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A Value Chain Approach to Measuring the U.S. Production Structure

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Abstract This paper develops a framework to examine the factor composition embedded in U.S. value added across final demand components by integrating value-added data with Integrated Industry-Level Production Account (KLEMS) statistics. This approach quantifies factor-specific value added within U.S. global value chains (GVCs) using the U.S. Bureau of Economic Analysis' (BEA's) domestic requirements tables and the BEA-BLS Integrated Industry-Level Production Account. The decomposition tracks both direct and indirect factor shares across upstream networks, revealing several patterns across final demand categories: exports are most intensive in research and development (R&D) capital, investment relies heavily on non-college labor, government spending has the highest share of college-educated labor, and consumption is least intensive in R&D and information technology (IT) capital. Moreover, investment, consumption, and government spending all contain notable embedded indirectly imported content, exceeding 5%. Sectoral comparisons highlight structural asymmetries: chemicals have the highest direct R&D intensity, financial services intensively use college-educated labor, and transportation and textiles primarily rely on non-college labor. These divergences highlight how upstream industries differ significantly from final-stage producers in factor intensity.

Keywords Trade in value added, global value chains, input–output analysis, factor decomposition

JEL Code F14, D57, D24, E01, O32, C67

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1. Introduction

Pinning down the production structure for a good or service, or a basket of goods and services, is important in order to understand the origins of economic value, demand for factors of production, and the sources of structural change. Often, the basket of interest is a component of final demand. In the parlance of gross domestic product (GDP) accounting, this means personal consumption expenditures, investment, government expenditures, exports, or imports. The U.S. Bureau of Economic Analysis' (BEA's) GDP by industry accounts and the BEA-BLS Integrated Industry-Level Production Account (ILPA) allow users to analyze the production structure of individual industries or groups of industries. For example, if one wanted to know the labor share of workers with a college degree in the computer and electronics sector, one could pull that information directly from the published accounts. If one wanted to know the labor share of workers with a college degree in the manufacturing sector, one could aggregate over published data and compute this directly.

The points of departure of this paper are threefold. First, we focus on bundles of final demand; this is what appears on the expenditure side of the GDP account, and in the United States, it is the featured measure of GDP. When analysts look for sources of GDP growth, the first stop is usually examining changes to the components of final demand. However, components of final demand are a complicated bundle of commodities that get linked to industry outputs in BEA's underlying Input-Output Accounts. So, our first objective is to focus on the baskets of final demand when studying production technology.[2] In the published GDP accounts, there are actually two estimates of the components of final demand: those that appear in the National Income and Product Accounts (NIPAs) and form the basis of the quarterly and annual expenditure accounts, and those within the input-output and industry accounts. The two are constructed to match, i.e., personal consumption expenditures (PCE) in the use table matches PCE in the NIPA tables, but the categories need to be connected with a "bridge table." Due to the connection with the Input-Output Accounts, we focus on the use table categorization of final demand.

Our second and primary objective, which is applicable to both components of final demand and industries, is that a more complete view of a production structure for a component of final demand (or an industry) should take into account the production structure of upstream

[2] This has the advantage of being a more applicable mapping for macro models. Macro models often represent the economy as C + I + G, where C denotes personal consumption expenditures, I represents private investment, and G captures government spending; however, these are components of final demand, not industry classifications.

intermediate inputs. Consider a commodity like a farm product. According to the ILPA, farm product has no research and development (R&D) capital assets and therefore no associated R&D capital services. However, the farm sector is an intensive user of chemical products, and chemical products are relatively intense in R&D capital services. Thus, one of our objectives is to account for the factor content of upstream intermediate inputs, comparing production structures across bundles. This approach yields estimates of factor content embedded in final demand and is useful for analyzing how the U.S. production structure has changed over time and across bundles. For example, if gross exports are more intensive in R&D inputs than the consumption bundle, this may have implications for macroeconomic policy. Or if investment is more intensive in workers with a college degree than in other bundles, this could have implications for policy around the interaction of investment and labor. Or if particular commodities are more intensive in information technology (IT) than the industry at the final stage of production, then having this information is important for assessing both international competitiveness and maintaining prospects for future economic growth.

Our third motivation is to parse out domestically contributed versus foreign-sourced value added embedded in the components of final demand. The parallel here is with the trade in value-added literature. Embedded in U.S. gross exports is U.S. value added at the source industry, U.S. value added at each upstream producer that contributes intermediate inputs, and foreign value added that is either directly imported as an intermediate input or imported as an intermediate input by an upstream producer. As a result of the burgeoning literature on the interconnections in production, BEA now produces "sources of value" in gross exports, distinguishing between U.S. value added and imported content in gross exports. Because imported content is produced out of the country, this is equivalent to importing value added.[3] Therefore, part of our objective is to identify the role of imported value added in bundles of final demand and see how this compares across components of final demand and over time. Importantly, for the portions contributed by domestic U.S. producers, we trace these contributions back to primary factors of production across the upstream chain.

At the outset, we note that with the results that we present, we are not able to distinguish between demand-driven and supply-driven structural change. The composition within and across bundles may change for supply-related reasons like prices of factors of production or technological change, or for demand-driven reasons like increasing preference for educational services over air

[3] Note that we cannot parse imported value added into value added by country. For example, gross imports of $1 are $1 of imported value added, even though within that $1, $0.50 of value added may be generated in Canada and $0.50 may be generated in Mexico when the gross $1 is recorded as coming from Canada. That is, we don't account for production chains in countries other than the United States and simply account for imported value added regardless of its origin.

transportation.

Keeping this in mind, our results show that the decomposition highlights several clear patterns in how capital and labor are distributed across U.S. value added. First, the value-added share of non-college labor has steadily declined in every component of final demand, and its share has been more volatile than other inputs—implying a greater sensitivity to economic cycles and sectoral shifts. By contrast, software and R&D capital have risen gradually, suggesting a slow but steady move toward more innovation-intensive production.

Looking across final demand categories, exports are the most R&D-intensive. Moreover, government spending exhibits the largest value-added share of college-educated labor, while investment has the largest value-added share of non-college labor. Consumption, on the other hand, has the lowest intensity of IT and R&D capital, due to its limited reliance on innovation inputs.

When comparing direct versus indirect factor shares, the results reveal a significant difference between measures that account for upstream contributions and those that account for final-stage producers. Specifically, direct R&D intensity is the highest in chemicals, college-educated labor is most concentrated in securities and financial services, and non-college labor remains prevalent in transportation and textiles. This contrast underscores the importance of tracking embedded inputs throughout the production network to fully understand how different factors are being used.

The rest of the paper is as follows: Section 2 reviews the literature on factor decompositions and value added, Section 3 outlines the analytical framework and data sources, Section 4 presents empirical results on labor and capital input structures, and Section 5 concludes with implications for structural analysis and future research.

2. Literature Review

This paper integrates two emerging strands of research: trade in value added (TIVA) and the KLEMS literature. The TIVA literature has advanced significantly, with key contributions from BEA and the National Center for Science and Engineering Statistics at the National Science Foundation, offering deeper insights into both domestic industry contributions and imported content.[4] Different from the traditional TIVA analyses, which focus primarily on exports, this study takes a broader approach by examining value-added contributions across all components of final demand.

In the United States, the long line of literature has led to BEA and the U.S. Bureau of Labor Statistics (BLS) collaborating to publish official statistics.[5] In relation to this body of work, we adopt the methodology proposed by Samuels [2022], which constructs an industry-level KLEMS production account to reallocate outputs and inputs to their secondary industries to align commodity trade with industry production.

Building on existing literature, our approach aligns closely with Timmer et al. [2014], which assesses the labor and capital content of the manufacturing sector using the World Input-Output Database. We expand this approach by examining the components of final demand rather than concentrating solely on the manufacturing sector. Furthermore, while Timmer et al. [2014] derives capital value added as a residual, we utilize the U.S. KLEMS database to directly measure the value-added shares of labor and disaggregated capital types like R&D and IT capital.

3. Methodology

Our methodology is an extension of standard single-country TIVA decompositions. At its core, we split the value added contributed across all domestic producers into factors of production required to produce each good or service, and then sum these over the value chain. Each producer assembles output using primary factors of production and intermediate inputs, some of which may be imported. Finally, some imports may be direct to personal consumption expenditures, investment, or government spending.

We start with the now-standard decomposition of gross exports to value-added exports. Following the notation in BEA's "Mathematical Derivation of the Domestic Requirements Tables for Input-Output Analysis" BEA [2023], we begin with the following variables that are directly

[4]For a detailed discussion, see Chute et al. [2023]. The research on TIVA has expanded significantly, with contributions from academic scholars and major international institutions. To name a few, Johnson and Noguera [2012] used input–output and bilateral trade data to compute the value added content of bilateral trade, and Koopman et al. [2014] developed a framework to trace domestic and foreign value-added in gross exports. In addition, the OECD and WTO have jointly developed the TIVA database OECD and WTO [2021], with detailed guidance provided in OECD [2023], while the World Bank has contributed through the edited volume by Mattoo et al. [2013].

[5]For further details, see Garner et al. [2021].

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e_f: an i x 1 vector of final demand commodities

g: an i x 1 vector of industry output

D: an i x i market share matrix

B_D: an i x i domestic requirements table

BEA explains (under standard input-output modeling assumptions) how the industry-level domestic output required to satisfy a given bundle of final demand can be derived using the domestic requirements table and the market share matrix in the following expression:

$$g = D(I - B_D D)^{-1} e_f$$

That is, given a bundle of items in final demand e_f, the vector g represents the output by each domestic industry required to produce that bundle. This derivation is conditional on the industry input-output relationships, including the fact that some industries produce multiple commodities. It is important to emphasize here that B_D is the domestic requirements table. It accounts for *domestic* production by recognizing that some intermediate inputs may be imported. If intermediate inputs are imported, these are accounted for in the import-use table. But for the purposes of this paper, we focus exclusively on identifying the domestic production associated with each bundle of final demand. The remainder is the imported value added.

BEA identifies value added embedded in gross exports via the following equation:

$$VA_X = \widehat{V} D(I - B_D D)^{-1} e_X \tag{1}$$

This decomposition works as follows. The term $D(I - B_D D)^{-1} e_X$ is the measure of industry gross output required to produce the export bundle. e_X comes straight from the published BEA use table.[6] Premultiplying this output vector by a diagonal matrix of value-added shares $\widehat{V}$ (a

[6] There are some nuisance cases where a commodity within a bundle is of opposite sign. These happen for technical reasons discussed in BEA's documentation. For ease, we set these to zero.

jxj matrix with the nominal value-added share of industry output in each industry) yields the associated value added by each industry for the export bundle. Because this is a single-country model and data, it does not account for multiple rounds of production across international borders. For example, there is no way to measure the U.S. content that may be embedded in imports if a U.S. part was exported to produce a final good that is then imported into the United States.

Our extension to the basic method recognizes that value added encompasses payments to factors of production. Under the assumptions of the BEA-BLS Integrated Industry-Level Production Account, value added reflects payments to capital and labor, that is, zero net pure economic profit.[7] In the published ILPA account, five types of capital and two components of labor are published, even though the account itself is built up from a finer level of detail. In the equations, we refer to each type of labor or capital as type k, where $k = 7$. The two types of labor include workers with and without a bachelor's degree (which we call college and non-college workers). The five types of capital include IT, R&D capital, software, entertainment original, and "other capital." Other capital includes instruments, structures, land, inventories, transportation equipment, and "other equipment."

We augment Equation 1 by imposing the accounting identity that $\widehat{V} = \sum_k \widehat{V_k}$. That is, the value-added share for each industry is simply the sum of the value-added share of the components of capital and labor services. The intuition for this is simple; labor compensation can be divided into payments to workers with a college degree or above and to workers without a college degree. Obviously, these two shares must sum to the total labor compensation share in value added. This allows us to write for each primary input k:

$$VA_X = \sum_k \widehat{V_k} D(I - B_D D)^{-1} e_X$$
$$VA_{X_k} \equiv \widehat{V_k} D(I - B_D D)^{-1} e_X \qquad (2)$$

The first equation substitutes the sum of the k matrices, each representing the value-added share associated with a distinct primary input. The second equation defines the value-added contribution for input k as the product of its share in gross output and the domestic industry output required to produce the export bundle e_X. Since the k matrices sum to the original $\widehat{V}$ matrix, the primary input contributions add up to the total U.S. value added embedded in

[7] In the latest update to the ILPA, net taxes on product are removed from value added. For this version of the paper, we use a version of the ILPA that implicitly assigns all taxes as a payment to capital input. A next step is to update the calculations here to reflect the new ILPA data.

gross exports. It is important to note that this approach decomposes only the U.S. value-added contributions. For a bundle like PCE, a portion of the total gross value includes both direct imports of consumption goods and indirect imports of foreign value added via intermediate inputs. In the results below, we provide evidence on how each of these components has evolved.

In addition to this extension, we also apply the same basic approach to analyze the other components of final demand:

e_C: an i x 1 vector of personal consumption expenditures

e_I: an i x 1 vector of gross investment

e_G: an i x 1 vector of government expenditures

e_X: an i x 1 vector of gross exports

e_M: an i x 1 vector of gross imports

For the consumption bundle e_C, we define the domestic value-added contribution of primary input k as: $VA_{C_k} \equiv \widehat{V_k} D(I - B_D D)^{-1} e_C$. This expression captures the domestic contribution of factor k to the gross consumption basket. However, not all components of e_C are produced domestically—some imports enter directly into final demand. To isolate the domestic production component, we define $e_{C,D}$ as the domestic production of the personal consumption basket and construct it as $e_{C,D} = e_C - e_{M,C}$, where $e_{M,C}$ is the import bundle that goes directly to personal consumption expenditures. Accordingly, the decomposition of domestic value added becomes: $VA_{C_k,D} \equiv \widehat{V_k} D(I - B_D D)^{-1} e_{C,D}$. The import vector $e_{M,C}$ is from BEA's import-use matrix, which provides the imports used by each industry by commodity and the imports directly to final demand by commodity. This decomposition is performed analogously for investment (I) and government consumption (G).

A note on e_M: this is imports by commodity. e_M is not domestic production; it is imported goods or services that are purchased by consumers or businesses. When analyzing e_M, we are posing a counterfactual question: *What would the U.S. production structure need to look like to domestically produce a bundle that is currently imported?* We speculate that tracking this over time may offer insight into how the economy would need to evolve to internalize production of currently imported final demand components.

Finally, we compare production structures for commodities by distinguishing between direct and upstream (indirect) contributions to the production structure of the industry for which that commodity is the final stage of production. For example, the final producer of motor vehicles, bodies, trailers, and parts is the motor vehicles, bodies, trailers, and parts industry. The share of primary input k directly contributing to the value added of industry j is referred to as the direct input share, denoted: $VASHR_{k,j}$. This measure captures the proportion of value added attributed to input k within industry j, relative to the total nominal value added of that industry. It is directly tabulated from the ILPA. We compare this to the structure of production that takes into account the upstream producers for all the intermediate inputs that flow into the motor vehicles, bodies and trailers, and parts sector, and the entire value chain embedded in the intermediate inputs of the intermediate producers, etc. We define the indirect value-added share for j as $VASHR_{k,j} = \frac{VA_{X_k,j}}{VA_{X,j}}$. This is the value of an embedded primary input k across all upstream industries contributing to the production of commodity j ($VA_{X_k,j}$) over the total value added across the entire production chain for a given j ($VA_{X,j}$). This formulation weights the primary input value-added shares across all contributors according to each industry's share of contribution in the production of final output j. This produces the same result as tabulating the direct and upstream structure for $1 worth of each commodity j.

4. Results

Table 1 presents the summary statistics for the share of value added created by each type of capital and labor, as well as the share of imports and the imported intermediate inputs for each component of final demand. Moreover, in the final section of the table, we document the hypothetical value-added shares for imported goods, constructed under the assumption that these goods were to be produced domestically in the United States using the U.S. domestic requirements matrix.

Considering the C, I, G, and X components of final demand, on average, college and non-college labor and other capital consistently account for the largest shares of value added among the factors of production. In addition, of the three components analyzed, non-college labor exhibits higher volatility, suggesting that it is particularly sensitive to economic shifts.

Exports have the largest share of value added from R&D compared to other components of final demand, implying a greater reliance on R&D capital in the production process over the entire value chain. Furthermore, under the counterfactual scenario in which imported goods are produced domestically using U.S. production methods, the value-added share of R&D capital inputs would be slightly higher than in the case of exports. The slightly higher R&D share under the counterfactual implies that many imported commodities originate from industries that are relatively R&D-intensive in the U.S. input-output structure, revealing latent R&D demand embedded in global supply chains.

Moreover, exports have the highest share of value added from imported intermediate inputs. This indicates that exports rely more heavily on foreign-sourced components throughout the production process relative to other final-demand categories. Additionally, under the counterfactual scenario in which imported goods are produced domestically using U.S. production methods, the value-added share of imported intermediate inputs would be slightly higher than in the case of exports.

Table 1. Summary of Statistics

Variable	Mean (%)	StdDev (%)	Min (%)	Max (%)
VAKIT$_G$	1.6	0.1	1.4	1.9
VAKRD$_G$	5.6	0.3	5.0	6.2
VAKSoft$_G$	2.1	0.3	1.6	2.7
VAKArt$_G$	0.4	0.0	0.3	0.4
VAKOther$_G$	26.6	2.4	21.5	30.5
VALCol$_G$	32.9	1.2	30.1	35.9
VALNoCol$_G$	22.8	3.4	17.6	29.2
Imports-II$_G$	6.7	0.9	5.5	8.7
Imports$_G$	1.3	0.3	0.9	1.8
VAKIT$_C$	2.1	0.3	1.6	2.8
VAKRD$_C$	2.0	0.2	1.8	2.7
VAKSoft$_C$	2.2	0.5	1.3	2.8
VAKArt$_C$	0.6	0.1	0.4	0.7
VAKOther$_C$	34.3	1.2	32.2	35.9
VALCol$_C$	24.5	1.9	22.1	28.8
VALNoCol$_C$	23.5	2.9	19.8	29.0
Imports-II$_C$	5.6	0.8	4.5	7.3
Imports$_C$	5.3	0.4	4.3	6.0
VAKIT$_X$	2.2	0.5	1.4	3.0
VAKRD$_X$	6.4	0.8	4.8	8.0
VAKSoft$_X$	2.7	0.4	1.7	3.3
VAKArt$_X$	0.8	0.2	0.5	1.0
VAKOther$_X$	26.4	2.5	21.5	29.4
VALCol$_X$	25.1	2.3	21.7	31.3
VALNoCol$_X$	23.4	4.5	17.9	31.1
Imports-II$_X$	13.1	1.5	10.5	16.5
Imports$_X$	0.0	0.0	0.0	0.0
VAKIT$_I$	2.0	0.3	1.5	2.4
VAKRD$_I$	3.5	0.5	2.7	4.5
VAKSoft$_I$	2.3	0.4	1.4	2.7
VAKArt$_I$	0.9	0.2	0.6	1.3
VAKOther$_I$	20.4	1.2	17.2	21.8
VALCol$_I$	25.0	2.6	21.3	30.4
VALNoCol$_I$	27.7	4.2	23.6	35.0
Imports-II$_I$	7.7	0.6	6.7	8.9
Imports$_I$	10.4	1.4	8.4	12.6
VAKIT$_M$	1.4	0.4	0.9	2.1
VAKRD$_M$	7.5	2.0	5.2	11.5
VAKSoft$_M$	2.2	0.3	1.6	2.7
VAKArt$_M$	0.3	0.0	0.2	0.3
VAKOther$_M$	26.3	2.7	22.5	31.9
VALCol$_M$	22.2	2.5	18.6	28.2
VALNoCol$_M$	23.5	4.1	19.2	31.7
Imports-II$_M$	16.5	1.4	14.3	19.6
Imports$_M$	0.0	0.0	0.0	0.0

Next, we compare factors of production with respect to each component of final demand. Specifically, for each final demand component, we first group the demand for domestically produced and imported goods. Next, we disentangle the total value added with respect to the upstream contribution of each domestic factor of production, as well as the imported intermediate goods. This grouping implies that the shares of contribution for domestic factors of production, imported intermediate goods, and imports add up to 1 for each demand component.

Figure 1. Value-Added Share of IT Capital

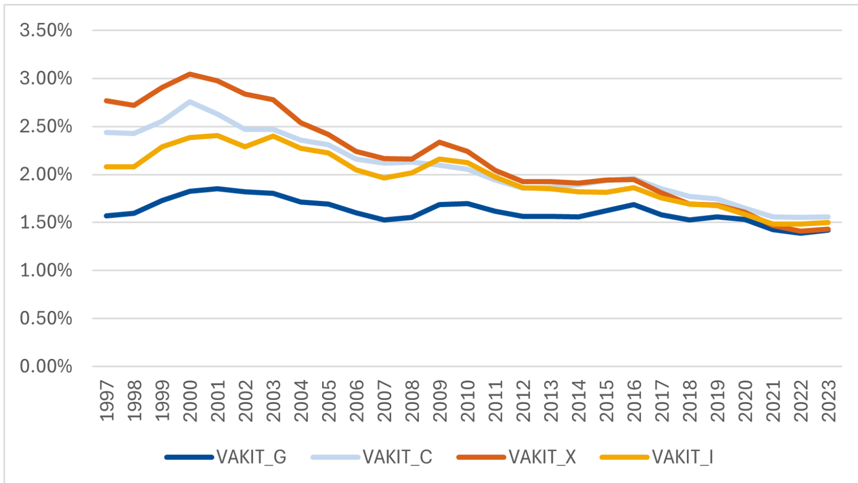


Figure 1 shows the distribution of total IT capital value-added shares, incorporating both direct and upstream contributions, over the period from 1997 to 2023. The IT value-added shares ranged between 1% and 3%, varying across different components of final demand. In the late 1990s, exports held the highest share of IT value-added. However, by the late 2010s, this share had declined and converged with those of consumption and investment. For government expenditures, the IT value-added share remained consistently around 1.5% throughout the entire period. This may be due to the diminishing marginal impact of IT capital on aggregate productivity growth. Specifically, more recent studies, such as Fernald [2015], argue that the productivity gains from the IT revolution of the 1990s have largely plateaued, and that the slowdown in total factor productivity is not due to reduced IT investment, but to the fading of its effects.

Figure 2. Value-Added Share of Software Capital

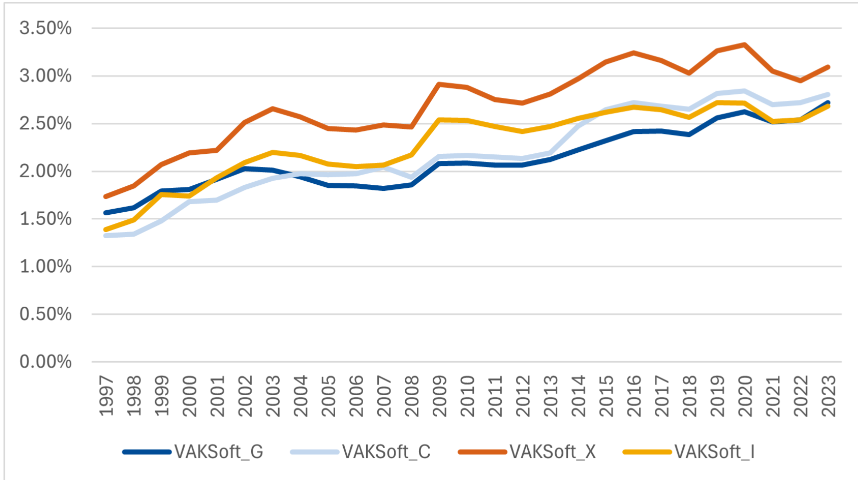


Figure 2 shows an upward trend in the value-added shares of software capital across all components, with exports exhibiting the most pronounced increase. Additionally, during the 2008 Great Recession, the software value-added share rose across all components. This pattern is in line with the findings of Corrado et al. [2009], who argue that software capital—alongside other intangible assets—has become an increasingly important contributor to U.S. economic growth as national accounts have started to treat it as a capital investment rather than an intermediate input.

Figure 3. Value-Added Share of R&D Capital

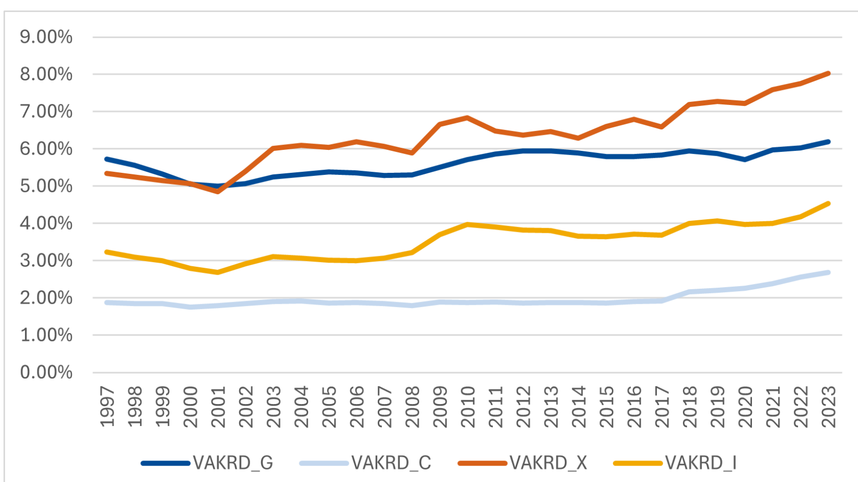


Figure 3 presents the share of upstream R&D value added. In the early years of the sample, exports and government spending had the highest share of R&D value added. However, while the R&D share declined and then rebounded only to the initial levels over time for government, this share increased for exports. The R&D value-added share in investment spending followed a similar pattern to exports, rising over the past two decades.

During the 2001 and 2008 recessions, the R&D value-added share declined for both exports and investments but rebounded during periods of economic recovery. Consistent with existing literature on R&D cyclicality,[8] Figure 3 suggests that this fluctuation is primarily driven by the export and investment components of final demand, whereas consumption and government spending exhibit minimal variation in their R&D share. Finally, consumption expenditures maintain the lowest R&D value-added share, remaining relatively stable throughout the sample period.

Figure 4. Value-Added Share of College Degree Labor

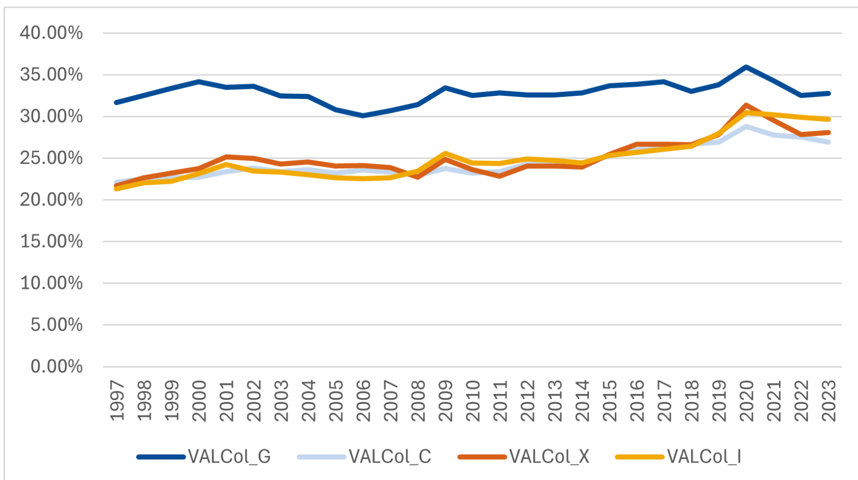


Figure 4 presents the share of upstream labor value added attributable to workers with a college degree. Throughout the sample period, government spending exhibited the highest share of college-educated labor value added, while the other components maintained similar levels. Additionally, following the 2008 financial crisis, the share of college degree labor value added increased for government spending, investment, and exports.

[8]See Barlevy [2007] on the cyclicality of R&D.

Figure 5. Value-Added Share of Non-College Degree Labor

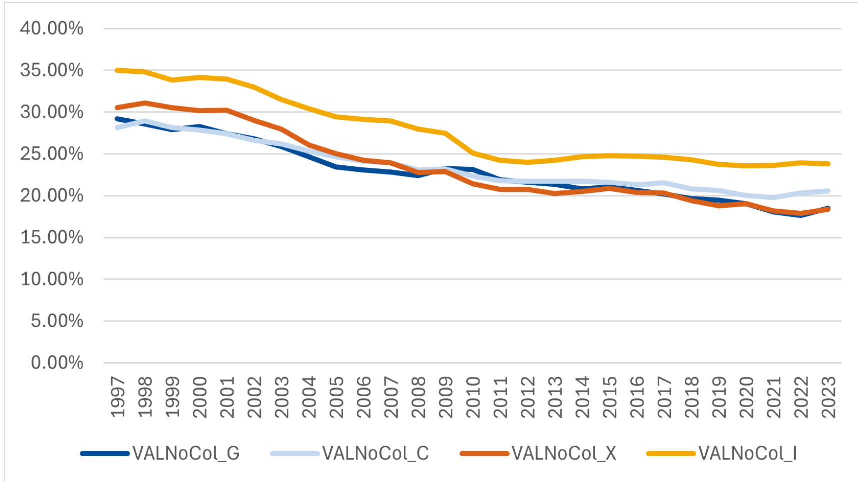


Figure 5 presents the share of upstream labor value added for workers without a college degree. Throughout our sample period, this share steadily declined across all components. Investment exhibited the highest share of non-college labor value added among all components, but following the 2008 recession, its decline became more pronounced before leveling off in subsequent years. Along with this downward trend, the value-added share of non-college labor in government and consumption spending was less volatile, indicating it's less sensitive to economic downturns.

Figure 6. Value-Added Share of Imported Intermediate Inputs

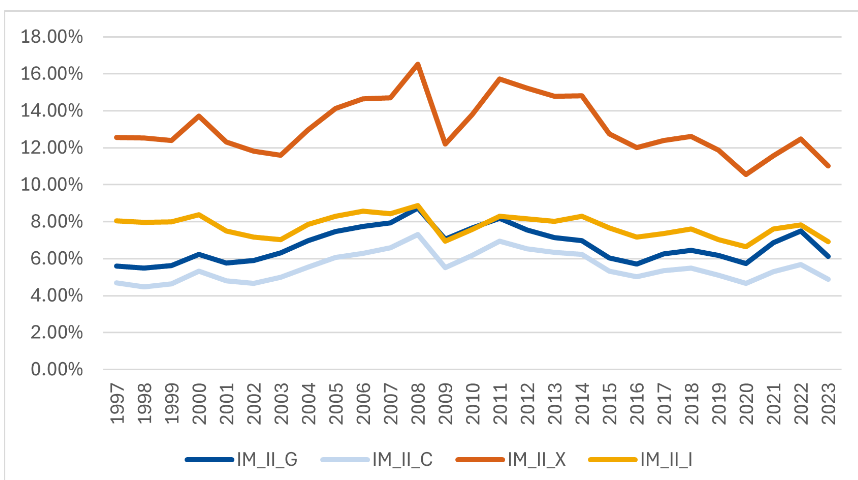


Figure 6 presents the share of upstream value added from imported intermediate inputs. This analysis helps assess import dependence in domestic production. Notably, exported goods consistently hold the highest share of imported intermediate inputs throughout the sample period. Moreover, the value-added share of imported intermediate inputs remains stable over time.

We now turn to a detailed examination of the share of value added created by each type of capital and labor for each component of final demand, specifically exports, consumption expenditures, government spending, investment, and the counterfactual for imports.

Figure 7. Value-Added Shares of Factors of Production (Exports)

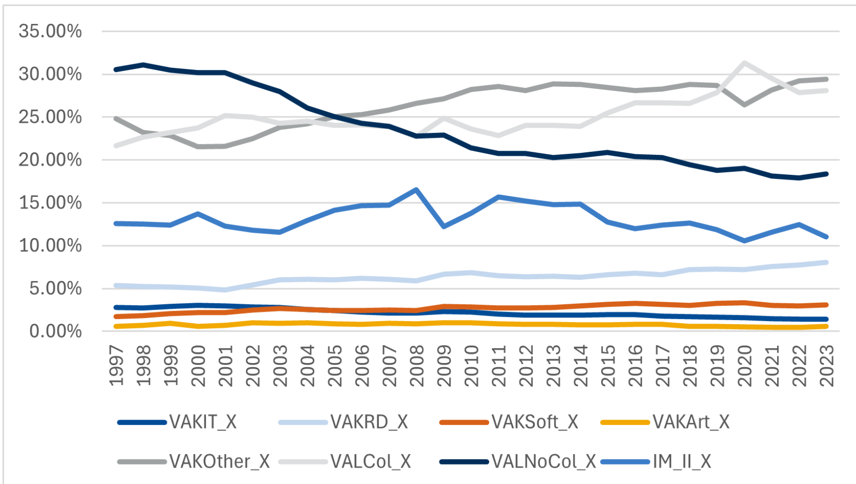


Figure 7 presents the upstream value-added share of each factor of production in exports. Since the early 2000s, the share of other capital has steadily increased, ultimately becoming the largest contributor by the end of the sample period. Additionally, the value-added share of college-educated labor has risen relative to that of non-college labor. While the share of imported intermediate inputs remains largely stable, it exhibits sensitivity to economic recessions. As for R&D, its share has increased over time, though not as significantly as other production factors.

Figure 8. Value-Added Shares of Factors of Production (Government Spending)

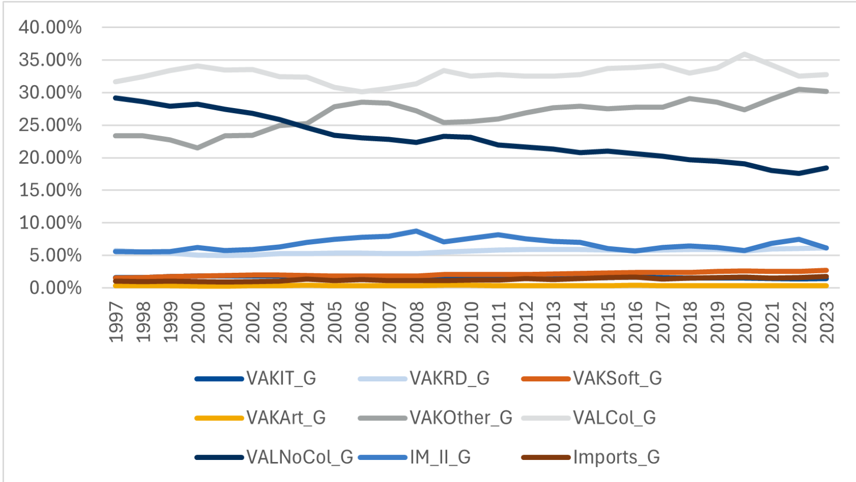


Figure 8 shows that the value-added share of other capital follows a consistent upward trend throughout the sample period. Regarding labor value added, college-degree labor maintains the highest share across the entire sample, while non-college labor experiences a substantial decline. The value-added share of imported intermediate inputs is relatively small. As for R&D, although there is a slight increase, its overall contribution remains minimal.

Figure 9. Value-Added Shares of Factors of Production (Consumption Expenditures)

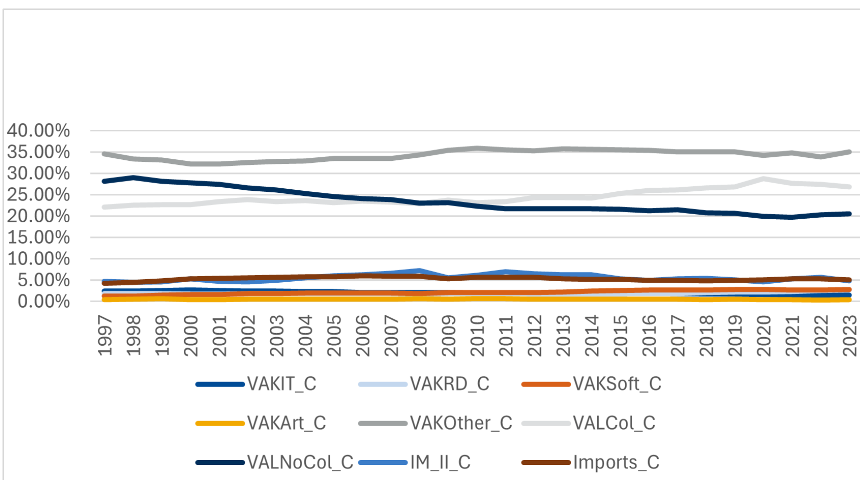


Figure 9 shows that the value-added share of other capital remains the highest throughout the sample period for consumption expenditures. Additionally, consistent with other components of final demand, the value-added share of college-degree labor has increased. Among all components of final demand, consumption exhibits the lowest value-added shares of both imported intermediate inputs and R&D.

Figure 10. Value-Added Shares of Factors of Production (Investment)

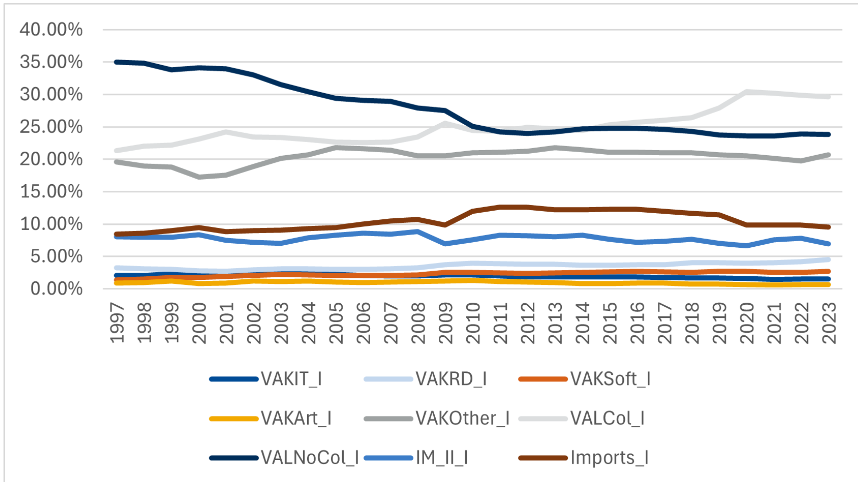
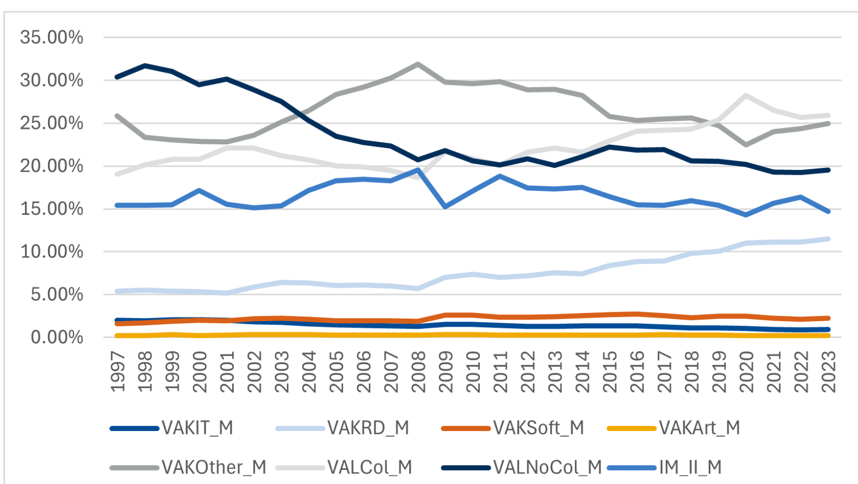


Figure 10 shows that in the early years, non-college labor held the highest value-added share. However, following the 2008 recession, the share of college-degree labor surpassed that of non-college labor. Additionally, the value-added share of other capital exhibited an upward trend, maintaining a higher proportion than other types of capital. Throughout this period, the value-added share of imported intermediate inputs in investment remained steady.

Figure 11. Value-Added Shares of Factors of Production (Counterfactual for Imports)



Lastly, in Figure 11, we explore a scenario where all of the imports are produced domestically and only intermediate inputs can be imported. In other words, we assume that the production technology is identical to that of domestically produced goods, and the decomposition has been conducted using the domestic requirements table and domestic value-added shares of factors of production. Interestingly, the shares are very similar to those in the exports case. Moreover, the value-added share of other capital follows a similar pattern, increasing until 2008. However, in the case of imports, the share of other capital starts falling in the following years, while it continues increasing for exports. Considering the labor share with respect to college and non-college degrees, the results imply a similar pattern. The share of imported intermediate inputs is larger than in the case of exports. For R&D, the increase in the value-added share of R&D over time is more significant in the case of imports.

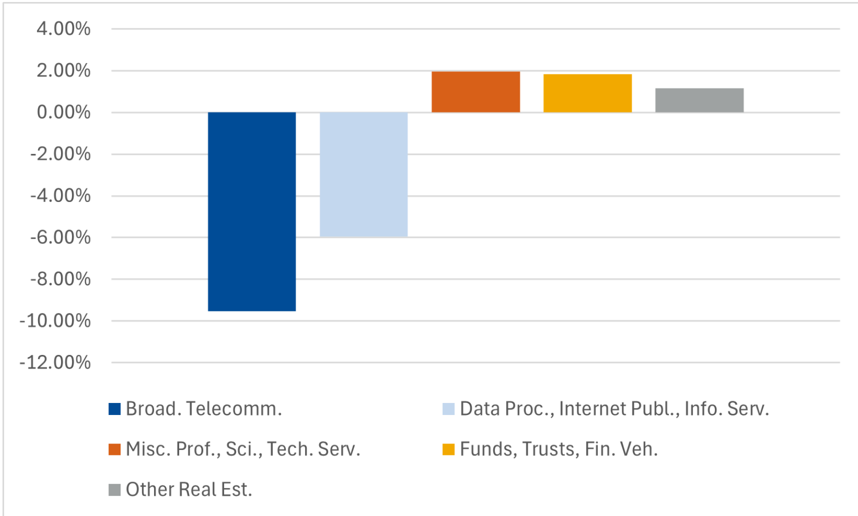
4.1. Indirect-Direct

In this section, we calculate the value-added shares of production factors required to generate $1 of each domestically produced commodity over time. This provides the value-added shares, which account for the entire production chain, which we then compare to the corresponding direct value-added shares for each commodity. If a factor of production has a higher indirect value-added share than its direct share, this indicates that upstream sectors rely on that factor more heavily than the primary sector. Conversely, if the indirect share is lower than the direct share, it indicates that the primary commodity sector utilizes that factor more extensively than the upstream sectors. As a reminder, these shares are relative to the total domestically produced value added, i.e., exclude imported value added and direct imports.

We identify the top five industries with the largest absolute difference between indirect and direct value-added shares for the year 2023, the most recent available data year.

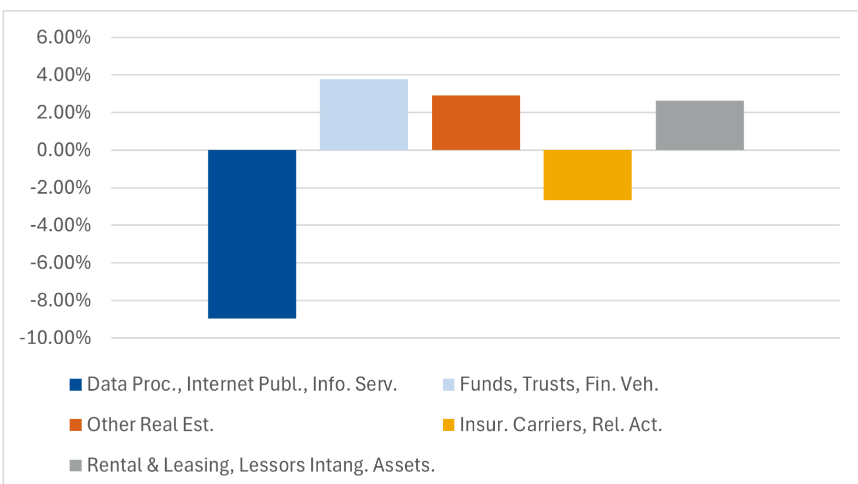
This analysis is important because it shows that for certain products, considering the production structure only at the last stage of production may yield an incomplete picture of the factors of production that are required to produce that item.

Figure 12. Difference Between Indirect and Direct Value-Added Shares (IT)



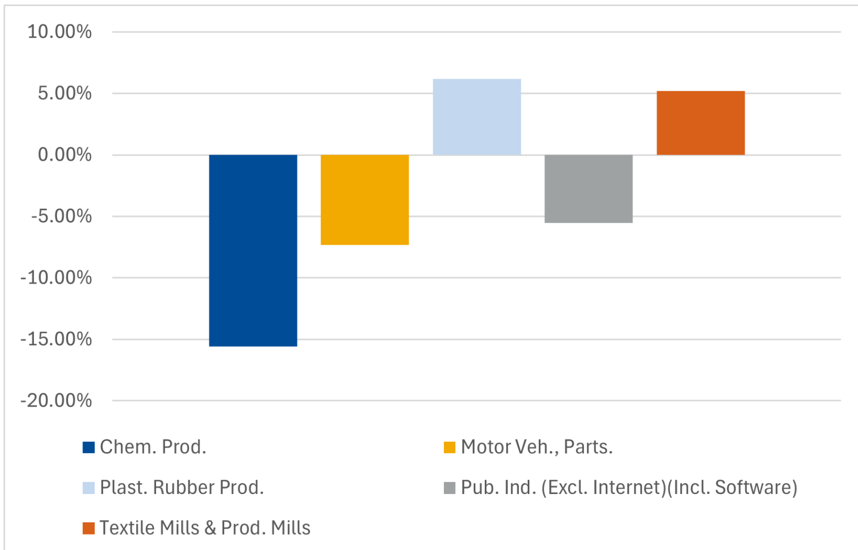
For IT capital, the broadcasting and telecommunications industry, along with data processing, internet publishing, and "other information services" and securities, commodity contracts, and investments, show a negative difference, indicating that these industries rely more heavily on IT capital compared to their upstream sectors. Conversely, in miscellaneous professional; scientific; and technical services, funds; trusts; and other financial vehicles, and "other real estate." show a positive differential, indicating that IT capital is more extensively utilized by upstream industries rather than primary industries.

Figure 13. Difference Between Indirect and Direct Value-Added Shares (Software)



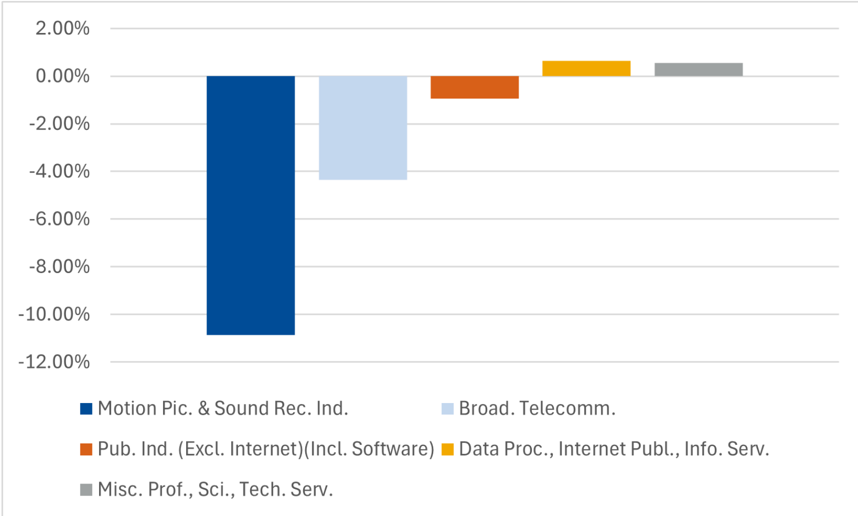
For software capital, data processing and internet publishing, along with insurance carriers and related activities, exhibit a negative difference, suggesting that these industries depend more heavily on software capital than their upstream sectors. In contrast, funds; trusts; and other financial vehicles, other real estate, rental and leasing services and lessors of intangible assets see greater utilization of software capital in upstream industries rather than in their primary industries.

Figure 14. Difference Between Indirect and Direct Value-Added Shares (R&D)



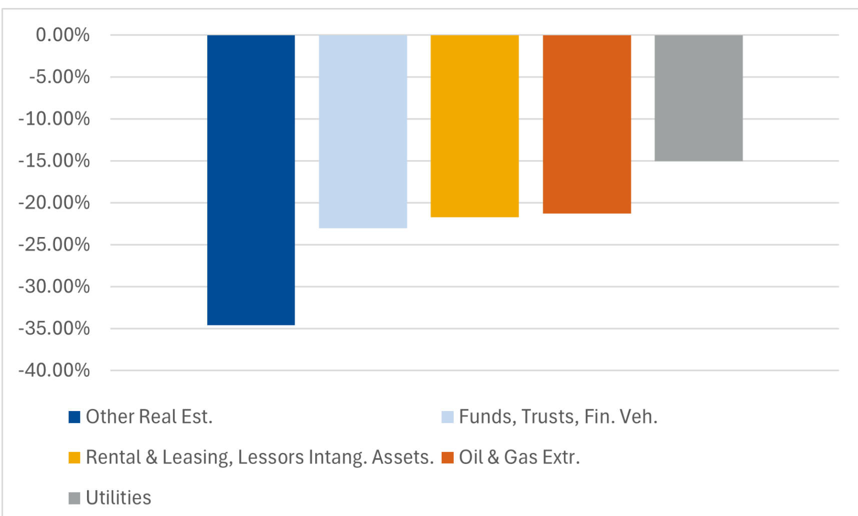
For R&D capital, industries such as chemical products, motor vehicles (including bodies, trailers, and parts), and non-internet publishing (including software) exhibit a negative differential, indicating a greater reliance on R&D capital compared to their upstream sectors. Conversely, plastics and rubber products, along with textile mills and product mills, show higher R&D capital usage in upstream industries rather than their primary industry.

Figure 15. Difference Between Indirect and Direct Value-Added Shares (Art and Entertainment Originals)



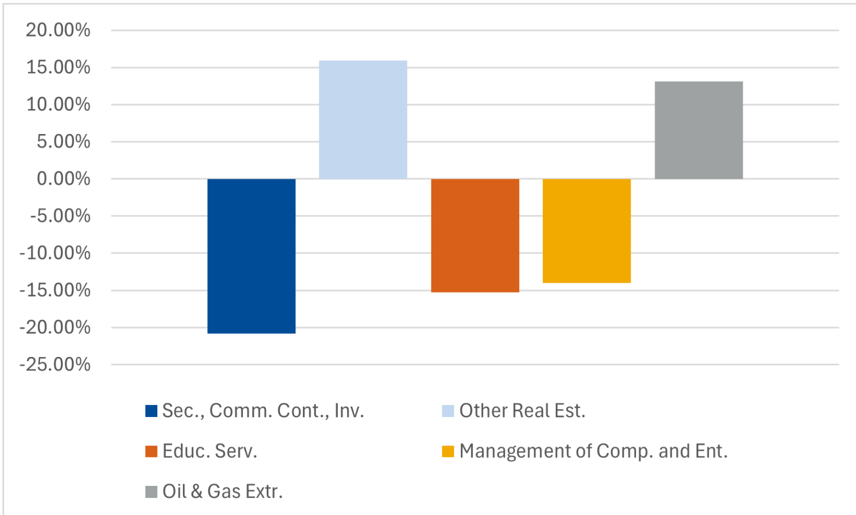
For art and entertainment originals, the motion picture and sound recording industries, along with the broadcasting, telecommunications, and non-internet publishing (including software) industries exhibit a negative differential, suggesting a heavier reliance on art and entertainment originals capital. Conversely, data processing, internet publishing, and other information services and the miscellaneous professional, scientific, and technical services industry demonstrate greater usage of art and entertainment originals capital in upstream sectors compared to their primary industry.

Figure 16. Difference Between Indirect and Direct Value-Added Shares (Other)



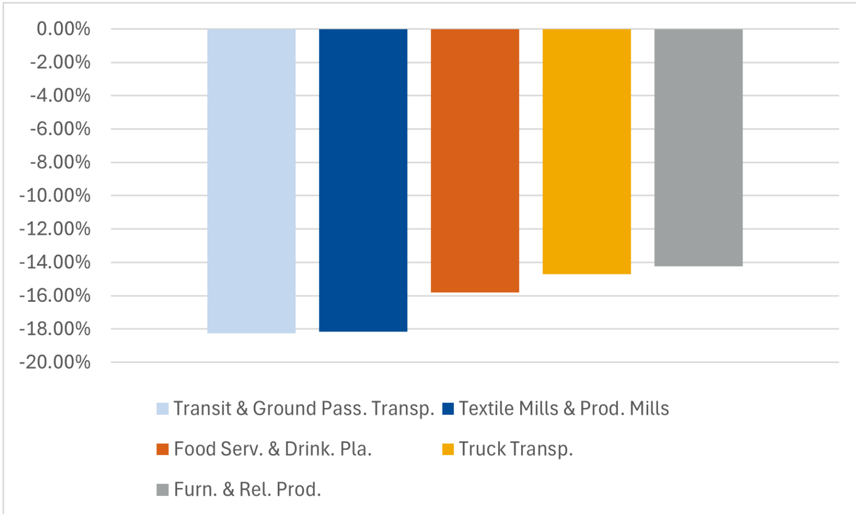
For other capital, all top five industries (other real estate, funds; trusts; and other financial vehicles, rental and leasing services and lessors of intangible assets, oil and gas extraction, and securities; commodity contracts; and investments) exhibit a negative difference, suggesting a heavier reliance on the other capital in the primary industry as compared to their upstream industries.

Figure 17. Difference Between Indirect and Direct Value-Added Shares (College Degree Labor)



For college degree labor, securities; commodity contracts; and investments, management of companies and enterprises, educational services industries demonstrate a negative difference, indicating that these industries rely heavily on college-degree labor as compared to their upstream industries. For instance, for securities, commodity contracts, and investments, the value-added share of college degree labor is 20 percent lower when we consider the overall upstream industries, while this share is 15 percent lower for the other two industries. On the other hand, the other real estate and oil and gas extraction industries convey a positive difference, implying that the upstream industries are more intensive in college-degree labor.

Figure 18. Difference Between Indirect and Direct Value-Added Shares (Non-College Degree Labor)



For non-college degree labor, all top five industries (transit and ground passenger transportation, textile mills and textile product mills, food services and drinking places, truck transportation, and furniture and related products) demonstrate a negative difference, indicating that these industries rely heavily on non-college degree labor as compared to their upstream industries.

Overall, the results indicate significant variation in the distribution of production factors across both direct and upstream stages of commodity production. In several industries, the shares of indirect value added differ considerably from those of direct value added, emphasizing the importance of examining the entire production chain. These findings demonstrate that relying only on direct value-added shares can obscure the true composition of factors in commodity production, particularly in sectors with intricate upstream linkages.

5. Conclusion

The main purpose of this paper is to examine the upstream contributions of primary factors of production in components of final demand. If a primary input is important in an upstream industry but not in the final stage of production, looking only at the final stage may provide a misleading picture of the resources needed in production and the evolution of structural change. To do this, we have linked domestic requirement tables with ILPA data that include information on the use of primary factors of production by industry.

Our analysis has found that there are common trends in the long-term trajectory of some input shares. For example, non-college labor shares have steadily declined across all final-demand bundles and exhibit greater volatility than other inputs. In contrast, software and R&D capital have risen modestly over time, signaling a gradual shift toward knowledge-intensive production. Among bundles, exports remain the most R&D-intensive. Government spending shows the highest value-added share of college-educated labor, while investment has the highest value-added share of non-college labor despite its overall downward trend. The consumption bundle exhibits the lowest intensity in IT and R&D capital, likely reflecting that the consumption bundle includes many consumer staples.[9] Furthermore, investment, consumption, and government spending all contain notable embedded indirectly imported content, exceeding 5%. Finally, we have found that looking only at the final stage of production may yield a misleading view of the entire production structure for specific commodities. For example, hospital-services production requires a larger share of software than the hospital industry's own software intensity, and chemicals production draws less on R&D than implied by the R&D share within the chemical sector itself. Across sectors, direct R&D intensity peaks in chemicals, college-educated labor concentrates in securities and financial services, and non-college labor dominates transportation and textiles. The implication is that if one is interested in the production of a given commodity, it is important to consider the entire upstream production structure.

This paper is early research on the basic issues discussed in the paper. There are some important next steps, including updating the data to cover more historical periods, breaking out the other capital piece into more intuitive components, and perhaps adding more detail on the components of labor. We also plan to further examine the contribution of goods and services within each upstream share. Nevertheless, this paper serves as a proof of concept that when analyzing the production structure for components of final demand and individual commodities, it is important to account for the production structure for the intermediate inputs across the entire U.S. value chain.

[9] Personal consumption expenditures are concentrated in sectors such as retail trade, food services, and transportation, which fall into the lowest R&D intensity categories according to the OECD taxonomy of economic activities Galindo-Rueda and Verger [2016].

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