours in a given industry.[16] The historical CES hours-paid data by industry are converted to an hours worked basis using adjustment ratios for 14 major industry group available from the BLS productivity program beginning with data for 1947.[17]

The CPS are the primary data to estimate hours worked for self-employed workers, and are used beginning in 1979.[18] Prior to 1979, data are available for a more aggregate set of 10 SIC sectors back to 1947. To create the more detailed industry data it is assumed that the distribution of self-employed workers within each sector is similar to the all employee distribution of workers. These data are scaled to be consistent with more aggregate measures currently published.

The data on hours for both employees and self-employed are converted from SIC 1987 to NAICS 2002 using SIC to NAICS CES conversion ratios then converted where necessary using CES NAICS 2002 to NAICS 2007 conversion ratios. The BEA National Income and Product Accounts contain NAICS industry employment and hours data for some industries back to 1947, with the level of industry detail improving over time. We convert these data to NAICS 2007, using the CES bridge ratios as well as NAICS 1997 to NAICS 2002 conversion ratios from the Economic Census Core Business Statistics. For consistency with output measures from BEA, the BLS data are scaled to these NIPA measures.

Labor Composition

Measures of hours worked treat every hour the same regardless of the worker's experience and education. Labor composition measures account for the effect of shifts in the age, education, and gender composition of the work force on the efficacy of labor for use in production. Growth in labor input in the production framework can be decomposed into the growth in hours and the

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[15] This is a limiting assumption as industries may not have existed or could be expanding so that their historic importance is overstated. However, this is the only data available. This is done for total number of employees, production workers, and production worker hours

[16] Measures of hours for nonproduction workers for 1987 forward use data from the CPS to more accurately capture hours worked. See Eldridge et al. (2004).

[17] Data for 1996 forward use hours worked to hours paid ratios based on the Employment Cost Index (ECI) of the National Compensation Survey. See https://www.bls.gov/lpc/lprhws/lprhwhp.pdf Accessed December 1, 2018. Hours worked to hours paid adjustments use data from the BLS Hours at Work survey for 1982-1996 and data on leave practices that were collected from Employer Expenditure surveys. These surveys begin in 1952 and were conducted periodically and only covered major industry groups

[18] Respondents are assigned to a class of worker based on their primary job from 1979-1993; class of worker is collected for primary and secondary jobs beginning in 1994. Data for 1987 are published by industry the BLS productivity program; Data from 1979 – 1987 are controlled to published BEA estimates.

growth in labor composition, which accounts for changes in the demographic composition of the labor force.

Equation (EQN 11.2) defines our measure of labor input that accounts for labor composition.

(EQN 11.2) $$\Delta lnL_j = \sum_i (s_{i,j}) \times \Delta lnHours_{i,j}$$

Where $s_{i,j}$ represents the two period average share of total compensation earned by worker type *i* within industry j. It is the *i* worker types, with specific gender, age and education groupings, that allow for changes in labor composition to impact the measure of labor input. Intuition for weighting by $s_{i,j}$ can be gained under the assumption that rates of labor compensation correspond to the marginal products of workers. Under this assumption, an hour worked by a (gender, age, education) group of workers is up-weighted if the marginal product of the group is high relative to other groups, and down-weighted if the group has a relatively low marginal product. Thus, a shift to workers of a higher "quality" would manifest as an increase in labor input, even if total hours worked in the economy remained fixed. Alternatively, if all worker types were the same and received the same wage, labor input growth would correspond to the growth rate in hours worked.

For this paper, for the years 1987-2016, workers are disaggregated by sex, eight age groups, six education groups, and employment class (payrolled vs. self-employed) for a total of 192 demographic categories. The estimation process begins by filling out information on employment, hours, and compensation for each demographic category of worker in each of the 63 industries, creating a 12,096 cell matrix for each year. 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. 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).

In preparing the 1987-1997 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 to go between SIC and NAICS were supplied by the

Federal Reserve Board based on research from Bayard and Klimek (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.

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. With this dataset, we are able to implement equation (EQN 11.2): $HOURS_{i,j,t}$ is the hours worked by worker type i in industry j and $s_{i,j,t}$ is worker type i's share in total labor compensation in industry j.[19]

The growth rate in labor composition for 1987-2016 is defined as the difference between the growth rate of labor input described above and the growth rate of hours worked (EQN 11.3):

$$\text{(EQN 11.3)} \qquad \Delta \ln Labor\ Composition_j \equiv \Delta lnL_j - \Delta lnHours_j$$

Because this same measure of labor composition is not available for 1947-1986, we take the labor composition growth estimates reported in Jorgenson, Ho, and Samuels (2018) and add this to the hours growth estimates based on the hours dataset described above to arrive at labor input measures. The method and data sources used to estimate labor composition in Jorgenson, Ho, and Samuels (2018) closely correspond to the methods used in this paper, so that historical data can be easily linked to the 1987-2016 time series. The labor share in gross output is taken from

[19] Additional information concerning data sources and methods of measuring labor composition can be found in Zoghi (2010).

this dataset as well. The BLS has also constructed labor composition measures from 1976-2016 using the monthly CPS data and BEA/BLS will work toward incorporating these measures into this integrated account in the future.

V. Capital inputs

Capital services data are from the multifactor productivity statistics produced by the BLS. The estimate of capital services are produced by first estimating the productive capital stock and then estimating the rental price of capital. The productive capital stock is measured as the sum of past investments net of deterioration and are constructed by BLS as vintage aggregates of real historical investments by U.S. industries using the perpetual inventory method (Fleck et al. 2014). Economic theory dictates aggregating the different capital stocks of assets by using the marginal product of each asset to estimate industry capital input measures. A profit-maximizing firm will accumulate capital up to the point at which its marginal product equals what it would have to pay to obtain the capital service. However, due to firms owning their capital, there is not a clear way to measure these marginal products from observable transactions. Thus, an implicit rental price, or user cost of capital, must be calculated for each asset within an industry. Vintage aggregation provides a mechanism to combine the value of various types and vintages of capital stocks over time into a single capital service measure using capital rental prices as weights.

Since some capital assets, such as railroad structures, can last up to 90 years, these vintage aggregations require a sizable amount of investment data over an extended period of time. With the previous release of the BEA/BLS integrated production account, historical vintages of real investment data needed to be made to compute capital service measures by industry. This investment data go back as far as the BEA fixed asset data- 1901 and a measure of productive capital stocks were generated for each of the roughly 100 assets in the capital service measure (Fleck et al. 2014). Because of the need to account for all previous investments, historical stocks covering 1947–2016 for equipment, structures and intangibles had previously been computed for past releases of the integrated BEA/BLS accounts. However, since inventory and land estimates are non-depreciable, vintage aggregation was not required to estimate those asset pieces. Hence, the historical stocks of inventories and land were not readily available from our previous iterations of the BEA/BLS integrated account. Stocks for these assets for 1947-1986 were estimated for the first time for this paper, as are 1947-1986 estimates of capital services for federal and state and local governments.

Estimating Inventory Stocks

Inventories consist of finished goods, work-in-process, and materials and services. They are the stock of goods held in reserve that are intended to be sold (finished goods) or transformed into finished goods (work-in-process or materials and supplies). Stock of inventories are considered to provide capital services because they represent both an input into the production process and an opportunity cost to the firm. Industry market value of inventories is reported annually in the BEA National Income and Product Accounts. This data is used to calculate capital stocks directly, because inventories are considered to be non-depreciable assets and thus vintage aggregation is not necessary.

Data on industry investment in inventories is provided quarterly in the BEA National Income and Product Accounts. For all NIPA manufacturing industries, data is available by stage of processing (finished goods, work-in-process and materials and supplies) starting in 1996. For nonmanufacturing industries, quarterly total inventories is available at the aggregate levels of Farm, Mining-Utilities-Construction, Manufacturing, Wholesale Trade, Retail Trade and All Other sectors. For currently published measures, BLS annualizes the quarterly BEA data, using converted SIC 1987-1996 data to create a full 1987-2016 time series. BLS then uses inventory investment data for each industry from the IRS to break out the aggregate nonmanufacturing sectors to the NIPA industry detail.

The differences between the SIC 1972 and 1987 classifications for Farm, Manufacturing, Wholesale Trade, Retail Trade and "All Other" aggregate sectors is negligible. Therefore, the quarterly inventory series were linked together using the latest definition on a level basis to obtain a series for 1947-1986.

A three step process to convert these data to a NAICS 2007 basis was used. Historical SIC data was converted to a NAICS 1997 basis by moving a piece out of manufacturing and into the "Other" sector to better align with the NAICS 1997 treatment of auxiliaries in the NAICS definition. The NAICS 1997-based inventory data for Farm, Mining-Utilities-Construction, Wholesale Trade, Retail Trade and All Other sectors were linked to the BLS 1987-2016 time series. This rudimentary assumption holds that at the aggregate sector, the differences introduced by the 2002 NAICS were not significantly different from the 1997 NAICS definition at this level of detail. The final step is to break out the aggregate sector data to the NIPA industry detailed level for the nonmanufacturing industries. For the 1947-1986 period, BLS used the 1997 ratios of IRS industry inventory investment for each year to distribute the detailed industries from the aggregate.

For industries within the manufacturing sector, we were able to take advantage of historical SIC inventory investment by stage of processing that is available for 1967-1986. To complete the time series, manufacturing total inventories for 1947-1966 were distributed by using the share of finished goods, work-in-process, and materials and supplies to total manufacturing in 1967. BLS then converted this SIC data to NAICS and linked it to its previous 1987-2016 estimates.

Estimating Land Stocks

As with inventories, land is not considered to have efficiency decline and thus vintage aggregation of the land stocks was not necessary for previous versions of the integrated account. For all nonfarm industries, land is estimated by applying a land-structure ratio based on unpublished estimates by the BLS to the value of structures. These ratios are based on data from 2001 for all counties in Ohio. Farm land stock is based on data from the Economic Research Service of the U.S. Department of Agriculture and is available for 1960-forward. For 1947-1959, the change in farm land value from 1961-1960 is applied.

Historical Capital Rental Prices

Capital rental prices equal the price of an asset multiplied by the sum of the rate of depreciation and the appropriate rate of return on the asset, accounting for both inflation and taxes. Because rental prices are computed separately for each asset category × industry combination, they have significant data requirements. Income components from BEA's GDP-by-Industry data play an integral role in calculating the rental price for each of the 63 industries.

With the release of the historical Input Output Tables, BEA published a time series of GDP by Industry data for all 63 industries back to 1947 on a NAICS 2007-basis. Additionally, the major components of value added were published beginning in 1987. Some of the underlying estimates of these data are also published on a NAICS-2007 basis starting in 1998.[20]

Of the 18 income pieces needed for the rental price computation, 13 are available in BEA's Historical SIC GDP-by-Industry dataset on a SIC 1972 basis. BLS converted these data to a NAICS 2007-basis to ensure that the data going into the BEA/BLS integrated production account would be consistent. The process for estimating these data is a four step process similar to that of the earlier work accomplished by the BEA in recoding their SIC National Income and Product Account data back to 1947.[21]

First, each detailed income component from the GDP-by-Industry data was converted to a NAICS 1997-basis by using the variable SIC 1972 to NAICS 1997 bridge previously used by BEA to convert the Input Output tables to a NAICS 1997 basis. This bridge was first used to publish NAICS-based GDP-by-Industry data that were released in December of 2005 and this bridge serves as the beginning point for the Integrated BEA/BLS production account value added conversion to a NAICS basis.[22] This work provided annual conversion ratios for 1978-1986 but due to limited data availability these ratios are held fixed prior to 1978. Future work will hope to add more information from which to pick up a bridge reflecting the changing industry dynamics from the 1947-1978 period.

Second, the NAICS 1997-based data were then converted to NAICS 2002 using historical data used in previous conversions by the BEA to move estimates to a more current NAICS definition during a comprehensive revision. These bridge ratios were provided to BLS to keep the consistency of the income conversions with the other statistics that BEA had already transitioned. BLS currently uses historical NAICS 2002-based data to create a complete time series of the GDP by Industry income components not published prior to 1998. This NAICS 2002-based data is converted to NAICS 2007 by using conversion ratios based off of the rate of change in the NAICS 2002 to NAICS 2007-based gross operating surplus for each industry for 1987-1997. The historical 1947-1986 GOS data, were linked to the 2002 basis using the overlapping 1987 (NAICS 1997) and 1987(NAICS 2002) gross operating surplus data. We linked that series onto the NAICS 2007 based GOS published estimates in 1998.

After initial conversion of the pieces of value added from 1947-1986 the fourth and final step of the process was to scale the value added components, GOS, employee compensation, and taxes on production and imports to ensure consistency with value added so that each sub component

[20] BEA chose not to convert the major components of value-added prior to 1987 due to limited SIC data in the 1947-1986 period and data validity concerns. See Yuskavage, (2007).
[21] See Garner et al. (2018).
[22] See Yuskavage, Robert E and Mahnaz Fahim-Nader (2005).

added up to the aggregate in an integrated and robust way. These adjustment ratios were minor, averaging around 1% across all years and industries.

The last two components needed to compute our rental prices are motor vehicle licenses taxes and property taxes. These data are available at the total economy level and are on a NAICS 2007 basis for the full time series. We used each industry's share of value added to the total economy in 1987 to break out the national tax data to an industry level for 1947-1986.

Estimating Capital Services for Government

BLS measures of capital services for government are an aggregation of equipment, structure and land stock. Capital stocks of equipment and land are derived from BEA government consumption of fixed capital, current cost net stock, chain-type quantity stock and current-cost depreciation. All data is available for 1947-2016. Rental prices for each asset category are calculated using the BLS external rate of return for the private nonfarm business sector.

Using the data described above on productive capital stock and rental prices by asset and industry, we construct capital input measures at the industry level by aggregating over assets. This completes our discussion of the estimates of capital input by industry.

VI. Integration Adjustments

Because the data used for this account are produced across statistical agencies and with inconsistent original data sources, a few additional steps were required to produce an account that is integrated with the official GDP by Industry accounts. We describe those details here. The first is that nominal capital services estimates produced by the BLS and the residual capital services estimates based on the GDP by Industry accounts data (calculated as value added less total labor compensation including payments to the self-employed) may be inconsistent because they are produced independently (although with related data). To reconcile these, we keep the nominal value of capital services implicit in the GDP by Industry accounts, and the quantity of capital services estimated by the BLS and make an implicit adjustment to the price of capital services. This yields the capital share and capital input growth rate required to implement equation (EQN 11.1) in a way that is consistent with the GDP by Industry accounts.

The second issue is that labor compensation is not available in the GDP by Industry accounts before 1987. To derive our measure of labor compensation for 1947-1986, we apply the labor share in value added from Jorgenson et al. (2018) to BEA's published industry value added estimates. Capital compensation is calculated as a residual and the implicit prices of labor and capital are adjusted such that the account balances. Future work is under consideration to produce the labor and capital services estimates across agencies so that they hit nominal GDP by Industry as an accounting identity without the need to make integration adjustments.

Our treatment of the government sectors is noteworthy as well. As noted above, BLS's primary focus is on the private business sector. For the purpose of this account an estimate of government land services based on the data sources described in (Jorgenson and Landefeld, 2006) were used. We then reaggregate total government inputs to create a total government inputs in current and constant dollars and this serves as our price and quantity of government output as well. Because we change government output, we adjust real government value added, and thus aggregate value added growth is changed as well. The approach taken to government land is an area for future research.

Our final note here is on the industry level of detail available in this report. From 1963 forward, the official GDP by Industry accounts includes sufficient detail to produce growth accounting estimates for 63 NAICS industries. For 1947-1963, less industry detail is available, and we are constrained in this version of the research to present estimates for only 44 industries. Providing additional industry detail for the 1947-1963 period is another topic for future research.

VII. Industry-level Sources of Growth

Tables 11.1 and 11.2 give the sources of growth at the industry level between 1947 and 2016. Because the output growth numbers have been previously published in the BEA estimates, we focus this write-up on the sources of output growth across industries. The first takeaway is that between 1963 and 2016, the accumulation of inputs (including substitution toward higher quality inputs) accounted for the preponderance of growth for all but seven of the sixty three industries.[23] Specifically, only in the Farms, Primary metals, Textile mills and textile product mills, Apparel and leather and allied products, Computer and electronic products, Petroleum and coal, and Rail transportation industries did growth in MFP account for more than the contribution of input growth. Between 1947 and 1963, six industries had MFP growth that accounted for more than half of output growth: Farms, Support activities for mining, Wood products, Textile mills and textile product mills, Administrative and waste management services, and Arts, entertainment, and recreation.

INSERT TABLE 11.1 HERE
INSERT TABLE 11.2 HERE

At the industry level, the accumulation of capital input was most important in the Rental and leasing services and lessors of intangible assets, Data processing, internet publishing, and other information services, Federal Reserve banks, credit intermediation, and related activities, and Broadcasting and telecommunications industries between 1963 and 2016. Between 1947 and 1963, capital contributed the most to growth in the Rental and leasing services and lessors of intangible assets, Real estate, Information, and Utilities industries. Obviously, information on the sources of growth is useful for classifying intensity of capital used across industries, and this is an important use of this new dataset.

Not surprisingly, the accumulation of labor input made the largest contributions to growth to industries in the service sector. For example, the industries with the largest labor contributions to growth between 1963 and 2016 were the Computer systems design and related services, Social assistance, Ambulatory health care services, and Administrative and support services. Between

[23] This includes industries that had positive MFP growth, but negative output growth, along with industries where MFP growth accounted for more than 50 percent of output growth.

1947 and 1963, State and local government, Health care and social assistance, and Other transportation equipment had the largest labor contributions to industry output growth.

Tables 11.3 and 11.4 present new information on the sources of intermediate input growth across industries. As noted above, this information is new because previously published estimates of intermediate input included the total, while those used in this account include breakdowns on energy, materials, and services. Between 1963 and 2016, the largest users of energy intermediate (measured as the contribution of energy to gross output growth) were Air transportation, Truck transportation, Water transportation, and Utilities industries. The largest users of materials inputs were the Computers and electronic products industry (likely from constant quality semiconductor inputs), Motor vehicles, bodies and trailers, and parts, and Other transportation equipment. The Data processing, internet publishing, and other information services, Securities, commodity contracts, and investments, Funds, trusts, and other financial vehicles, and Administrative and support services industries made extensive use of intermediate inputs of services. Obviously, this data is extremely useful for analyzing production processes across industries.

INSERT TABLE 11.3 HERE
INSERT TABLE 11.4 HERE

Because the tabulations from this account are based on preliminary data, we have chosen to present only the high level results as a proof of concept. Future data development and research will permit a more fundamental analysis on the sources of growth across industries.

VIII. The Sector Origins of Economic Growth

In this section, we describe the sector origins of economic growth using the dataset described above and aggregating over industries. Before moving on to the results, we describe our framework for aggregating across industries. The starting is production possibility frontier model of production described in Jorgenson, Ho, Samuels, and Stiroh (2007).

(EQN 11.4) $$\Delta lnV = \sum_j \gamma_j \Delta lnV_j$$

Equation (EQN 11.4) says that aggregate value added growth, $\Delta \ln V$, in year t is the share weighted growth in industry level real value added growth, $\Delta \ln V_j$, where the weights are the average of period t and t-1 shares of each industry's nominal value added in aggregate nominal value added. Because value added growth is not directly measured, we use the growth accounting identity that the growth of gross output (Q_j) equals the weighted growth of intermediate inputs, (which itself is an aggregate of the energy, material, and service inputs from industry j, and value added (V_j) to back out the growth rate of value added. Rearranging equation (EQN 11.5), which is the growth accounting relationship between gross output, intermediate inputs, and value added, yields equation (EQN 11.6):

(EQN 11.5) $$\Delta lnQ_j = w_{vj}\Delta lnV_j + w_{Ej}\Delta lnE_j + w_{Mj}\Delta lnM_j + w_{Sj}\Delta lnS_j$$

where the weights are the average of period t and t-1 shares of value added and intermediate input factors in nominal gross output.

(EQN 11.6) $$\Delta lnV_j = \frac{\Delta lnQ_j - w_{Ej}\Delta lnE_j - w_{Mj}\Delta lnM_j - w_{Sj}\Delta lnS_j}{w_{vj}}$$

Combining equations (EQN 11.1), and (EQN 11.6) cancels the intermediate inputs of E, M, S such that

(EQN 11.7) $$\Delta lnV_j = \frac{w_{K_{jt}}\Delta lnK_{jt} + w_{L_{jt}}\Delta lnL_{jt} + \Delta lnMFP_j}{w_{vj}}$$

Combining equations (EQN 11.4) and (EQN 11.7) yields the bottom up growth accounting that we use to present results:

(EQN 11.8) $$\Delta lnV = \sum_j \gamma_j \frac{w_{k,j}}{w_{V,j}} \Delta lnK_j + \sum_j \gamma_j \frac{w_{L,j}}{w_{V,j}} \Delta lnL_j + \sum_j \gamma_j \frac{1}{w_{V,j}} \Delta lnMFP_j$$

Equation (EQN 11.8) is the direct aggregation approach to analyzing the sources of growth. That is, we define $\sum \gamma_j \frac{W_{K,j}}{W_{V,j}} \Delta lnK_j$ as the aggregate contribution of capital to aggregate value added growth. Similarly, $\sum \gamma_j \frac{1}{W_{V,j}} \Delta lnMFP_j$ is the contribution of industry j to aggregate value added growth in addition to also being the industry contribution to aggregate MFP growth, where the weights are typically referred to in the literature as "Domar weights."

Table 11.5 presents the bottom up sources of U.S. economic growth for the period as a whole and for major sub-periods. Between 1947 and 2016, GDP grew by slightly more than 3 percentage points per year based on the integrated account. Of this, capital input accumulation accounted for about half of GDP growth, labor input accounted for a bit more than a quarter, and MFP growth a bit less than a quarter of growth. The data that we have described above allows us to decompose the contributions of capital input by type of capital input, and the contribution of labor input by type of worker. Over the period as a whole, Information technology equipment capital accounted for about 15 percent of the total capital input contribution, Research and development capital about 10 percent, and Other capital about seventy percent.[24]

INSERT TABLE 11.5 HERE

[24] IT Equipment includes Computers and Communications equipment. Other capital includes structures, land, and other durable equipment.

The fastest growth sub-period that we consider was the decade between1963-1973, but across all sub-periods (even the Information technology boom between 1995 and 2000), the contribution of MFP growth never exceeded 35 percent of GDP growth.

One important use of this data and framework is to put the post 2000 growth period in historical perspective. Our results show that growth during the period that includes the ongoing recovery from the financial crisis and the jobless growth period in the early 2000s was slow even in comparison to the slow growth period between 1973 and 1995 that preceded the IT investment boom. On average MFP during the 2000-2016 period was actually higher than MFP growth during the 1973-1995 period, putting the current MFP slowdown in historical perspective. Of the approximately 1.10 percentage point difference in GDP growth between the 2000-2016 period and the 1973-1995 period, capital and labor input both contributed about 0.6 points less during the 2000-2016 period than during the 1973-1995 period, highlighting the importance of slow input growth over the last sixteen years.

Tables 11.6 and 11.7 present information on U.S. economic growth from the bottom-up at the major sector level.[25] Table 11.6 includes information that was previously available from BEA's GDP by Industry accounts, while Table 11.7 includes new information on the sources of growth. Starting with Table 11.6, the Manufacturing sector was the largest contributor to growth over the period as a whole; the next largest contributors were the Finance, insurance, real estate, rental and leasing, Other services, and the Trade sectors. It is also instructive to compare the sector sources of the slow growth period after 2000 with the slow growth period between 1973 and 1995. While the slowdown was broad based across sectors, the slowdown in the Manufacturing and Trade sectors accounted from more than half of the slowdown in 2000-2016 relative to 1973-1995.

INSERT TABLE 11.6 HERE
INSERT TABLE 11.7 HERE

The transformation of the economy from Agricultural and Manufacturing toward services is evident in the bottom panel of Table 11.6. In the 1947-1963 period, these two sectors accounted about a third of nominal GDP. In the 2007-2016 period, these sectors accounted for less than fifteen percent of nominal GDP.

The bottom-up sources of growth are given in Table 11.7. As noted earlier, the accumulation of capital input accounted for the majority of economic growth between 1947 and 2016. The largest contributor at the sector level was Finance, insurance, real estate, and rental and leasing, which includes owner occupied housing. The Manufacturing sector also made significant capital investments over the period. The key advantage of the sources of growth framework is that it quantifies the impact of these investments on economic growth in a way that is integrated with the national accounts. While the aggregate results presented in Table 11.5 indicate that a major source of the relatively slow growth in 2000-2016 was the slowdown in the contribution of capital input, Table 11.7 shows the sector origins of this. Of the approximately 0.60 percentage point slowdown in the contribution of capital input, more than half of this was accounted for by

[25] Sector level information is created by aggregating contributions described in equation (6) to the reported sector level.

lower capital contributions in the Finance, insurance, real estate, rental and leasing and Manufacturing sectors.

Labor input was the next largest contributor to economic growth over the period as a whole. The aggregate contribution was driven largely by increases of labor input in the Other services, Government, and Trade sectors. The slowdown in the contribution of labor input in 2000-2016 in comparison to 1973-1995 was slightly larger than the slowdown in the contribution capital input. Unlike capital input, however, the relatively low contribution of labor input was spread more equally across sectors.

MFP growth between 1947 and 2016 accounted slightly over 20 percent of aggregate GDP growth. As noted in the data description, the aggregate MFP estimate embeds the underlying assumption for the government sector that output grows at the rate of input.[26] The Agriculture, Manufacturing, and Trade sectors contributed almost all of aggregate MFP growth. Similar to the other sources of growth, we use the long time series to compare MFP growth during the 2000-2016 period to 1973-1995. Somewhat surprisingly given the recent focus on the productivity slowdown, MFP actually grew faster during 2000-2016 than 1973-1995. Comparing 2007-2016 to 1973-1995, MFP grew slowly in both periods, but slightly faster in 1973-1995. The Trade sector contributed somewhat less to aggregate MFP growth between 2000-2017 than in 1973-1995, while the Information and Finance, insurance, real estate, rental and leasing sectors had marginally higher MFP contributions.

IX. Conclusions and Next Steps

The purpose of this paper has been to present research work toward a BEA-BLS Integrated Industry-level Production Account for 1947-2016. The methods that we have documented in this paper link disparate data sources across the BEA and BLS to create an internally consistent KLEMS production account that is also consistent with the official BEA GDP by Industry accounts back to 1947. As presented, there are many assumptions that are necessary to create the historical data, as industry detail is limited for many of the data series in the early years. That the results reported in this paper are broadly consistent with Jorgenson, Ho, and Samuels, (2018), suggests that the approaches taken in this paper are reasonable. It is important to note that the results presented are not yet official data, however this study provides a proof of concept that an account beginning in 1947 is feasible. These data provide insights on sources of output and productivity growth over a much longer time horizon than was previously available and will be sure to spur important research and further our understanding of the mechanisms underlying economic growth.

To close, a few concrete "next steps" are worth documenting. Firstly, BEA and BLS will continue to analyze industry data for the early years to identify ways to improve the assumptions used to move some of the series back in time. In addition, the labor composition estimates used in this paper are a combination of historical estimates from Jorgenson, Ho, and Samuels, (2018), and BEA estimates for 1987-2016. Yet, BLS produces labor composition estimates that are similar and begin in 1976 using CPS data. Future research is planned to reconcile these estimates

[26] Technically, only MFP growth for the general government sectors is assumed to be zero. For the government enterprise sectors, we use BEA's published output prices.

and move toward a single labor composition estimate. BEA and BLS will also be completing previous work to release the 1987-forward data as a complete time series. Finally, this paper uses reduced industry detail between 1947-1963 due to limited availability of GDP by Industry data from BEA. Future work will investigate the possibility of using the more detailed industry list over the entire time series. Given the work and initial steps presented in this paper, we are optimistic that these are attainable goals.

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