Price Chains and the Origins of PCE Price Growth

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Abstract Off-the-shelf growth accounting is typically used to assess the sources of economic growth, and recently established approaches to measuring trade in value added are typically used to decompose domestic and foreign content in bundles of final demand. This paper merges the two approaches to measure the sources of personal consumption expenditures (PCE) price change in the United States, parse out the contribution of foreign prices across the price chain, and trace price change to changes in prices in the factors of production. Between 1997 and 2021, PCE prices grew by about 1.8% per year, on average. Direct imports to PCE accounted only for a small portion of PCE price change (about 1.3% of the total change, reflecting the small share of imports in PCE), but including upstream imported intermediate inputs across the entire produc-tion chain reveals that foreign prices embedded in PCE accounted for almost 11% of PCE price change. By linking value-added prices to prices in the BEA–BLS industry-level production account, price growth accounting reveals that prices for labor inputs accounted for a large share of PCE price growth but that total factor productivity growth played an important role in dampening PCE price growth over the period.

Keywords Price change, globalization, imports, total factor productivity

JEL Code E01, E31, D24

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1. Introduction

Work on measuring global value chains by economic statisticians and researchers has established the importance of measuring economic interconnections in understanding the origins of economic value across borders and industries. For example, the U.S. Bureau of Economic Analysis (BEA) now produces regular updates to its trade in value added (TiVA) statistics. A primary application of BEA TiVA measures is the identification of imported content in U.S. gross exports, but a recently released customizable table builder allows users to drill down to exporting industry, destination, and source of value. Value chains are also important for understanding the production structure of economies. Timmer et al. [2014] and others have used value chains to study, for example, the allocation of skilled labor and capital across the global economy. In this paper, I introduce a new, but related, concept that I label "price chains." Just like a bundle of final demand embeds all of the contributions of value added across the chain of production (including embedded foreign value added), a price chain embeds the contributions of upstream prices across the entire chain of production.

One way to motivate attention to price chains is to consider trying to analyze the role of import prices within a country's gross domestic product (GDP) accounts. First, imports are excluded from GDP, so import prices are not included as a contributor to aggregate GDP price growth by definition (more discussion on how this works below). To set ideas, let us start with a narrow component of personal consumption expenditures (PCE). If this good or service is directly imported, import prices directly impact PCE price change. Consider motor vehicles. If 50 percent of motor vehicles purchased by households are imported, a change in import prices would directly (with approximately a 50 percent weight) impact the PCE price for motor vehicles. Even with this direct relationship, information on the contribution of imports to prices in the United States is not published as part of the GDP accounts. But with information on imports, import prices, and import shares that are assigned to PCE (which are available in BEA's import use matrix), it is relatively straightforward to measure the direct contribution of import price change to change in U.S. PCE prices.

This paper examines the indirect role of import prices via the production chain by: 1) parsing price change for final demand commodities to upstream prices across the value chain and 2) linking value-added prices to prices of factors of production and changes in total factor productivity (TFP) in upstream industries. Continuing with the motor vehicle example: first, as just noted, a certain portion of motor vehicles are imported and thus import prices directly impact PCE prices. But consider the 50 percent (in this stylized example) of cars that are that are domestically produced and purchased by households. Surely, the auto manufacturer purchases parts that are imported, and surely the auto manufacturer purchases parts that are domestically produced; and of the parts that are domestically produced, surely components of the domestically produced parts are also imported. Thus, it is important to trace the entire production chain of prices in assessing the role of import prices on motor vehicle prices. For example, it may not be the import price of a car part that is leading to price changes in car prices; it may be foreign primary metals that are impacting the prices charged for final products that are two or three stages removed in the production process. The first objective of this paper is to measure import price contributions that are embedded as prices of intermediate inputs across the entire production chain for each commodity.

The second objective of the paper is to connect output (value added) prices with input prices and total factor productivity. The BEA–BLS Integrated Industry-Level Production Account (ILPA) allows users to trace the growth rate of aggregate value added to its sources across the growth of labor, capital, and TFP. On the price side, changes in aggregate prices can be traced to changes in the growth of labor and capital prices, and changes in TFP. By linking the upstream components of value added from supply chain decompositions to prices of the relevant inputs, PCE price change can be decomposed to changes in prices of factors of production, changes in foreign prices, and changes in TFP.

Between 1997 and 2021, PCE prices grew by about 1.8% per year, on average. Direct imports to PCE accounted only for a small portion of PCE price change (about 1.3% of the total change, reflecting the small share of imports in PCE), but including upstream imported intermediate inputs across the entire production chain reveals that foreign prices embedded in PCE accounted for almost 11% of PCE price change. By linking value-added prices to prices in the ILPA, price-growth accounting reveals that prices for labor inputs accounted for a large share of PCE price growth but that TFP growth played an important role in dampening PCE price growth over the period. These aggregate changes are measured from the bottom-up across commodities and industries so the results below include the industry origins of aggregate price change. This is important, in part, because TFP growth rates vary a lot by industry.

2. Methodology

The basic approach to parsing price impacts into upstream domestic components and foreign prices is an extension of the well-established approach to measuring value chains. Many, although not all, value chain decompositions rely on input-output relationships. In summary, the IO-based relationships decompose a component of final demand into value added across all industries that produce value added that feed directly and indirectly into the final product.

For a good or service i that is a component of final demand, the gross value reflects U.S. domestic value-added contributions across the entire production chain, imported goods or services of i that go directly to final demand, and also foreign value added contributed along the production chain to the final purchase of bundle i. That is, consider the purchase of motor vehicles. Some motor vehicles are directly imported and some are produced in the United States. For motor vehicles that are produced in the United States, some of the intermediate inputs used in the production of motor vehicles are imported by the motor vehicle industry, and the suppliers of intermediate inputs to the motor vehicle industry also likely import a portion of their intermediates.

Each industry's contribution to the gross value of final demand takes into account the entire upstream production chain for commodity i:

$$V_{FD,i} = VA_{i,1} + VA_{i,2} + VA_{i,3}... + VA_{i,J} + VA_{i,ROW} + M_{i,FD} \tag{1}$$

In equation (1), $M_{i,FD}$ is the imports that go directly to the final purchaser. Note, in the data $M_{i,FD}$ is not directly observed. Gross imports M_i are observed. But BEA's import use table provides information on the allocation between $M_{i,FD}$ and M_i. For the purposes of this paper, $M_{i,FD}$ is considered to be raw data.

For each commodity i, $VA_{i,j}$ is the domestic value-added contribution of industry j to the value of the final purchase. Under the assumption of the model, $VA_{i,j}$ incorporates all domestic upstream transactions necessary to produce the final good or service. For example, in the case of motor vehicles (MV), $VA_{MV,primarymetals}$ does not solely capture that motor vehicles needs to directly purchase primary metals (and thus value added from the primary metal industry) but also that motor vehicles need to purchase computer parts, and the computer industry also needs make purchases of primary metals. That is, $VA_{MV,primarymetals}$ reflects the value-added contribution of the primary metal industry to the final purchase of motor vehicles that takes into account all the rounds of production. Finally, $VA_{i,ROW}$ is foreign value added contributed along the production chain to the final purchase of bundle i. This is determined as a residual. As will be described in more detail below, $VA_{i,1}$ is solely the domestic contribution. Thus, the remainder after accounting for direct purchases from abroad is foreign value added that is embedded in the final purchase. Another way to think about this is that it accounts for imported intermediate inputs across the entire production chain. But it is important to note that $VA_{i,ROW}$ is *not* imported intermediate inputs of product i. It reflects imported intermediates of all goods and services across the entire production chain. Thus, this is labeled as value added supplied by the rest of the world (since all imports can be traced back to value added in some industry,country pair. Identifying the industry,country pair is beyond the scope of this paper as it would require an integrated world input-output table with corresponding prices. Importantly, because the decomposition in this paper relies solely on U.S. tables, it is not possible to separate $VA_{i,ROW}$ into U.S. exports that may then be reimported as intermediate use, and goods and services that are wholly produced overseas. The same is true for currently published BEA statistics on TiVA as in Chute et al. [2023]. Equation (1) builds mostly on previous work by others and is not a contribution of this paper. A good reference for how BEA constructs its TiVA measures is BEA [2023].

The main contribution of this paper is to use the basic accounting in equation (1) to measure the contribution of price chains to price change in components of final demand with a focus on the role of foreign prices. The approach, which is analogous to most other price and quantity decompositions within national accounting, is to recognize that each component is associated with a price and quantity:

$$\begin{aligned} P_{FD,i}Q_{FD,i} &= P_{VA,i,1}Q_{VA,i,1} + P_{VA,i,2}Q_{VA,i,2} + ... + P_{VA,i,J}Q_{VA,i,J} \\ &\quad + P_{VA,i,ROW}Q_{VA,i,ROW} + P_{M,i}Q_{M,i} \end{aligned} \tag{2}$$

Choosing a functional form for price and quantity indexes is a common issue in national accounting. This paper does not delve into that issue. Because the prices will be linked to productivity data, which in the official U.S. statistics is calculated with törnqvist indexes, this paper will use törnqvist aggregation as well. Thus, the key equation for this paper is to decompose equation (2) using a törnqvist price index:

$$\Delta \ln P_{FD,i} = \left(\sum_j \frac{\overline{VA_{i,j}}}{V_{PCE,i}} \Delta \ln P_{VA,i,j} \right) + \frac{\overline{VA_{i,ROW}}}{V_{PCE,i}} \Delta \ln P_{VA,i,ROW} + \frac{\overline{M_{i,FD}}}{V_{PCE,i}} \Delta \ln P_{M,i} \tag{3}$$

where the bar indicates the two-period average. That is, the price change of a component j of final demand is the weighted average of log price growth of the component prices, where the weights are the shares contributed across the value chain.

An assumption necessary to implement equation (3) is that the price of producing a unit of value added is the same regardless of the purchaser. For example, if a motor vehicle producer purchases a dollar's worth of valued added from a plastic manufacturer, the price of this value added is the same as the price the construction industry would pay. This assumption must hold at the industry j level of detail. This is basically a law of one price for value added.

An aside on the price of value added may be helpful as this price is not measured directly. The basic approach to value-added prices is that each industry's gross output is governed by a production function $Y_j = F(Q_{II,j}, Q_{VA,j})$. With prices and quantities of gross output and intermediate input for the industry, $P_{VA,j}$ can be backed into using a törnqvist index like that in equation (3). This basic approach is often referred to as double deflation; output and intermediate inputs have different prices, and the weighted value-added price is defined as the price that makes the price accounting decomposition hold.

This value-added decomposition is different from the typical industry contributions to price change that may be part of a country's national accounts. In the official U.S. accounts, GDP prices can be measured from the expenditure side or the industry side. When prices are internally consistent, both measures produce the same aggregate price change. From the expenditure side, the price decomposition would be by component of final demand. From the industry side, the price decomposition would be by the industry price of value added, $P_{VA,j}$. But, as noted earlier, GDP by construction excludes imports, so there is no role for imports to impact GDP prices by definition. Thus, the accounting in equation (3) shows how prices across the chain impact prices of bundles of final demand in a way that is not captured by standard GDP and industry accounting even though the industry value-added prices are the same in both the aggregate GDP decomposition and the decomposition of the components of final demand.

Another important clarification is on valuation within the decomposition. PCE on the expenditure side of the GDP account is in "market prices" and reflects prices paid by final consumers, including taxes net of subsidies. The input-output tables are in producers prices and also include net taxes in the components of final demand and gross output. Therefore, the value added of each industry in the decomposition includes net taxes on production and imports. That is, $VA_{i,j}$ and therefore $P_{VA,j}$ embed tax revenue that is generated with each dollar of production. This is consistent with BEA's TiVA tables, but approaches to remove net taxes from value added in TiVA are under consideration within BEA.[2]

The other main contribution of the paper is to link price change across the production chain to prices of factors of production and changes in productivity. This linking does not take a stand on the causes of price change but merely applies growth accounting techniques to demonstrate how the prices are related. The approach is similar to other price accounting exercises; if a component of PCE has a large price change, attributing a large contribution of that component to an aggregate's price change leaves open the fundamental cause of the price change. Similarly, linking value-added prices to factor prices leaves open the fundamental cause of the price and productivity changes but is useful in showing the connections.

One objection to linking factor prices to value-added prices is that this linking presumes that there is an underlying economic link, i.e., that output price change must be the direct result of input price or productivity changes.[3] Of course, this objection is valid as certainly there are many mechanisms where there may be a wedge between output and input price change. But because the same factor prices underlie the published sources of economic growth and productivity calculations, duality theory results demonstrate that if one accepts the primal TFP results as being useful measures, one must also accept the prices that are used in constructing those measures. That is, TFP measures are the same if one constructs them from the primal (as done in the official U.S. statistics) or the price dual.

[2] In the decomposition to primary inputs discussed below, this amounts to including taxes in capital services. The most recent version of the ILPA makes adjustments for this, but this updated version of the dataset is not used in this version of the paper.

[3] For example, if pure profit exists over time, the link between output prices and input prices breaks down.

The price-dual approach to productivity measurement is the key to linking value-added price change to factor price change.

$$\Delta \ln P_{GO,j} = \overline{w_{VA,j}} \Delta \ln P_{VA,j} + \overline{w_{II,j}} \Delta \ln P_{II,j} \tag{4}$$

Equation (4) is the equation for double deflation using törnqvist indexes. For industry j, the (log) growth in output prices is simply a weighted average of the price change of intermediate inputs and value-added prices. Under the assumptions of the ILPA, the shares of VA and II must sum to 1. The second component is the TFP dual:

$$\Delta \ln T_j = \overline{w_{K,j}} \Delta \ln P_{K,j} + \overline{w_{L,j}} \Delta \ln P_{L,j} + \overline{w_{II,j}} \Delta \ln P_{II,j} - \Delta \ln P_{GO,j} \tag{5}$$

Equation (5) is just the price dual to measuring TFP by industry. As mentioned earlier, if one constructs TFP measures from the primal quantity side (as in the ILPA) and accounting identities hold, the price dual simply falls out of the accounting relationship. That is, no extra economic theory or restrictions are needed. Equation (5) says that the industry growth rate of input prices less the growth rate of output prices equals the growth rate of industry TFP.

Solving (4) for $\Delta \ln P_{VA,j}$ and using equation (5) results in an expression for the change in value-added prices as a function of capital and labor prices and changes in TFP.

$$\Delta \ln P_{VA,j} = \frac{1}{\overline{w_{VA,j}}} (\overline{w_{K,j}} \Delta \ln P_{K,j} + \overline{w_{L,j}} \Delta \ln P_{L,j} - \Delta \ln T_j) \tag{6}$$

Equation (6) says that increases in capital and labor prices increase valued-added prices proportionally to (approximately) each factor's share in nominal value added and increases in TFP reduce prices. The intuition for this is that if producers are able to reduce prices charged to customers after accounting for prices of capital and labor inputs, this is due to increased productivity.

Finally, plugging equation (6) into (3) yields an expression for how factor price and productivity change impact PCE prices:

$$\begin{aligned} \Delta \ln P_{FD,i} = & \left(\sum_j \frac{\overline{VA_{i,j}}}{V_{PCE,i}} \frac{1}{\overline{w_{VA,j}}} (\overline{w_{K,j}} \Delta \ln P_{K,j} + \overline{w_{L,j}} \Delta \ln P_{L,j} - \Delta \ln T_j) \right) \\ & + \frac{\overline{VA_{i,ROW}}}{V_{PCE,i}} \Delta \ln P_{VA,i,ROW} + \frac{\overline{M_{i,FD}}}{V_{PCE,i}} \Delta \ln P_{M,i} \end{aligned} \tag{7}$$

Equation (7), for each commodity i, takes factor price and TFP growth for industry i and all the upstream industries involved in the production. That is, if the commodity is motor vehicles, the labor, capital, and TFP of the motor vehicle sector is the relevant price for the value added contributed by that sector. But the final PCE involves value added from the upstream industries as well, and this decomposition uses the relevant prices (and TFP) from those upstream industries. Notice, the labor price change is the same regardless of where it fits in the value chain; what changes is its weight in the final component of PCE. So the motor vehicle capital and labor prices would have a high weight in motor vehicle PCE, but would have a smaller weight in PCE of farm products.[4] The terms on the second line of the equation are exactly those from equation (3). That is, the price contribution from direct imports and foreign value added is the same as in that equation; only the value-added prices are decomposed further into factor prices.

3. Data

The data used to implement the price-chain decomposition involves small modifications to mostly published data. The key piece to do the nominal value-chain decomposition (to get the value-added shares in equation (3)) are the domestic requirements tables. These give the amount of industry output to produce a bundle of final demand accounting for all of the upstream and downstream intermediate inputs. BEA produces its TiVA measures using "after redefinition" requirements tables to provide a closer connection between commodity bundles and the industries producing these commodities. A simple way to think about this is that the computer and electronic product sector "before redefinitions" produces both electronic products and research and development (R&D). But the exports of computers and electronic products mostly includes the hardware. Thus, the "after redefinition" tables move the production of R&D to the miscellaneous professional, scientific, and technical services industry. As a result of this, the value chain analysis avoids the assumption that every time an electronic product is purchased, more R&D must also be produced.[5]

Implementing equation (7) requires shares of primary factor inputs within each industry's value added and prices for capital and labor inputs. These are directly available from the ILPA for industries before redefinitions. In this version of the price-chain measures, the prices for capital and labor services and value-added shares are before redefinition. The underlying assumption is that the price paid per unit of capital and labor services reflects the joint production of primary and secondary products. Within value added the shares of capital and labor are also before redefinition shares. So across the value chain, value added is distributed to after definition shares across producers, while within value added and the corresponding prices before redefinition shares and prices are used. In effect, this means that nominal values are moved to appropriate secondary industries, but within these reallocated industries the internal

[4] The value added contributed by motor vehicles to farm PCE is likely motor vehicle parts.

[5] If the question of interest was how much output needed to be undertaken to produce computers in the *future*, using the before redefinition accounts may be more appropriate.

production process requires inseparable capital and labor structures, i.e., joint production of primary and secondary outputs.[6] TFP growth by industry also comes directly from the ILPA.

Also within equation (7) are the data for direct imports. The value of direct imports that goes to final demand is from BEA's import-use matrix. The price of imports is based on published BLS import prices by commodity, but for this paper is taken from BEA's unpublished data that assigns each of these import prices to commodities that are used in its GDP by industry accounts. The prices used are those that reflect the composition of bundles within final demand.[7]

PCE prices by commodity in equations (3) and (7) are not part of BEA's published accounts. BEA publishes industry output prices. To construct final demand prices for each commodity j, a törnqvist index of industry output prices is constructed using the make table as weights.[8]

Finally, all prices are scaled to match price change in published National Income and Product Accounts (NIPA) PCE price growth. Aggregating commodity prices using PCE weights based on the Use table does not equal published NIPA PCE price change due to the complicated mappings between producer price indexes, industries, commodities, and consumer prices indexes. All prices are scaled proportionally to hit published PCE price growth.

4. Results

A major motivation for this research is to try to measure how prices of imported goods and services impact prices in the United States. Aggregating commodity prices of goods and services produced domestically with prices of imports that are also a component of final demand gives one accounting. While this decomposition is not part of BEA's standard published tables, it can be computed directly by aggregating the components of PCE. The left panel of figure 1 provides this decomposition for PCE price growth between 1997 and 2021. Over this period, PCE prices grew by about 1.8% per year on average. In nominal terms, domestically produced goods accounted for about 14.7% of PCE, domestically produced services accounted for 80.6%, and imports for 4.7% ("goods" includes North American Industry Classification System (NAICS) industries 11–33; "services" includes all other NAICS codes). Within PCE price growth, domestically produced goods accounted for about 15.5% of price growth, domestically produced services accounted for 83.1%, and imports for 1.3%. This indicates that the bundle of imports had prices that grew less rapidly than domestically produced goods and services. It does not indicate that for the same good or services, imports were cheaper than domestically produced

[6] See Samuels [2023] for a discussion of before and after redefinition TFP accounting. More research may be needed on using before and after redefinition prices and value shares.

[7] For example, BEA has import prices for the commodities underlying the summary-level commodity farms. Because the bundle of the farm commodity purchased as an intermediate input may differ from the bundle of the farm commodity for PCE, the import price used here is the price reflating the composition of the farm commodity PCE bundle.

[8] The make table gives a mapping between industry and commodity output.

goods or services. This reinforces that when doing price (and quantity) decompositions of aggregates in terms of contributions, nominal changes embed changes of both price and quantity. The price contributions in this paper are constructed to be only the effects of changing prices.[9]

The right panel of figure 1 shows that embedded foreign prices that are not part of the off-the-shelf PCE accounting played an important role in PCE price change over the period. These prices are not directly observed. As noted above, they are prices that are consistent with the price accounting equations and represent prices of imported intermediates across the entire production chain. The reader may be wondering why is there not an attempt to use import prices and intermediate use directly in measuring the role of these prices. The answer is similar to why the same basic approach is used in the nominal accounting of TiVA: the objective is to figure out value-added contributions; by definition value added does not include imports so intermediate inputs do not appear as a contributor to price change when doing value-added decompositions. But, imports as intermediate inputs do appear as a component of gross PCE and the price chain equations allow for parsing out this component. Including the contributions of these imported intermediates, foreign prices accounted for almost 11% of PCE price change over the period (combining direct imports to PCE and the prices of foreign value added). That is, the production structure and global linkages of foreign-sourced inputs is important to take into account when analyzing the sources of price change of bundles of final demand. Also note that the value-added approach to measuring prices changes the decomposition between goods and services contributions to PCE price change. On the commodity basis, goods accounted for about 15.7% of domestically produced price change, while on a value-added basis, the production of goods accounted for 10.6% of price change from domestically produced value added. One way to think about what could be driving this: if value-added prices in the services sectors are growing more rapidly than the value-added prices in the goods sectors and the goods sector uses relatively more services as an intermediate input (than the service sector uses goods), this would result in attributing more of the price change to value-added prices in the service sector in comparison to the commodity-based decomposition.

Additional intuition for the price decompositions can be gleaned from the results shown in figure 2. The width of each bar is the contribution of that respective commodity to aggregate PCE price change between 1997 and 2021. That is, summing all of the price contributions equals total PCE price change of 1.8% per year on average. The largest contribution to PCE price growth was real estate over the period. The price chain decomposition allows one to parse this contribution into the components in equation (3). Furthermore, one can decompose the industry j value-added components in to j=goods and j=services. For real estate, almost all of the contribution of PCE price change is from domestically produced service industries. The chemical products sector is a useful comparison. It was in the top 10

[9] This is a little confusing because chained price indexes, like those used in this paper, have nominal weights that change over time. But the theory of price indexes results show that this is still a price index stripped of changes in quantities. Similarly, the real GDP index, even though it is a fisher index that allows for weights to change over time, is conceptually stripped of price change.

largest contributors to aggregate PCE price change (reflecting both its high weight in PCE and price growth of chemical products); the accounting reveals that direct imports of chemical products played a significant role of PCE price change as did foreign value-added prices from intermediate inputs that are used to produce chemicals across the entire production chain. It is important to emphasize that this is not imported intermediate inputs of chemicals. It is any imported intermediate input into chemical production or any imported intermediate input that is used by the entire U.S. value chain of suppliers that ultimately end up as an input into chemical production. Finally, even though chemical products belong to the goods sector, the production uses intermediate inputs of domestically produced services; therefore these prices also contribute to the PCE price change in chemical products. Also note that the contributions of foreign prices summed across commodities equals the aggregate contribution in figure 1. This is also the case for the contributions of imports, goods, and services prices.

From a cost function growth accounting perspective, the sources of changes in output (value added) prices like those considered above are changes in labor prices paid by industry, capital prices, or TFP growth (again, an increase in TFP leads to a decrease in output prices ceteris paribus). Figure 3 adds the input price decomposition to the sources of U.S. PCE price change. Like earlier, the contributions add to total PCE price change between 1997 and 2021. The contributions of direct imports and foreign value added are the same as in the middle bar. This decomposition shows that over this period, increases in the prices of labor inputs accounted for about 68% of PCE price growth, prices of capital inputs accounted for about 36%, and increases in TFP accounted for about –15%. What this means is that everything else equal in the economy, without TFP growth, PCE price growth would have been about 2.1% per year instead of the observed 1.8% per year. It is interesting to compare this to the contribution of TFP growth to aggregate real value-added growth over the same period. According to the ILPA, TFP growth accounted for about 22% of aggregate value-added growth over the period.[10] The intuition for the difference is that the underlying sector composition of PCE is different from the composition of GDP.

Figure 4 gives the contributions of input prices and TFP by industry to PCE price growth between 1997 and 2021. The width of the bar is the same as figure 2, i.e., the prices add up to the same contribution by commodity. It is not surprising that the large majority of price change in real estate was driven by changes in the prices of the underlying capital inputs and that the large majority of the price change in hospitals and nursing care was driven by labor prices. The retail trade commodity is an interesting example; price change in retail trade was the third-largest contributor to aggregate PCE price change over the period. A large portion of this was driven by increases in the prices of labor inputs used in the industry. But the overall contribution was dampened by significant TFP growth in the sector. In fact, TFP increases outweighed the increases in capital input prices in the sector. The figure also shows how TFP increases in the motor vehicle and parts and broadcasting and telecommunications sectors counterbalanced input price increases for those sectors. Finally, it is worth noting that it would be

[10] From the ILPA published in September 2023.

relatively straight forward to further decompose this figure into contributions from labor, capital, and TFP broken down by goods and services industries within each commodity. That is, the labor price for each bar could be split into labor prices from goods industries across the entire price chain and labor prices from service industries across the entire price chain.

5. Conclusions and Next Steps

Off-the-shelf growth accounting is typically used to assess the sources of economic growth, and recently established approaches to measuring trade in value added are typically used to parse domestic and foreign content in bundles of final demand. This paper merges the two approaches to address the sources of PCE price change in the United States, parse out the contribution of foreign prices across the price chain, and trace price change to changes in the prices of factors of production. Between 1997 and 2021, PCE prices grew by about 1.8% per year, on average. Direct imports to PCE accounted only for a small portion of PCE price change (about 1.3% of the total change), but including the upstream imported intermediate inputs across the entire production chain reveals that foreign prices embedded in PCE accounted for almost 11% of PCE price change. By linking value-added prices to prices in the industry-level production account, price-growth accounting reveals that prices for labor inputs accounted for a large share of PCE price growth but that TFP growth played an important role in dampening PCE price growth over the period. Next steps in this research include applying the same basic method to decompose prices of other components of final demand. For example, changes in export prices, which are more directly tied to U.S. international economic competitiveness. Also, the same method applied to different sample periods (for example the 2021 inflation) could yield important insights into the role of price chains during differing economic events.

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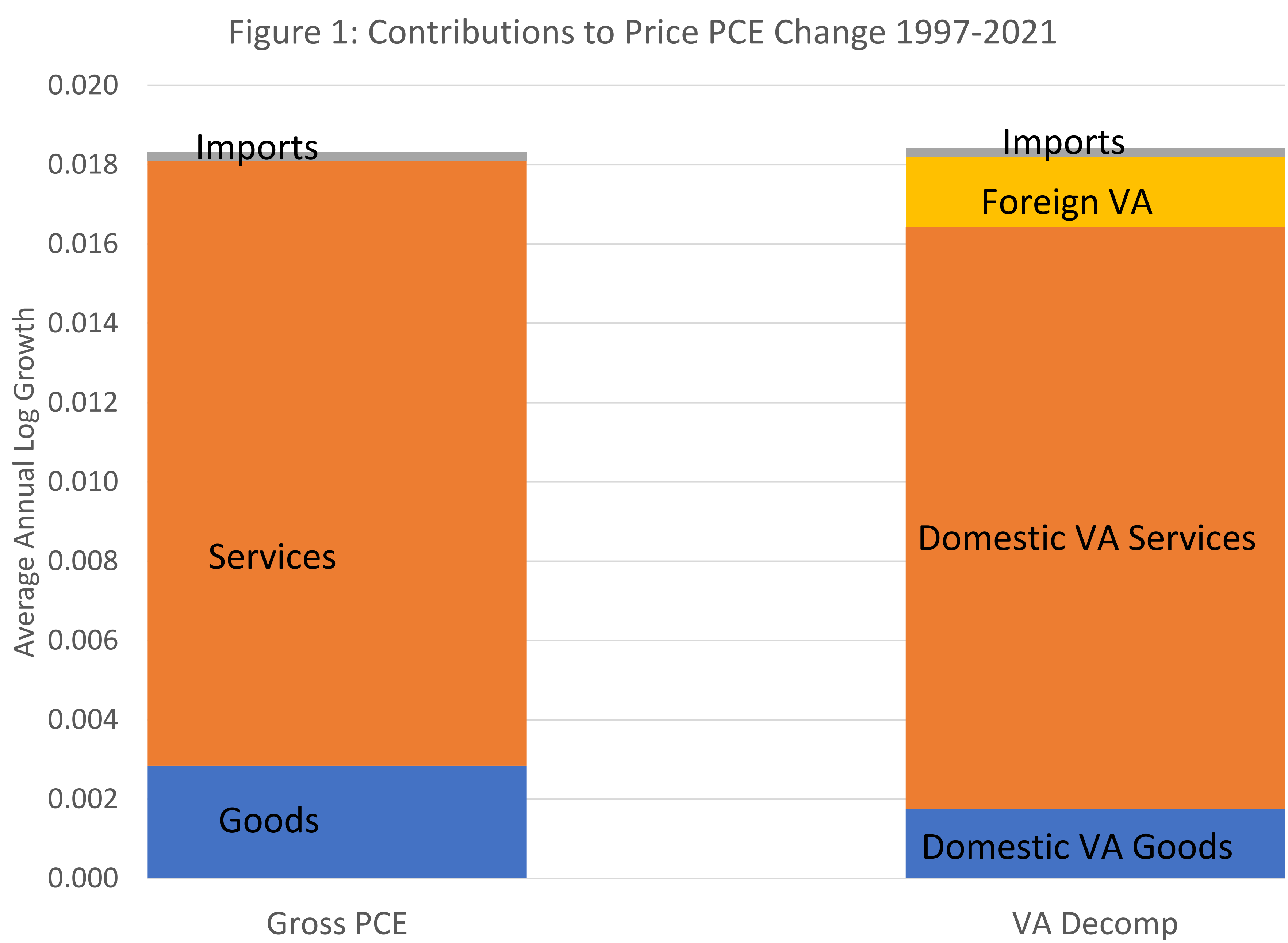
Figure 1: Contributions to Price PCE Change 1997-2021
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Average Annual Log Growth
Imports
Services
Goods
Imports
Foreign VA
Domestic VA Services
Domestic VA Goods
Gross PCE
VA Decomp

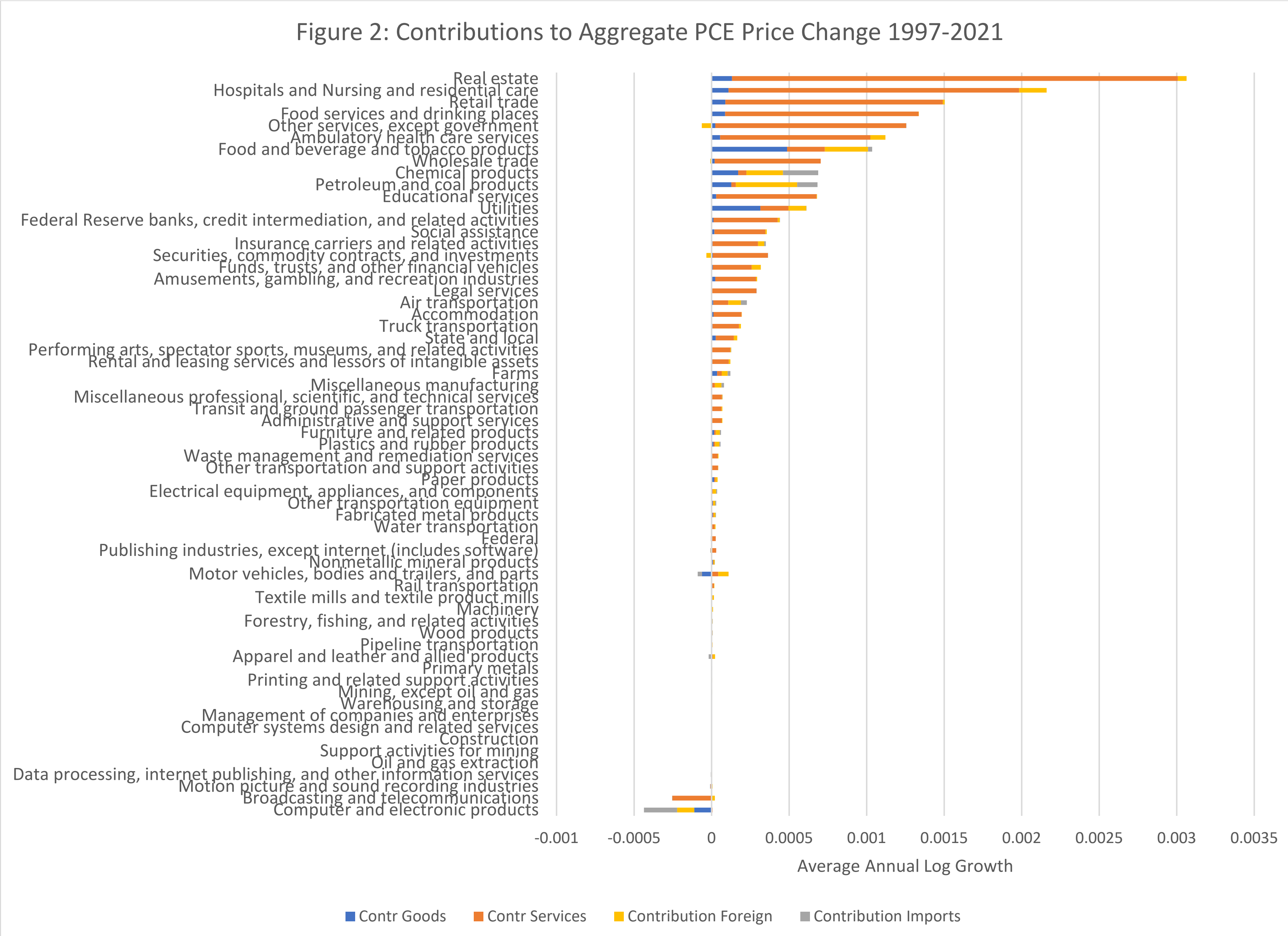

Figure 2: Contributions to Aggregate PCE Price Change 1997-2021
Real estate
Hospitals and Nursing and residential care
Retail trade
Food services and drinking places
Other services, except government
Ambulatory health care services
Food and beverage and tobacco products
Wholesale trade
Chemical products
Petroleum and coal products
Educational services
Utilities
Federal Reserve banks, credit intermediation, and related activities
Social assistance
Insurance carriers and related activities
Securities, commodity contracts, and investments
Funds, trusts, and other financial vehicles
Amusements, gambling, and recreation industries
Legal services
Air transportation
Accommodation
Truck transportation
State and local
Performing arts, spectator sports, museums, and related activities
Rental and leasing services and lessors of intangible assets
Farms
Miscellaneous manufacturing
Miscellaneous professional, scientific, and technical services
Transit and ground passenger transportation
Administrative and support services
Furniture and related products
Plastics and rubber products
Waste management and remediation services
Other transportation and support activities
Paper products
Electrical equipment, appliances, and components
Other transportation equipment
Fabricated metal products
Water transportation
Federal
Publishing industries, except internet (includes software)
Nonmetallic mineral products
Motor vehicles, bodies and trailers, and parts
Rail transportation
Textile mills and textile product mills
Machinery
Forestry, fishing, and related activities
Wood products
Pipeline transportation
Apparel and leather and allied products
Primary metals
Printing and related support activities
Mining, except oil and gas
Warehousing and storage
Management of companies and enterprises
Computer systems design and related services
Construction
Support activities for mining
Oil and gas extraction
Data processing, internet publishing, and other information services
Motion picture and sound recording industries
Broadcasting and telecommunications
Computer and electronic products
-0.001
-0.0005
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
Average Annual Log Growth
Contr Goods
Contr Services
Contribution Foreign
Contribution Imports

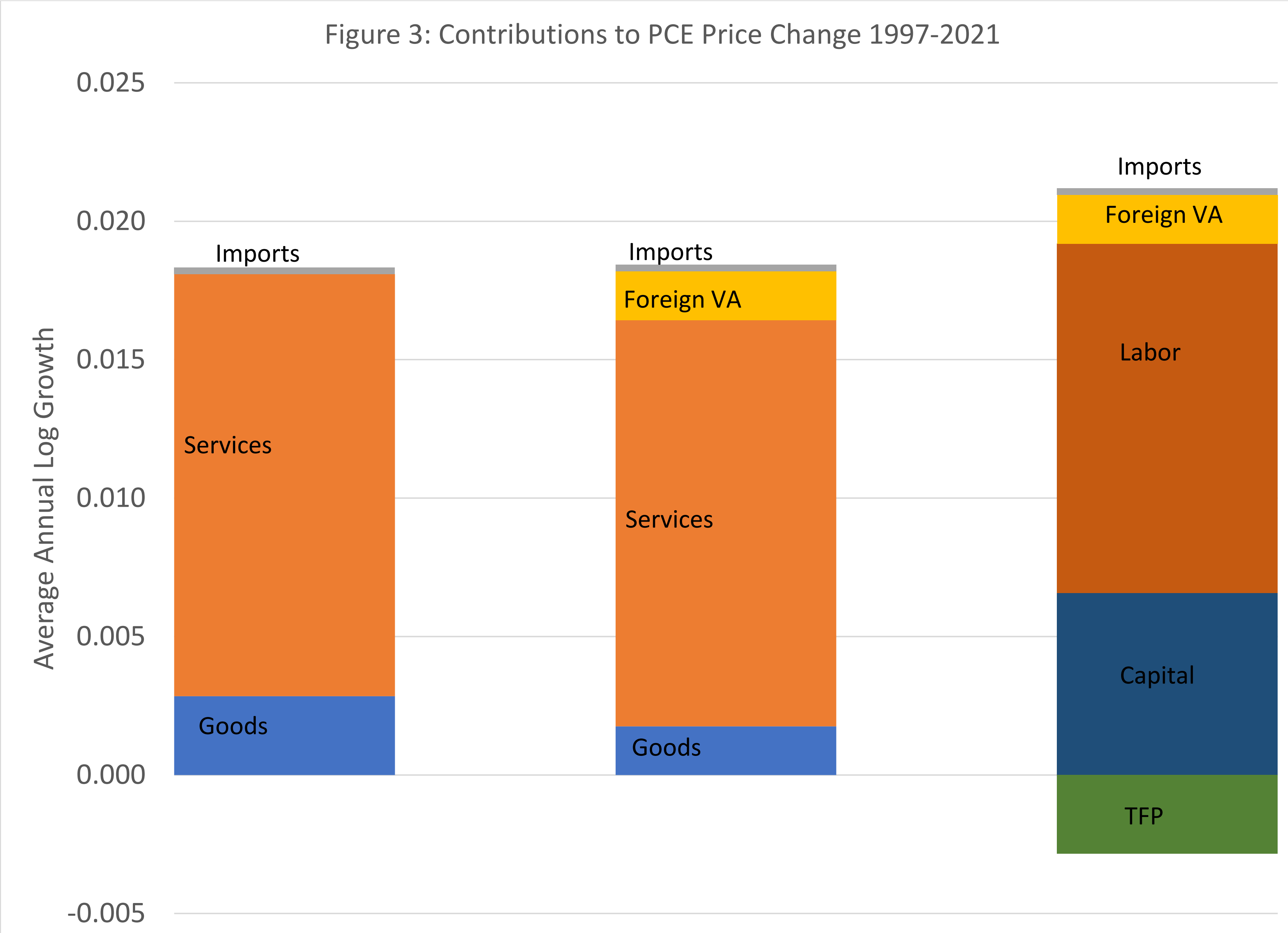
Figure 3: Contributions to PCE Price Change 1997-2021
Average Annual Log Growth
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
Imports
Services
Goods
Imports
Foreign VA
Services
Goods
Imports
Foreign VA
Labor
Capital
TFP

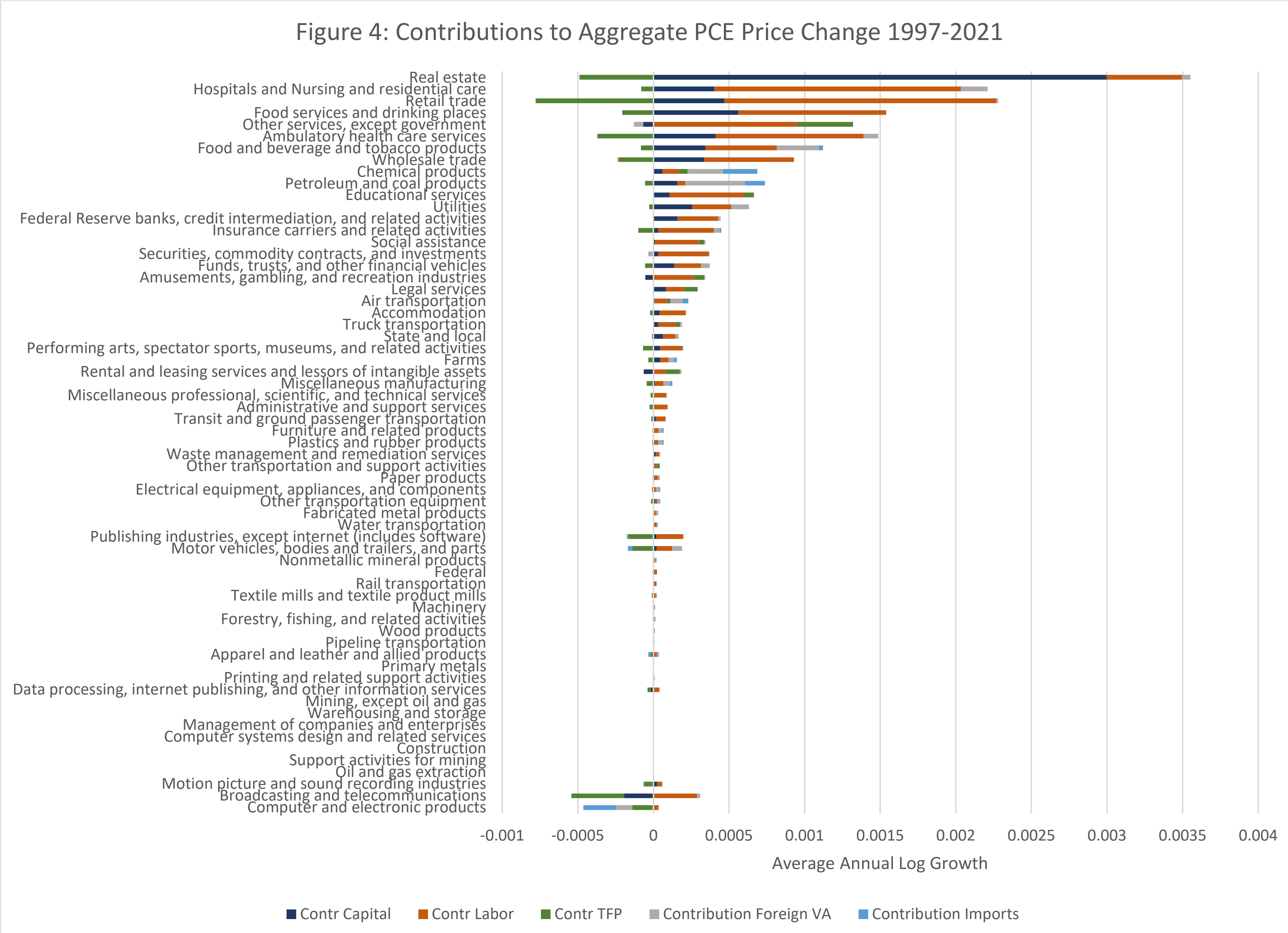

Figure 4: Contributions to Aggregate PCE Price Change 1997-2021
Real estate
Hospitals and Nursing and residential care
Retail trade
Food services and drinking places
Other services, except government
Ambulatory health care services
Food and beverage and tobacco products
Wholesale trade
Chemical products
Petroleum and coal products
Educational services
Utilities
Federal Reserve banks, credit intermediation, and related activities
Insurance carriers and related activities
Social assistance
Securities, commodity contracts, and investments
Funds, trusts, and other financial vehicles
Amusements, gambling, and recreation industries
Legal services
Air transportation
Accommodation
Truck transportation
State and local
Performing arts, spectator sports, museums, and related activities
Farms
Rental and leasing services and lessors of intangible assets
Miscellaneous manufacturing
Miscellaneous professional, scientific, and technical services
Administrative and support services
Transit and ground passenger transportation
Furniture and related products
Plastics and rubber products
Waste management and remediation services
Other transportation and support activities
Paper products
Electrical equipment, appliances, and components
Other transportation equipment
Fabricated metal products
Water transportation
Publishing industries, except internet (includes software)
Motor vehicles, bodies and trailers, and parts
Nonmetallic mineral products
Federal
Rail transportation
Textile mills and textile product mills
Machinery
Forestry, fishing, and related activities
Wood products
Pipeline transportation
Apparel and leather and allied products
Primary metals
Printing and related support activities
Data processing, internet publishing, and other information services
Mining, except oil and gas
Warehousing and storage
Management of companies and enterprises
Computer systems design and related services
Construction
Support activities for mining
Oil and gas extraction
Motion picture and sound recording industries
Broadcasting and telecommunications
Computer and electronic products
-0.001
-0.0005
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
Average Annual Log Growth
Contr Capital
Contr Labor
Contr TFP
Contribution Foreign VA
Contribution Imports