

Why Is Manufacturing Productivity Growth So Low?

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Abstract

We examine the recent slow growth in manufacturing productivity. We show that nearly all measured TFP growth since 1987—and its post-2000s decline—comes from a few computer-related industries. We argue conventional measures understate manufacturing productivity growth by failing to fully capture quality improvements. We compare consumer to producer and import price indices. In rapidly changing industries, consumer price indices indicate less inflation, suggesting mismeasurement in industry standard deflators. Using an input-output framework, we estimate that TFP growth is understated by 1.7 percentage points in durable manufacturing and 0.4 percentage points in nondurable manufacturing, with no mismeasurement in nonmanufacturing industries.

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After outpacing overall US productivity growth for decades, manufacturing productivity growth has collapsed. The Bureau of Labor Statistics (BLS) total factor productivity (TFP) index for the manufacturing sector increased by 1.2% per year between 1987 and 2009, faster than the 0.9% TFP growth rate for the overall private economy. Between 2009 and 2023, manufacturing TFP *fell* ever so slightly, even as private economy TFP maintained a 0.8% annual growth rate.

The leader-follower flip we highlight has not garnered much research attention until recently, and is still not well understood. The manufacturing sector’s considerable size makes its productivity performance of inherent interest. The concern raised by this stagnation is heightened by the fact that manufacturing typically punches above its weight in innovative activity, at least by some common metrics (R&D spending and patenting, in particular). This means that there is considerable potential for productivity growth patterns in manufacturing to spill over to other parts of the economy. If the sector’s productivity growth slows down, there could be broader implications for economy-wide growth as well.

In this paper, we introduce a price-based dual approach—contrasting consumer-facing and producer-facing price indices—to assess measurement in real output and TFP growth. We begin our analysis by documenting that, while productivity growth slowdowns are observed in multiple manufacturing industries, most of the measured sector-wide stagnation is quantitatively explained by productivity changes in Computer and Electronic Products Manufacturing (NAICS 334). In fact, nearly all of the manufacturing sector’s productivity growth since 1987—and its deceleration since 2009—can be attributed to this single 3-digit industry.

We then show that consumer price indices for computers and electronic products indicate less inflation than do corresponding producer and import price indices. This pattern is consistent with too little quality improvements being incorporated into producer and import price indices. We demonstrate this pattern holds more broadly. We compare Bureau of Economic Analysis (BEA) industry gross output deflators and BLS import price indices to corresponding category deflators within the personal consumption expenditures (PCE) price index. We find that inflation according to PCE price indices is substantially less than what gross output deflators and import price indices would indicate. This difference exists only within manufacturing and is concentrated within durable goods manufacturing, especially so for durable goods experiencing the greatest quality adjustments. Overall, annual price changes of durable goods are 2.6 percentage points greater when using gross output deflators and import price indices than when using PCE price indices.

In a final step of our analysis, we consider the implications of these differences for mis-measurement in productivity. Under the interpretation that price indices measuring con-

sumers’ experiences of inflation more comprehensively measure quality improvements than price indices measuring producers’ experiences of inflation, real output growth is likely understated for durable goods manufacturing industries using conventional national accounts data. However, by the same token, intermediate input price growth is also understated for these industries. Using BEA Input-Output matrices to parse these offsetting effects, we find that manufacturing TFP growth (from 1997 to 2023) is understated by 0.8 percentage points: 1.7 percentage points for durable goods industries and 0.4 percentage points for nondurable goods manufacturing industries. By contrast, TFP growth in nonmanufacturing industries is slightly *overstated*, by 0.1 percentage points annually. TFP mismeasurement is slightly larger before 2009 than after.

In sum, correcting for the under-counting of quality improvements implies that manufacturing TFP growth has continued to grow since the late 2000s, even if this growth rate has slowed. Our corrections matter most for ICT-related industries, but are pertinent for the rest of manufacturing as well.¹

Our results reshape our understanding of research on innovation and on the desirability of public policies targeting the manufacturing sector. In terms of the academic literature, recent research has highlighted the manufacturing sector’s over-representation in innovation: It accounts for only one-tenth of aggregate employment, but more than two-thirds of corporate patents and R&D spending (Autor et al., 2020; Fort et al., 2020). Given this, stagnant manufacturing productivity presents something of a puzzle (Lashkari and Pearce, 2024, 2025). We argue that much of this apparent stagnation can be explained by properly accounting for quality improvements. In terms of policy, over the last several decades, the US federal government has enacted several programs to boost manufacturing productivity growth, spending many billions of dollars annually.² These programs are premised on the pivotal role

¹In the appendix, we explore whether any ICT-related nonmanufacturing industries share the distinctive features of Computer and Electronic Products Manufacturing—its steep productivity decline, its large producer-vs.-consumer price gaps, and its employment of a substantial share of production workers. While Software Publishing and ICT-related wholesale industries share one or two of these features, none match Computer and Electronic Products Manufacturing on all three dimensions. See Appendix E.

²These programs include SEMATECH (a public-private partnership established in 1987), the Manufacturing Extension Partnership (1988), the Advanced Manufacturing Partnership (initiated in 2011), and Manufacturing USA (formed in 2014). See <https://web.archive.org/web/20130702191328/http://www.sematech.org/corporate/history.htm>, <https://www.nist.gov/mep>, <https://obamawhitehouse.archives.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership>, and <https://www.manufacturingusa.com/pages/history> for more details on each program. In addition, the American Recovery and Reinvestment Act of 2009 and the 2022 CHIPS ACT (2022) provided tens of billions for firms for, respectively, energy-related and semiconductor production. See <https://obamawhitehouse.archives.gov/blog/2010/04/21/impact-american-recovery-and-reinvestment-act-clean-energy-transformation>, and <https://www.congress.gov/crs-product/R47523>.

that the manufacturing sector plays in national security, in global trade, and in generating high-quality jobs for people without a college degree. To the extent that these policies are judged on the basis of boosting productivity, past assessments may have presented an overly negative depiction of their success.

Related Literature This paper builds on a literature interrogating the measurement of real output growth and a related literature on the manufacturing productivity slowdown.

Specific to the manufacturing productivity slowdown, [Syverson \(2016\)](#) documents that the Computer and Electronic Products Manufacturing industry was key to the 1995–2004 productivity resurgence and the subsequent productivity slowdown. These results are echoed by [Sprague \(2021\)](#).³ By contrast, [Lashkari and Pearce \(2024; 2025\)](#) consider the slowdown in productivity growth, but argue that it is “broad based.” They find that the contrast between the high (and increasing) R&D intensity and the slow productivity growth of the manufacturing sector is “puzzling”. Our results in [Section 1](#) more closely align with [Syverson \(2016\)](#) and [Sprague \(2021\)](#), though we emphasize the central role of the Computer and Electronic Products Manufacturing industry even more so than these earlier works. Finally, by showing that manufacturing TFP growth is materially understated, our results in [Sections 2 and 3](#) provide one resolution to the puzzle proposed in [Lashkari and Pearce \(2025\)](#).

Second, our work contributes to the literature assessing biases in government-produced price indices and in applying these indices to measure improving living standards. [Groshen et al. \(2017\)](#) provide a recent overview of efforts at the BEA and BLS toward measuring quality improvements and the contribution of new products to real output growth. [Byrne et al. \(2016\)](#) and [Syverson \(2017\)](#) examine the “mismeasurement hypothesis”—the idea that aggregate growth is increasingly mismeasured either due to price deflators that (increasingly) do not properly reflect quality growth or due to the proliferation of goods and services that are sold for free and thus do not enter in the measurement of real output. While not seeking to explain the aggregate slowdown, [Brynjolfsson et al. \(2025\)](#) estimate substantial consumer welfare gains from the introduction of Facebook and the development of smartphone cameras, above and beyond what is captured by the consumer price index. We share with these articles the idea that price indices may understate quality improvements, especially for goods and services linked to information and communication technologies. Distinct from [Byrne et al. \(2016\)](#) and [Syverson \(2017\)](#), we do not seek to measure why productivity growth has slowed down. Rather, we attempt to estimate mismeasurement in productivity growth that

³[Houseman \(2018\)](#) considers the special role that the Computer and Electronic Products industry played in the decline of the manufacturing sector’s employment. She notes that, from the 1980s onward, manufacturing real output and labor productivity growth would have been much weaker without the Computer and Electronic Products industry.

differs between the manufacturing and nonmanufacturing sectors. Distinct from all of these studies, we do not seek to estimate mismeasurement in the CPI. Instead, our contribution is to apply consumer price indices—which, to be sure, face challenges in measurement and interpretation—to learn about biases in producer price indices (and, in turn, gross output deflators).

Closer to our work, David Byrne and coauthors have examined the performance of producer price indices, focusing on individual information-and-communication technology (ICT) industries. [Byrne and Corrado \(2015a,b\)](#) compute significant biases in conventional producer price indices for communications equipment. [Byrne \(2015b\)](#) argues that BLS PPI may understate price declines in data storage equipment, potentially because of unmeasured increases in storage *within* a product’s life cycle. Along similar lines, [Byrne et al. \(2018\)](#) argue that the PPI for semiconductors vastly understates price declines—by more than 15 percentage points between 2000 and 2013—in that industry. They argue that the difference is primarily due to the lack of hedonic quality adjustment in the PPI. Partially in response to the publication of [Byrne et al. \(2018\)](#), the BLS has adopted hedonic quality adjustments in their PPI for semiconductors. Unlike these works, we seek to provide comprehensive economy-wide measures of these biases.

Finally, also with an aggregate focus, [Houseman et al. \(2011\)](#) argue that an “offshoring bias” may lead official statistics to *overstate* manufacturing productivity growth. In the 1990s and 2000s, US manufacturers substituted away from (relatively expensive) domestically sourced intermediate inputs to (relatively inexpensive) imported intermediate inputs. This substitution is not picked up in conventional input price indices, leading one to understate real purchases of the inputs that manufacturers use and, in turn, overstate productivity growth. In practice, [Houseman et al. \(2011\)](#) argue that this bias is on the order of 0.1 to 0.2 percentage points per year and is concentrated in the Computer and Electronic Products industry.

1 A Handful of Industries Are Responsible for Nearly All of the Manufacturing Sector’s TFP Trajectory

In this section, we argue that essentially all of the gains in manufacturing productivity since 1987 *and* the productivity growth stagnation since 2010 are due to a single 3-digit manufacturing industry: Computer and Electronic Products Manufacturing (NAICS 334).

To make this point, consider the following equation linking TFP growth in the manufacturing sector ($\Delta \log A_{t,M}$) to TFP growth in each of the sector’s constituent industries:

$(\Delta \log A_{t,j})$:⁴

$$\Delta \log A_{t,M} = \sum_{j \in \text{Manufacturing}} \omega_{tj} \Delta \log A_{t,j},$$

where ω_{tj} denotes industry j 's share of manufacturing output at time t . Both $\Delta \log A_{t,j}$ and ω_{tj} come from the BLS Major Sector and Major Industry Total Factor Productivity dataset.⁵

Figure 1 plots the average $\Delta \log A_{t,j}$ for each manufacturing industry j for each of three subperiods within the 1987 to 2023 sample. The clear outlier is the Computer and Electronic Products Manufacturing industry. Its TFP grew at an 8.3% annual rate from 1987 to 1997. It then decelerated, modestly, to a 7.4% clip between 1997 and 2009. From 2010 on, TFP growth has slowed to 0.8% per year. So, while productivity in the Computer and Electronic Products Manufacturing industry is still above average, it has slowed considerably compared to prior decades.⁶

Over the sample period, the Computer and Electronic Products industry's share of manufacturing output has followed an inverted-U shaped trajectory; see Appendix Figure A.3. It rose from 9.4% to 12.3% between 1987 and 2000, but has since fallen to 5.5% in 2023. Some of the slowdown in manufacturing productivity is therefore attributable to this high-productivity-growth industry's declining share of output.

It turns out that the combination of the Computer and Electronic Products industry's TFP growth slowdown and its shrinking size within the manufacturing sector can explain nearly 100% of the trajectory of the whole sector since the late 1980s. We make this point in Figure 2 by plotting the cumulative contribution to manufacturing productivity growth for all industries other than Computer and Electronic Products Manufacturing. This is defined as the cumulative total of:

$$\Delta \log A_{t,M}^c = \sum_{\substack{j \in \text{Manufacturing excluding} \\ \text{Computer and Electronic Products}}} \omega_{tj} \Delta \log A_{t,j},$$

⁴Throughout this paper, we focus on TFP as opposed to labor productivity or other possible productivity measures. This choice is motivated by the fact that an industry's TFP is more closely linked to its marginal cost of production and, as a result, its output price (though, as noted above, the manufacturing sector's productivity stagnation is also observed in labor productivity).

⁵See <https://www.bls.gov/productivity/data.htm> ; these data begin in 1987.

⁶In Appendix Table A.3, we consider which 4-digit industries are responsible for the deceleration of TFP growth in Computer and Electronic Products Manufacturing. Within this 3-digit industry, annual TFP growth in Computers and Peripheral Equipment (NAICS 3341) fell from 16.2% in 1997 to 2009 to 0.5% in 2009 to 2023. TFP growth in Semiconductors and Other Electronic Components (NAICS 3344) fell from 8.0% to 2.3%. Other 4-digit industries—accounting for roughly half of the output—within NAICS 334 already had TFP growth below 3% in the 1997 to 2009 period.

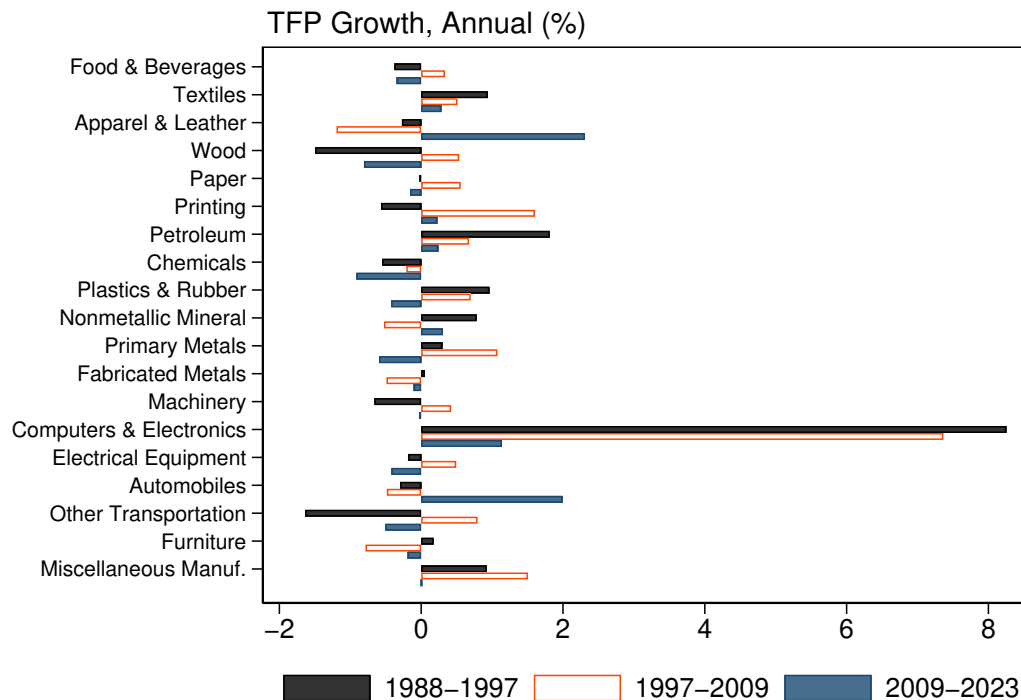


Figure 1: Annual TFP Growth Rate by 3-digit Manufacturing Industry

Notes: “Food & Beverages” is the collection of NAICS 311 and 312. “Textiles” is the collection of NAICS 313 and 314. “Apparel” is the collection of NAICS 315 and 316. “Automobiles” is the collection of NAICS 3361, 3362, and 3363. “Other Transportation” is the collection of NAICS 3364, 3365, 3366, and 3369. All other rows give the TFP growth rates for a single 3-digit NAICS industry.

from the beginning of the sample to year t . Figure 2 also plots TFP growth (relative to 1987) in both the manufacturing sector and the private economy.

Two patterns stand out in this figure. First, between 1987 and the late 2000s, TFP growth was faster in manufacturing than in the rest of the economy. This flipped in the mid-to-late 2000s, when manufacturing productivity growth collapsed while TFP for the broader private business sector grew by more than 8%. Second, Computer and Electronic Products Manufacturing accounted for nearly all of the manufacturing sector’s productivity growth between 1987 and 2009. With the exception of a few years of modest TFP growth during the early 2000s, all other manufacturing industries combined saw basically zero TFP growth over the sample.

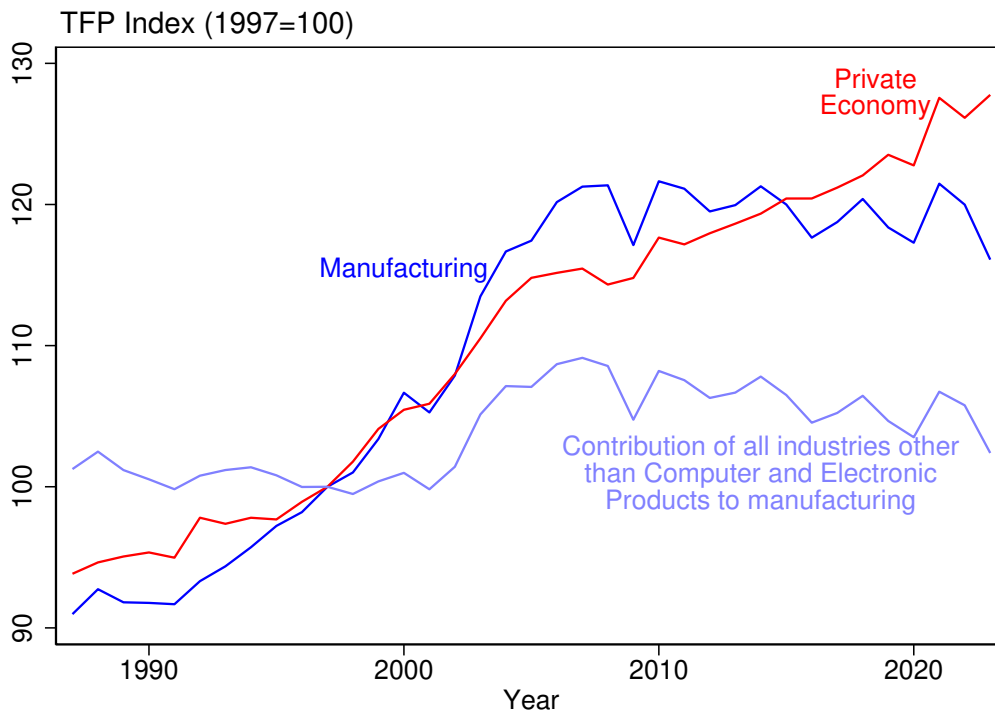


Figure 2: TFP for Manufacturing, Manufacturing excluding Computer and Electronic Products, and the Private Business Sector

2 For Computer and Electronic Products, Producer and Import Price Indices Suggest Less Quality Growth Than Do Consumer Price Indices

In this section, we relate industry gross output deflators and import price indices to components of the PCE price index. We find that, for rapidly innovating durable goods industries, the PCE price index shows much larger price declines than the other two price indices. From this pattern, we infer that gross output deflators understate quality growth within durable goods manufacturing.

Our primary comparison in this section is of the PCE price index against the BEA industry gross output deflators and BLS import price index. The components of the PCE price index come from National Income and Product Accounts (NIPA) Table 2.4.4U (which contain price indices for 212 consumption categories). The gross output deflator, also constructed by the BEA, measures changes in the price of industries' (domestically produced) output.⁷ Beginning in 1997, the data cover 414 detailed industries. Finally, we use the BLS import price index to measure changes in the price of imported commodities.⁸

⁷See worksheet UGO304-A within <https://apps.bea.gov/industry/Release/XLS/UGdpxInd/GrossOutput.xlsx>.

⁸These indices measure price changes using various industry and commodity categorizations. To provide

In computing industries’ gross output deflators, the BEA uses the PPI (produced by the BLS) for most industries across all sectors, and essentially all industries within the manufacturing sector; see Appendix Table A.1. By contrast, in constructing its PCE price index, the BEA relies on the CPI (also produced by the BLS) for essentially all manufactured goods and for a majority of all consumption categories. So, methodological differences between the CPI and PPI will be key.

We divide these methodological differences into what the indices aim to measure and how they account for quality improvements over time. Regarding the former, aiming to characterize inflation from the household’s perspective, the CPI measures price changes for domestically produced and imported commodities, inclusive of margins paid to wholesalers, retailers, and firms in transportation and warehousing. By contrast, aiming to characterize inflation from the producer’s perspective, the PPI measures price changes for only domestically produced commodities, excluding distribution margins.

Regarding differences in quality adjustment procedures, the BLS invests significantly—in its survey design, in its data collection efforts, and in its statistical and economic methodology—to ensure *all* of its price measures provide accurate and representative depictions of inflation experienced by households and firms. But, given its finite budget, some prioritization must inevitably be made in where BLS resources are allocated. Given the BLS’s frequent reference to the CPI as the “nation’s principal gauge of inflation”⁹ as well as the many government programs whose parameters are directly tied to the CPI, we hypothesize that the CPI may better confront the perennially challenging task of adjusting for quality improvements over time.¹⁰

Consistent with this, consider how the BLS measures quality adjustment for commodities with rapid technological change. For these commodities, the BLS preferred method to identify quality changes involves “hedonic quality adjustment”. In this method, for a given product category, researchers at the BLS determine the set of relevant product characteristics. They then apply a regression model to estimate consumers’ valuation for—or, in the case of the PPI, the additional costs associated with—these characteristics. The BLS applies

the cleanest match to other data series used in this paper, we apply the version measuring inflation by NAICS commodity. These data begin in 2006 and cover nearly all commodities produced by the manufacturing sector, though only a handful of nonmanufactured products.

⁹See page 47 of the most recent Annual Performance Report of the Department of Labor—<https://www.dol.gov/sites/dolgov/files/general/budget/2024/FY2024APR.pdf>—or page 39 of the most recent budget request for the Department of Labor—<https://www.dol.gov/sites/dolgov/files/general/budget/2025/CBJ-2025-V3-01.pdf>.

¹⁰Among other things, the CPI helps determine IRS federal income tax brackets, eligibility thresholds for the Earned Income Tax Credit, and Social Security benefits to retirees; see <https://www.dol.gov/sites/dolgov/files/general/budget/2024/CBJ-2024-V3-01.pdf>.

this hedonic quality adjustment to multiple CPI product categories—in various apparel, electronics, and housing categories—but in only three narrow PPI product categories: computers (NAICS 334111), microprocessors (NAICS 334413), and broadband internet access (517311) with the latter two introduced only in 2016 and 2018 (Sawyer and So, 2018). By contrast, the BLS applies hedonic adjustments to 36 of the 273 entry level items in the CPI.^{11,12,13}

For these reasons, we take any differences between the CPI and PPI/import price index as suggestive evidence of incomplete quality adjustment in the latter indices, especially so if these differences are concentrated in goods experiencing rapid technological progress. The same premise will apply to comparisons of indices derived from the CPI and PPI, such as the PCE price index and the BEA’s industry gross output deflators.

Having spelled out the different aims and methodological foundations for the various price indices, in Figure 3 we show for a single consumption category—Televisions (NIPA Line 41)—how inflation rates vary between the consumer and producer perspectives.¹⁴ For each year between 1997 and 2023, the vertical axis plots the change in prices according to the PCE price index. Over this 26-year period, the average price change was -15.4% per year. On the horizontal axis, we present the gross output deflator (orange filled circles with the year listed) and the import price index (blue hollow circles without the year), with the latter first published in 2005. The gross output deflator for the corresponding industry—Audio and Video Equipment Manufacturing, NAICS 3343—fell by only 1.1% between 1997 and 2023, while the import price index fell by 2.9%, annually, since 2005. Some of the difference between PCE inflation and gross output or import price inflation likely reflects the inclusion of

¹¹See Appendix A for a list of commodities for which the BLS applies hedonic quality adjustment in the PPI and CPI.

¹²Byrne et al. (2016, p.123) note that the hedonic quality adjustments the BLS employs for the PPI may omit design improvements that raise the value of product to consumers that are not clearly tied to costs or not easily identified in technical specifications. As a result, the PPI quality adjustments may be less impactful than those for the CPI.

¹³Another salient difference between the price indices, one which is not necessarily related to quality adjustment, the CPI applies a geometric mean formula when combining price changes of individual products within a product category whereas the PPI applies a Laspeyres formula (an arithmetic mean.) Dalton et al. (1998) estimates that using a geometric mean formula—instead of an arithmetic mean formula—leads to a 0.2 percentage point reduction in the reported aggregate CPI inflation rate.

¹⁴Despite the near-total offshoring of mass-market television processing and assembly since the early 2000s, domestic manufacturing still accounts for a substantial share of personal consumption of TVs. Indeed, as of 2017—the most recent date for which the BEA produced detailed input-output tables—less than half, approximately 44%, of Audio and Video Equipment Manufacturing (NAICS 3343) personal consumption expenditures came from imports. Much of the domestic Computer and Electronic Products Manufacturing industry now either focuses on producing special-purpose electronics (Byrne, 2015a) or—for general-purpose electronics—on engineering, computing, and design, with assembly largely occurring overseas. As of 2023, production occupations account for roughly a quarter of Computer and Electronic Products Manufacturing employment. See Appendix D.2 for more details.

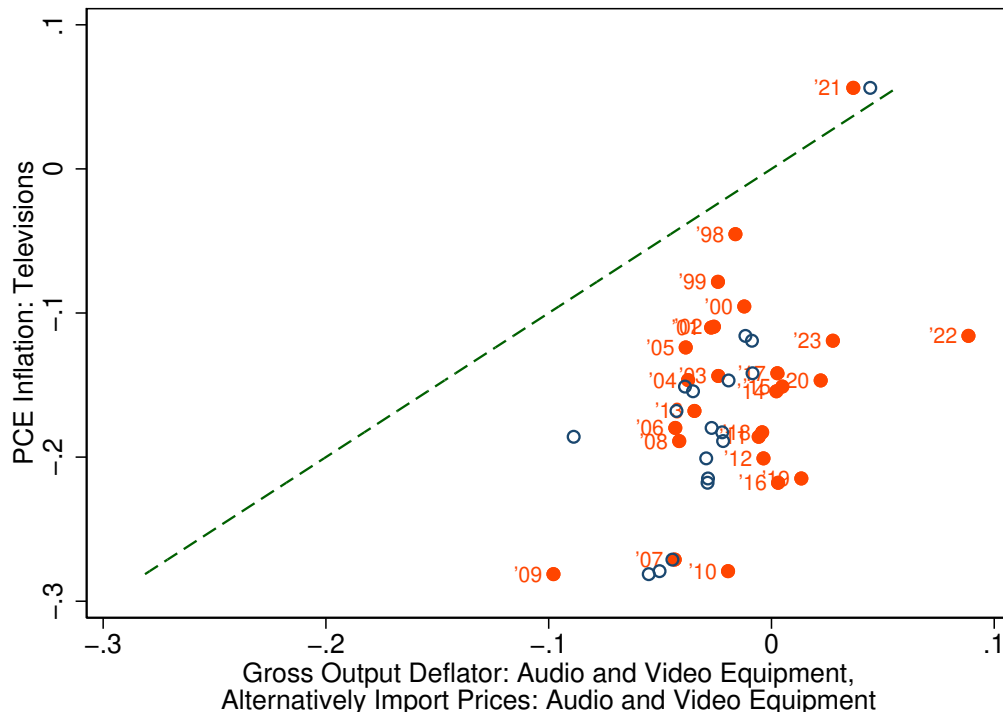


Figure 3: Television Inflation

Notes: The vertical axis gives Television inflation according to the PCE price index. The horizontal axis gives two measures of producer inflation. In orange filled circles, we plot changes in the gross output deflator for the Audio and Video Equipment Manufacturing industry (NAICS 3343). For this data series, we write out the corresponding year as well. The listed year, t , refers to the price growth between years $t - 1$ and t (e.g., the point for '14 refers to price growth between 2013 and 2014). The import price index for Audio and Video Equipment Manufacturing is plotted using hollow blue circles without listing the year. This latter data series begins in 2005 only.

Audio Equipment and Other Video Equipment in the latter two measures. However, PCE inflation for these other categories were also exceptionally low: -4.8% for Audio Equipment and -9.4% for Other Video Equipment. So, for Televisions and Other Audio and Video Equipment, PCE deflation is vastly greater than deflation according to price indices from the producer perspective.

In Figure 4, we expand the scope of analysis beyond Televisions. For each PCE category, the vertical axis gives the average annual price growth between 1997 and 2023. The horizontal axis gives our attempt at re-creating the corresponding measure of inflation but using gross output deflators and import price indices.¹⁵ Each PCE category may comprise multiple

¹⁵For 1997 to 2005, we impute commodities' import price growth using the 2005-to-2023 historical relationship between gross output deflator price growth and import price growth. In more detail, for 2005 to 2023, we estimate a regression with the commodity j summand into Equation 1—namely,

distinct commodities, and each commodity may be produced domestically or imported. We use the PCE Bridge Table to assign weights to each commodity. For each component of the PCE price index, the PCE Bridge Table lists the contribution of individual commodities, the latter of which are measured using the NAICS commodity system. This table also lists the contribution of the transportation, wholesale, and retail sectors to the value of each PCE category.¹⁶ We use the Input-Output Tables to assign weights for domestic production vs. imports.¹⁷

Written out explicitly, we use the term “Producer Inflation” to refer to this weighted average of deflators:

$$\Delta \log P_{t,c}^{\text{Producer}} = \sum_j s_{t,j \rightarrow c} \left[(1 - m_{t,j}) \Delta \log P_{t,j}^{\text{GO}} + m_{t,j} \Delta \log P_{t,j}^{\text{Import}} \right], \quad (1)$$

where c indexes a PCE category, j a NAICS commodity, $s_{j \rightarrow c}$ gives the share of PCE category c that is made up of commodity j , and $m_{t,j}$ equals the share of personal consumption expenditures of commodity j that comes from imports. For each category, we use the finest level of commodity detail that is available. In some instances—for example, in Telephone Apparatuses category—the level of aggregation is coarser in the import price index (where it is defined only at the 4-digit NAICS level) than in the BEA industry gross output deflator (where information at the 5-digit NAICS is available).

For the most part, looking across PCE categories and averaging over the 1997–2023 sample, PCE inflation is highly correlated to changes in $\Delta \log P_t^{\text{Producer}}$. The (consumption-weighted) correlation across the two measures is 0.75. Our Producer Inflation measure exceeds PCE by 0.5 percentage point overall, but with much larger gaps in nondurable

$(1 - m_{t,j}) \Delta \log P_{t,j}^{\text{GO}} + m_{t,j} \Delta \log P_{t,j}^{\text{Import}}$ —as the dependent variable. The two explanatory variables are (i) gross output price growth, $\Delta \log P_{t,j}^{\text{GO}}$, and (ii) the interaction of import price growth and the import share of PCE, $m_{t,j} \Delta \log P_{t,j}^{\text{GO}}$. We restrict the intercept of the regression to be equal to 0. The estimated coefficients on the two explanatory variables are 0.998 and -0.736. The R-Squared on the regression is 0.994. If we further restrict the coefficient on $\Delta \log P_{t,j}^{\text{GO}}$ to be equal to 1, the coefficient on the interaction term is -0.743. Given this, for each year between 1997 and 2005, we impute $(1 - m_{t,j}) \Delta \log P_{t,j}^{\text{GO}} + m_{t,j} \Delta \log P_{t,j}^{\text{Import}}$ as $\Delta \log P_{t,j}^{\text{GO}} - 0.743 \cdot m_{t,j} \Delta \log P_{t,j}^{\text{GO}}$.

¹⁶These data are produced at the same level of detail as the data on gross output deflators and PCE inflation for 2007, 2012, and 2017 and at a higher level of aggregation for all years beginning in 1997. In Appendix B, we discuss how we combine detailed and more aggregated PCE Bridge Tables to construct estimates of commodity-to-consumption category linkages for each year at the more detailed 414-commodity-by-212 consumption category level.

¹⁷See <https://www.bea.gov/industry/input-output-accounts-data>. These tables contain information on total personal consumption expenditures as well as imported personal consumption expenditures—at a 71-industry level of aggregation for each year beginning in 1997 and a more detailed 402-industry level of aggregation for 2007, 2012, and 2017. We, again, combine the two data sets to infer industry-by-commodity measures at the more detailed level of aggregation for all years beginning in 1997. See Appendix B for a discussion of how we do so.

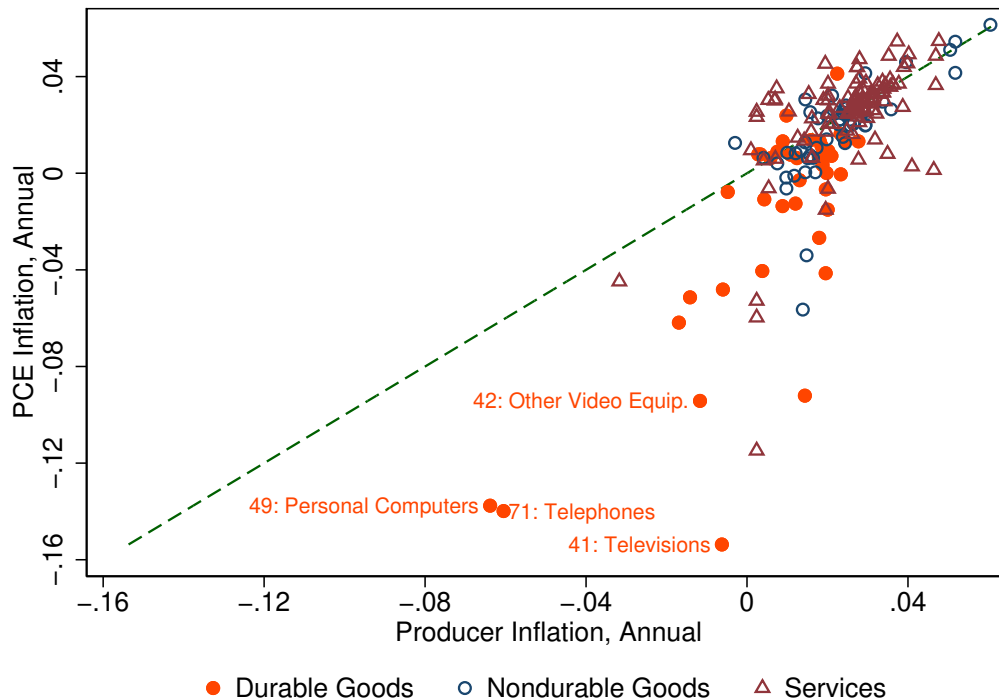


Figure 4: Two Measures of Inflation Across PCE Categories, 1997–2023

Notes: Each point is a single PCE category. The vertical axis gives annual inflation according to the PCE price index between 1997 and 2023. The horizontal axis gives our measure of Producer Inflation (defined by Equation 1) over the same period. For the four data points in the bottom of the figure, the number preceding the colon is the NIPA line number.

goods (where the gap is 1.1 percentage points) and durable goods (with a 2.6 percentage point gap.) We see the largest gaps in computers and other consumer electronics. Between 1997 and 2023, PCE inflation ranges between -9.4% and -15.4% for Televisions, Other Video Equipment, Personal Computers, and Telephones. By contrast, our “Producer Inflation” measure for these four consumption categories shows much more modest price declines, ranging from -6.7% Producer Inflation for Personal Computers to -0.6% for Televisions.

Our preferred interpretation of these patterns is that output price indices—like the BEA’s gross output deflator—insufficiently account for quality improvements in high-tech products. As a result, growth in real output and productivity growth in these industries may be understated. Even if gross output deflators overstate durable goods inflation by 2.6 percentage points, we do not believe that TFP growth is understated by this amount. After all, similar considerations would imply that durable goods input price growth is understated. Accounting for this would partially offset the 2.6 percentage point gap that we have highlighted. In the next section, using the BEA’s input-output tables we estimate the extent to which TFP

growth may be overstated for goods-manufacturing industries.¹⁸

3 Manufacturing TFP Growth May Be Understated 0.8 Percentage Points

In the final step of our analysis, we consider the implications of mismeasured gross output deflators for TFP growth. We apply the following accounting relationship between gross output prices, input prices, and TFP:

$$\begin{aligned}
\Delta \log A_{t,j} &= -\Delta \log P_{t,j}^{\text{GO}} + \Delta \log P_{t,j}^{\text{Input}} \\
&= -\Delta \log P_{t,j}^{\text{GO}} + \gamma_{w \rightarrow j,t} \Delta \log w_{t,j} + \gamma_{r \rightarrow j,t} \Delta \log r_{t,j} \\
&\quad + \sum_{i=1}^N \gamma_{t,i \rightarrow j} \left[(1 - m_{t,i}) \Delta \log P_{t,i}^{\text{GO}} + m_{t,i} \Delta \log P_{t,i}^{\text{Import}} \right] \\
\Delta \log \mathbf{A}_t &= -\Delta \log \mathbf{P}_t^{\text{GO}} + \gamma_{w,t} \Delta \log \mathbf{w}_t + \gamma_{r,t} \Delta \log \mathbf{r}_t + \\
&\quad \mathbf{\Gamma}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}} \right].
\end{aligned} \tag{2}$$

According to this equation, industries are more productive when they are able to produce at lower cost given the price of the inputs that they use. The second line breaks out changes in industry j 's input price growth into the price growth of labor, capital, and individual intermediate inputs, i . The final line writes this equation in vector notation. Here, the “ \circ ” operator denotes element-wise multiplication.

Below, we use $\tilde{\mathbf{x}}$ to refer to mismeasurement in variable \mathbf{x} . Since our preceding analysis did not pertain to mismeasurement in unit labor costs or the rental price of capital, we assume $\Delta \log \tilde{\mathbf{r}}_t = \Delta \log \tilde{\mathbf{w}}_t = 0$. With this assumption, Equation 2 implies:

$$\Delta \log \tilde{\mathbf{A}}_t = -\Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} + \mathbf{\Gamma}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \tilde{\mathbf{P}}_t^{\text{Import}} \right]. \tag{3}$$

Our second building block comes from comparing Producer Inflation—defined in Section 2—and PCE inflation. We attribute differences between PCE and Producer Inflation to

¹⁸An alternative interpretation is that producer-consumer price gaps reflect falling retail markups, particularly in electronics. Data from the Annual Retail Trade Survey indicate that retailers gross margins *increased* (albeit modestly, by 0.16 percentage points per year between 1997 and 2022), with a similar increase in Electronics and Appliance Stores and the broader retail sector. See <https://www2.census.gov/programs-surveys/arts/tables/2022restated/gmper.xlsx>

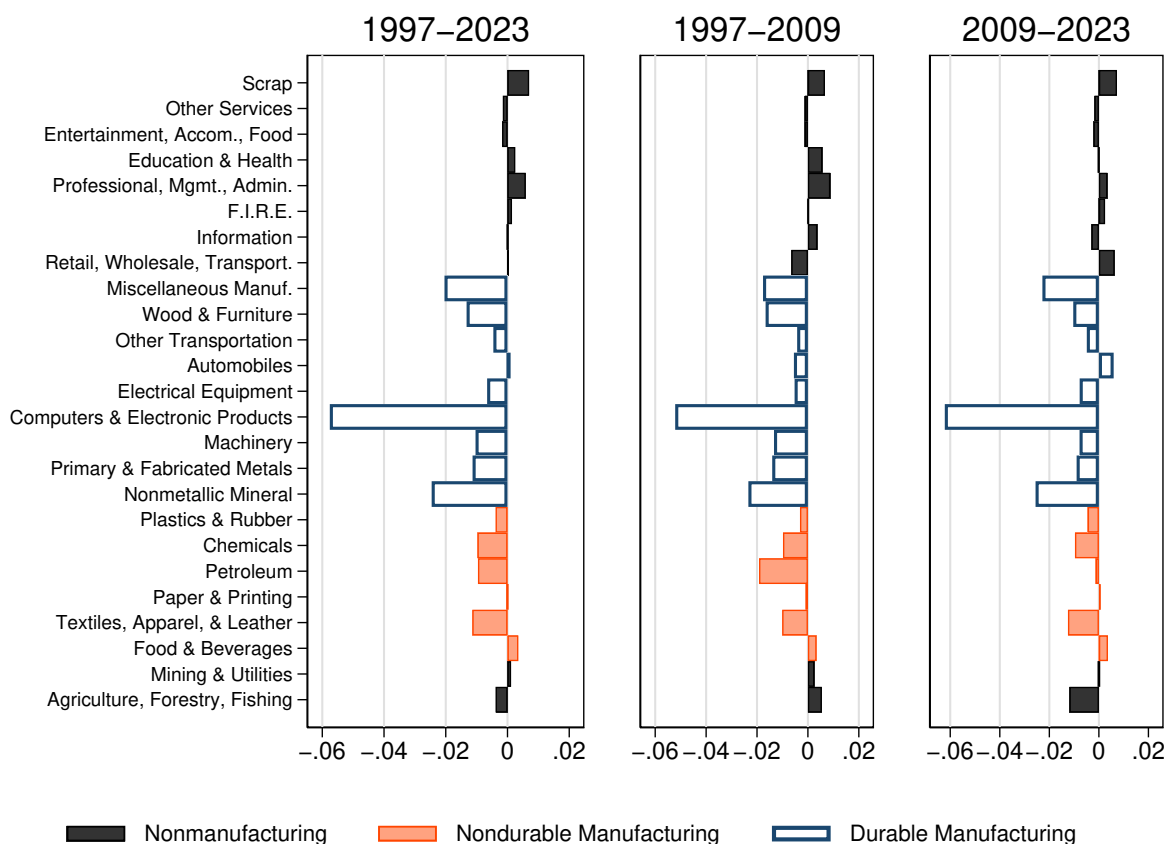


Figure 5: TFP Mismeasurement

Notes: We apply Equation 7 to recover the mismeasurement in TFP by industry and year. We average these variables by broad sector and years, weighting industries according to their gross output within each year. Compared to Figure 2, we combine the following, where at least one of the industries has a small share of its output sold as personal consumption: We combine Wood (NAICS 321) and Lumber (NAICS 337); Textiles (NAICS 313-314) and Clothing and Leather (NAICS 315-316); Paper (NAICS 322) and Printing (NAICS 323); and Primary Metals (NAICS 331) and Fabricated Metals (NAICS 332).

mismeasurement in import price indices and gross output deflators:

$$\begin{aligned} \Delta \log P_{t,c}^{\text{PCE}} = & \sum_j s_{t,j \rightarrow c} \left[(1 - m_{t,j}) \left(\Delta \log P_{t,j}^{\text{GO}} + \Delta \log \tilde{P}_{t,j}^{\text{GO}} \right) \right. \\ & \left. + m_{t,j} \left(\Delta \log P_{t,j}^{\text{Import}} + \Delta \log \tilde{P}_{t,j}^{\text{Import}} \right) \right] . \end{aligned} \quad (4)$$

We write this equation in matrix form:

$$\begin{aligned} \Delta \log \mathbf{P}_t^{\text{PCE}} = & \mathbf{S}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \left(\Delta \log \mathbf{P}_t^{\text{GO}} + \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} \right) \right. \\ & \left. \mathbf{m}_t \circ \left(\Delta \log \mathbf{P}_t^{\text{Import}} + \Delta \log \tilde{\mathbf{P}}_t^{\text{Import}} \right) \right] . \end{aligned} \quad (5)$$

This implies that we can write mismeasurement in output deflators and import price indices as:

$$\begin{aligned} (\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \tilde{\mathbf{P}}_t^{\text{Import}} = & \mathbf{O}_t \left[\Delta \log \mathbf{P}_t^{\text{PCE}} \right. \\ & \left. - \mathbf{S}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}} \right] \right] . \end{aligned} \quad (6)$$

Above, \mathbf{O}_t is a matrix that transforms mismeasurement in “consumption category” space to “NAICS commodity” space. In our baseline calculations, presented below, row j and column c elements of \mathbf{O}_t are equal to 1 if PCE category c has the largest value in the PCE Bridge Table for NAICS commodity j .

If we assume that mismeasurement in gross output deflators equals mismeasurement in import price indices, we can combine Equations 3 and 6 to infer mismeasurement in productivity:

$$\begin{aligned} \Delta \log \tilde{\mathbf{A}}_t = & -[\mathbf{I} - \mathbf{\Gamma}_t] \mathbf{O}_t \left[\Delta \log \mathbf{P}_t^{\text{PCE}} \right. \\ & \left. - \mathbf{S}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}} \right] \right] . \end{aligned} \quad (7)$$

We apply Equation 7 using data from 1997 to 2023. We highlight four main results. First, within the durable goods manufacturing industry, TFP is understated for the Computer and Electronic products industry, by 5.8 percentage points per year. Second, looking across sectors, TFP mismeasurement is greatest in the durable goods manufacturing sector (understated by 1.7 percentage points per year), much smaller in the nondurable goods manufacturing sector (understated by 0.4 percentage points per year), and essentially nonexistent in the nonmanufacturing sector (overstated by 0.1 percentage points per year.) Third, even though TFP mismeasurement was most severe in the Computer and Electronic Products industry, it is pervasive throughout manufacturing. Finally, mismeasurement of TFP growth

was slightly larger towards the beginning of the sample. So, while our corrections can explain why manufacturing TFP growth is so slow throughout the sample, they cannot explain why TFP growth has slowed down beginning around 2009.¹⁹

Adding our estimates of TFP mismeasurement in Figure 5 to observed TFP growth rates in Figure 1, we find continued TFP growth for the manufacturing sector since 2009, with a growth rate much closer to that of the rest of the private economy (even if this growth rate is appreciably slower than in early decades); see Figure 6 for the time series of corrected TFP. Our estimates imply that true TFP growth rate in the manufacturing sector was 0.6% between 2009 and 2023—1.9% in durable goods manufacturing industries and -0.1% in nondurable goods manufacturing industries. This is slower than TFP growth in the manufacturing sector between 1997 and 2009 (2.3%), but much stronger than what the official statistics would suggest.

Sensitivity Analyses To close this section, we discuss four sets of sensitivity analyses.

In Equation 1, we have excluded the wholesale, retail, and transport margins when summing over commodities j —that is, we include only entries from the “Producers’ Value” column of the PCE Bridge Table when computing $s_{t,j \rightarrow c}$. Under this (extreme) definition, price increases from distribution margins are excluded from Producer Inflation. In Appendix C, we consider an alternative: including distribution margins in proportion to columns F-H of the PCE Bridge Table. Under this alternate assumption, the gap between PCE inflation and Producer Inflation is at least as large as what is reported in Figure 4, with substantially larger gaps for durable goods industries. This, in turn, implies that TFP is understated for durable goods industries even more than what we report in Figure 5.

A potential concern with our approach is that, even aside from quality measurement issues, within the same detailed NAICS commodity consumer-facing products may have different inflation rates than business-facing products. For instance, it is conceivable that Broadcasting and Wireless Communications Equipment Manufacturing Equipment (NAICS 33422) sold to consumers (e.g., iPhones) has faster price declines than those sold to businesses (e.g., Cisco). In this scenario, we would erroneously attribute gaps between PCE and “Producer Inflation” to inadequate quality adjustment in the latter index. To explore this concern, in Appendix D.4, we progressively restrict the sample to NAICS commodities that have more of their sales sold as personal consumption expenditures. The patterns given in

¹⁹For the durable goods sector, the average of $\Delta \log \tilde{\mathbf{A}}_t$ was -1.9 percentage points between 1997 to 2009 and -1.5 percentage points between 2009 and 2023. For nondurable goods, $\Delta \log \tilde{\mathbf{A}}_t$ was (on average) -0.6 percentage points between 1997 and 2009 and -0.3 percentage points between 2009 and 2023. For the nonmanufacturing sector, the average of $\Delta \log \tilde{\mathbf{A}}_t$ was 0.2 percentage points between 1997 and 2009 and 0.0 percentage points between 2009 and 2023.

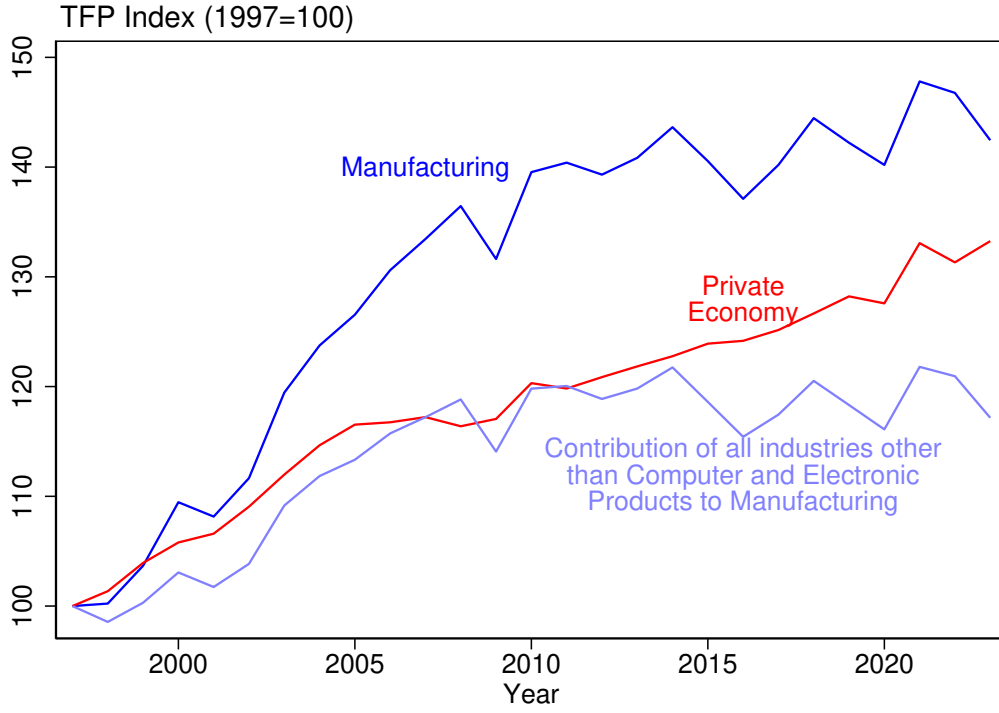


Figure 6: TFP for Manufacturing, Manufacturing excluding Computer and Electronic Products, and the Private Business Sector

Notes: This figure reproduces Figure 2, but correcting for TFP mismeasurement using the adjustments in this section.

Figure 5 are robust to these restrictions.

In Appendix D.5, we consider an alternate definition for row j and column c of the \mathbf{O}_t matrix: the contribution of NAICS commodity j to consumption category c , where each row is normalized to have sum equal to 1. Our results are unchanged with this alternate definition.

Finally, in Appendix D.6 we re-compute $\Delta \log \tilde{\mathbf{A}}_t$ under different assumptions on the relative mismeasurement of gross output deflator growth and import price growth. In our baseline calculations, we assume that mismeasurement in the two sets of inflation rates are equal. In Appendix D.6, we consider how our results would change if mismeasurement in import price growth was 25% (or 50%) larger than mismeasurement in gross output deflator growth. Under this alternate assumption, the TFP growth mismeasurement that we infer is smaller, but only modestly so. When import price growth mismeasurement is 50% larger than gross output deflator growth mismeasurement, we find that manufacturing TFP growth is understated by 0.7 percentage points (as opposed to 0.8 percentage points in the baseline calculations). As before nonmanufacturing TFP growth mismeasurement is, on average,

immaterial.

4 Conclusion

In contrast to decades prior, beginning in the late 2000s manufacturing productivity growth started to fall behind productivity growth elsewhere. This article investigates the sources of this pattern from two angles. The first half of the article documents that these trends can be explained by the resolution of the ICT revolution. Between 1987 and 2009, Computer manufacturing TFP grew by an astronomical 15% per year. Semiconductor manufacturing TFP grew by more than 11% per year. By the early 2010s, productivity growth in these industries had decelerated substantially. Were it not for the Computer and Electronic Products Manufacturing industry, productivity growth in the manufacturing sector would have been measured to be sluggish throughout the late 1980s, the 1990s, and the 2000s.

We then marshal suggestive evidence that quality improvements and, by implication, productivity growth may be substantially underestimated in durable goods manufacturing, primarily so in the manufacturing of computers and other electronic goods. We estimate that annual TFP growth in durable goods manufacturing may be understated by up to 1.7 percentage points and by 0.4 percentage points in nondurable goods manufacturing industries.

In interpreting these results, we sound a point of caution. Our approach to inferring quality growth mismeasurement is, by its nature, indirect: Rather than applying more comprehensive measures of product characteristics, we infer quality growth from discrepancies across price indices. We use household price indices—in particular the PCE—as a benchmark against which to infer quality mismeasurement. It is entirely conceivable that published producer price indices (and hence gross output deflators) provide the correct measure of real output growth and that consumer price indices *overstate* quality improvements in computers and other electronic goods. While possible, such a scenario would conflict with economists’ general presumption on the direction of quality biases (Moulton, 2024). It would also contradict the conclusions of the few studies that have detailed micro data on product characteristics and prices to measure biases in producer price indices (e.g., Byrne, 2015b; Byrne and Corrado, 2015a; Byrne et al., 2018.)

The US manufacturing sector has changed profoundly over the last quarter century. Its’ employment has collapsed, declining by more than one-quarter (even as private nonfarm employment has grown by more than one-quarter) since 1997.²⁰ It has grown more import-reliant, first from China and then from Vietnam and Mexico (Alfaro and Chor, 2023), more

²⁰See <https://fred.stlouisfed.org/series/MANEMP> and <https://fred.stlouisfed.org/series/PAYEMS>.

capital intensive,²¹ and more robot intensive (see Figure 5 of [Klump et al., 2021](#)). Assessments of these particular changes—and on the evolution of the manufacturing sector, more generally—hinge on properly measuring manufacturing real output and productivity. If quality improvements (and, hence, TFP) in goods manufacturing are understated, as our findings suggest, then conventional data sources may distort our understanding of the forces reshaping the manufacturing sector.

²¹See <https://fred.stlouisfed.org/series/MPU9900082> .

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A Discussion of Underlying Source Data and Quality Adjustment

In this appendix, we discuss the sources of inflation data, both from the household and producer perspectives. We first discuss the data sources that the BEA draws on when constructing the individual components of the PCE price index. We then discuss the data sources that the BEA draws on when constructing its industry gross output deflators. Each BEA dataset draws on multiple sources, and the data sources employed have changed somewhat since 1997. However, the PCE price index for goods almost exclusively has (throughout the sample period) drawn on the CPI. Manufacturing gross output deflators (also throughout the sample period) are derived from the PPI.

In the final portion of this appendix, we discuss changes in the methodology that the BLS has employed to produce its PPI and CPI. The two most important changes were (a) a steady expansion in the set of commodities covered in the PPI, concentrated in service industries; and (b) an increase in the number of commodities for which the BLS applies a hedonic adjustment to account for quality improvements over time. For both price indices, the increasing use of hedonic adjustments have occurred either before 2000 or beginning in the late 2010s. An implication of this discussion is that, since most methodological changes occurred in the service sector (or for service consumption categories), or either took place before the early 2000s or beginning in the late 2010s, they are unlikely to explain the deceleration in measured manufacturing productivity growth that occurred in the late 2000s.

Components of the PCE Price Index

For goods commodities, components of the PCE price index draw almost exclusively on the CPI. The three exceptions include Food Produced and Consumed on Farms (which draws on USDA prices received by farmers); Standard Clothing Issued to Military Personnel (which draws on the PPI line for Apparel); and Expenditures on Goods by US Residents Who are Abroad (which draw on the BEA index for installation support services.) For service commodities, while the CPI is the primary data source for many components of the PCE price index, a larger set of components draw on the PPI (examples include most financial service charges and fees, air transportation; hospitals, and physician services) and BEA input cost indices (examples include labor organization dues, life insurance, financial services furnished without payment, among others). For a comprehensive list of the sources used in the construction of the PCE price index, see [Bureau of Economic Analysis \(2024, Chapter 5\)](#).

Industry Gross Output Deflators

The BEA industry gross output deflators draw on a mix of data from the PPI, CPI, and other sources. For manufacturing industries, the BEA relies primarily on the PPI to construct its gross output deflators ([Bureau of Economic Analysis, 2024](#), Chapter 4). There are two sets of exceptions. First, for military equipment, the BEA applies price indices from the Department of Defense (“prices paid for military equipment”). Second, the BEA employs quality-adjusted price indices for computers, photocopying equipment, digital telephone switching equipment, and LAN equipment. Some of these quality-adjusted price indices draw on the BLS PPI. In other cases, where quality adjustment has not been available, the BEA has constructed its own ([Bureau of Economic Analysis, 2024](#), Chapter 4). For service industries, the BEA gross output deflators draw on a wider variety of sources. Table [A.1](#) lists the underlying sources of the BEA gross output deflator for a year near the beginning (2004), middle (2010), and end (2018) of the sample.

Year	2004	2010	2018
Agriculture, Forestry, Fishing, and Hunting (11)	—————	—————	—————
Farms (111, 112)	USDA prices received by farmers; PPI	USDA prices received by farmers; PPI	NIPA prices based on USDA price indexes PPI, NIPA PCE,
Forestry, Fishing, and Related Activities (113, 114)	PPI; NOAA; NIPA deflator.	USDA; PPI; NIPA PCE; for fisheries for aquaculture, NOAA	USDA National Agricultural Statistics Service unit prices
Mining (21)	—————	—————	—————
Oil and Gas Extraction (211)	For crude petroleum and natural gas, IPD from DOE; for natural gas liquids, PPI	PPI; EIA	PPI and EIA
Mining, Except Oil and Gas (212)	IPD from DOE and USGS.	EIA, USGS, and PPI	EIA, USGS, and PPI
Support Activities for Mining (213)	IPD from DOE, USGS and trade sources; for exploration, PPI	EIA, USGS, PPI, and trade sources	EIA, USGS, PPI, and trade sources

Year	2004	2010	2018
Utilities (22)	PPI for Electric Utilities and Natural Gas, CPI for Water, Sewage, and Other Systems	CPI and PPI; EIA	CPI and PPI
Construction (23)	_____	_____	_____
Residential (2361)	Census Bureau price index for new single-family houses under construction; BEA price index for multifamily construction.	Census Bureau price deflator for new single-family houses under construction; NIPA price index for multifamily home construction.	Census Bureau price deflator for new single-family houses under construction and BEA prices for multifamily home construction
Nonresidential (2362, 237, 238)	_____	NIPA composite price indexes based on cost per square foot; cost indexes from trade source data; for single family houses under construction, Census Bureau price deflator; PPI	PPI and BEA composite prices based on trade source data and on the Census Bureau price deflator for single-family houses under construction
For the Department of Defense	DOD prices for military construction; cost indexes from trade sources and government agencies for other construction.	_____	_____
For State and Local Highways (2373)	Cost indexes from government agencies	_____	_____
For Private Electric and Gas Utilities (2371)	Cost indexes from trade sources and government agencies	_____	_____

Year	2004	2010	2018
For Farms, Excluding Residential	Trade sources cost index; Census Bureau price deflator for new single family houses under construction		
For Other Nonresidential	Trade sources and government agency cost indexes; Census Bureau price index for new single-family houses under construction; BEA quality-adjusted price indexes for factories, office buildings, warehouses, and schools		
Manufacturing (31, 32, 33)	PPI; quality adjusted price indexes for computers, photocopying equipment, digital telephone switching equipment, and LAN equipment; BEA price indexes based on DOD prices paid for military equipment.	PPI; NIPA price indexes based on DOD prices paid for military equipment; NIPA hedonic price indexes.	PPI and NIPA prices based on DOD prices paid for military equipment, and NIPA hedonic prices
Wholesale Trade (42)	Sales price by kind-of-business computed from PPI	Census Bureau AWTR and MWTR data to derive margin rates; IRS Statistics of Income (SOI); NIPA sales prices and import prices; IRS SOI commodity taxes.	PPI and NIPA sales deflators

Year	2004	2010	2018
Retail Trade (44, 45)	Sales price by kind-of-business computed from CPI	PPI; NIPA retails sales prices; Census Bureau ARTS and MRTS; IRS SOI	PPI and NIPA sales deflators
Transportation and Warehousing (48, 49)	_____	_____	_____
Air Transportation (481)	IPD for total passenger-related revenues and passenger miles from DOT; IPD for total freight-, mail-, and express-related revenues and ton miles from DOT; wages and salaries per employee from BLS.	PPI; BTS prices.	PPI
Rail Transportation (482)	PPI	For rail passengers, CPI; for freight, PPI	PPI
Water Transportation (483)	PPI for freight; for passengers, CPI.	PPI and CPI; trade source data	For freight, PPI; for passenger, CPI
Truck Transportation (484)	PPI	PPI	PPI
Transit and Ground Passenger Transportation (485)	For taxicabs, intercity buses, and other local transit, PCE price index; for school buses, BLS data on wages and salaries per employee.	NIPA PCE; BLS QCEW.	NIPA PCE
Pipeline Transportation (486)	PPI	PPI	PPI
Other Transportation and Support Activities (488)	For sightseeing, PCE price index; for other transportation and support activities, PCE and PPI	NIPA PCE; PPI	PPI and NIPA PCE

Year	2004	2010	2018
Warehousing and Storage (493)	PPI	PPI	PPI
Information (51)	_____	_____	_____
Publishing Industries, Except Internet (Includes Software) (511)	BEA price indexes for prepackaged and custom software for software publishers; for all other publishing industries, PPI	PPI	PPI and BEA price indexes for software
Motion Picture and Sound Recording Industries (512)	PCE	CPI; NIPA PCE	NIPA PCE
Broadcasting and Telecommunications (515, 517)	For cable networks, programming, and telecommunications, PPI; for radio and television broadcasting, network receipts, and all other telecommunications, composite price index of PPIs.	PPI; for radio and TV broadcasting, NIPA PCE based on PPI	PPI
Data processing, Internet Publishing, and Other Information Services (518, 519)	For information services, PCE; for data processing services, PPI	CPI and PPI; for publishing and broadcasting content on the Internet, NIPA PCE	PPI and NIPA PCE
Finance and Insurance (52)	_____	_____	_____

Year	2004	2010	2018
Federal Reserve Banks, Credit Intermediation, and Related Activities (521, 522)	PCE; other government data	For financial services, NIPA PCE based on BLS quantity output indexes for commercial banks and employee hours for other depository institutions; PPI and CPI	FRB-priced services and NIPA PCE
Securities, Commodity Contracts, and Investments (523)	PCE	PPI and CPI; NIPA PCE	PPI and NIPA PCE
Insurance Carriers and Related Activities (524)	For health and life insurance, PCE; for property and casualty insurance, PPI; for agents, brokers, and services, composite price index based on trade sources data and PCE	For life insurance, NIPA PCE data on input prices; for health insurance, quantity extrapolations of premiums and benefits deflated with PPI; for all other property and casualty insurance, PPI; for agents, brokers, and services, composite indexes based on trade source data and NIPA PCE	PPI and NIPA PCE
Funds, Trusts, and Other Financial Vehicles (525)	IPD from NIPA imputed service charges; composite price index based on PCE; PPI data; BLS data on wages and salaries per full-time employee.	CPI; NIPA PCE	NIPA PCE

Year	2004	2010	2018
Real Estate and Rental and Leasing (53)			
Real Estate (531, 532)	For nonfarm residential dwellings, NIPA price index; for nonresidential dwellings, PPI; for real estate managers and agents, PPI and trade sources; IPD for nonprofit and farm residential dwellings.	For residential dwellings, CPI; for nonresidential dwellings, PPI; for real estate managers and agents, PPI and trade source data.	For residential dwellings, NIPA PCE and NIPA implicit price deflators for farm rents paid; for nonresidential structures, PPI; for real estate managers and agents, PPI and trade source data
Rental and Leasing Services and Lessors of Intangible Assets (533)	For automotive equipment rental, PPI; for other rental services, PCE; for royalties, PCE price index and IPD from DOE and PPI	PPI	NIPA PCE and implicit price deflators, PPI, BTS, EIA crude oil receipts, and trade source data
Professional, Scientific, and Technical Services (54)			
Legal Services (5411)	PPI	PPI	PPI and NIPA PCE
Computer Systems Design and Related Services (5415)	BEA price indexes for prepackaged and custom software.	NIPA price indexes for prepackaged, custom, and own-account software	BEA price indexes for software
Miscellaneous Professional, Scientific and Technical Services (5412, 5413, 5414, 5416, 5417, 5418, 5419)	PPI; BLS wages and salaries per full-time employee.	PPI and QCEW	PPI, NIPA PCE, and BEA price indexes for R&D

Year	2004	2010	2018
Management of Companies and Enterprises (55)	BLS wages and salaries per full-time employee	BLS QCEW	PPI
Administrative and Waste Management Services (56)	For administrative support: BLS wages and salaries per full-time employee; PCE; PPI For waste management: CPI	NIPA PCE based on CPI data; BLS QCEW; PPI	PPI and NIPA PCE
Educational Services (61)	PCE	NIPA PCE based on trade source data for input costs	NIPA PCE
Health Care and Social Assistance (62)	PPI; PCE	_____	PPI and NIPA PCE
Ambulatory Health Care Services (621)	PPI; PCE	NIPA PCE based on CPI; PPI	_____
Hospital and Nursing and Nursing Care Facilities (622, 623)	PCE	NIPA PCE based on CPI and Centers for Medicare and Medicaid Services	_____
Social Assistance (624)	PCE	NIPA PCE based on trade source data on input costs	_____
Arts, Entertainment, and Recreation (71)	PCE	NIPA PCE based on CPI.	NIPA PCE
Accommodation and Food Services (72)	_____	_____	_____
Accommodation (721)	For hotels and motels, PPI; PCE price index.	PPI; NIPA PCE based on CPI Census Bureau	PPI and NIPA PCE
Food Services (722)	CPI	ARTS; PPI composite price index.	PPI
Other services, except government (81)	CPI; BLS data on wages and salaries per full-time employee; PCE	CPI; NIPA PCE based on CPI.	PPI and NIPA PCE

Year	2004	2010	2018
Government (92)	_____	_____	_____
Federal	_____	_____	_____
		NIPA price index based on PPI and CPI; for military facilities, DOD data on employment, prices for military construction; construction cost indexes from trade sources.	NIPA prices based on PPI and CPI; for military facilities, DOD data on employment, prices for military construction, and construction cost indexes from trade source data
General Government	NIPA price indexes		
	For USPS and electric utilities, PPI; for all others, PCE price index and NIPA price indexes	PPI; NIPA PCE based on PPI and agency data	PPI
Government Enterprises			
State and Local	_____	_____	_____
General Government	NIPA price indexes	PPI; NIPA PCE based on CPI.	PPI and NIPA PCE
Government Enterprises	PPI	PPI	PPI

Notes: The acronyms mentioned within this table are as follows: ARTS: Annual Retail Trade Survey; AWTR: Annual Wholesale Trade Report; DOD: Department of Defense; DOE: Department of Energy; DOT: Department of Transportation; EIA: Energy Information Administration; FRB: Federal Reserve Board; IPD: Industrial Demonstrations Program; IRS SOI: IRS Statistics of Income; LAN: Local Area Network; MRTS: Monthly Retail Trade Survey; MWTR: Monthly Wholesale Trade Report; QCEW: Quarterly Census of Employment and Wages; USDA: United States Department of Agriculture; USGS: United States Geological Survey; USPS: US Postal Service. The sources for this table are Table D of <https://apps.bea.gov/scb/pdf/2004/03March/0304IndustryAcctsV3.pdf>, Table C of https://apps.bea.gov/scb/pdf/2010/03%20March/0310_indy_accts.pdf, and Table A of <https://apps.bea.gov/scb/issues/2018/08-august/pdf/0818-industry-tables.pdf>. In the first column, the numbers in parentheses give the applicable NAICS commodity code.

Expansion of the PPI; Incorporation of Hedonic Quality Adjustment to the CPI and PPI

[Moulton \(2024\)](#) summarizes changes to BLS consumer and producer price indices in the two decades following the Boskin commission.

Over this period, the producer price index increased the set of commodities in its sample. These changes include the introduction of:

- In 1997: PPIs for home health care services; legal services; engineering services; and architectural services;
- In 1998: PPIs for prepackaged software; and property and casualty insurance;
- In 1999: PPIs for life insurance; wireless telecommunications; and physicians;
- In 2000: PPIs for grocery stores; meat and fish markets; fruit and vegetable markets; candy, nut, and confectionery markets; retail bakeries; miscellaneous food stores; and new car dealers;
- In 2001: PPIs for 17 retail industries (the largest being drug stores and proprietary stores); security brokers, dealers, and investment banking; and data processing services;
- In 2002: PPIs for additional retail industries (including gasoline service stations, boat dealers, and recreational vehicle dealers); and television broadcasting;
- In 2003: PPIs for investment advice; and insurance agencies and brokerages;
- In 2004: PPIs for the remaining retail industries; electric power generation; electric bulk power transmission and control; and direct health and medical insurance carriers;
- In 2005: PPIs for commercial banking; savings institutions; construction, mining, forestry machinery, and equipment rental and leasing; nonresidential building construction; wholesale trade; internet service providers; web search portals; security guards and patrol services; and fitness and recreational sports centers;
- In 2006: PPIs for nonresidential building construction for schools; amusement and theme parks; and golf courses and country clubs;
- In 2007: PPIs for nonresidential building construction for offices; management consulting services; blood and organ banks; computer training; commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance;

- In 2008: PPIs for nonresidential building construction for industrial buildings; and non-residential building construction for contractors performing poured concrete, roofing, electrical, and plumbing/HVAC work;
- In 2010: PPIs for internet publishing and web search portals;
- In 2011: PPIs for dentists;
- In 2013: PPIs for nonresidential building construction for health care buildings;
- In 2014: PPIs for health care services by payer type; and
- In 2022: PPIs for pipeline transportation for natural gas.

The BLS applies a hedonic adjustment to a large set of commodities in the CPI.²² In 1988, it began applying age-bias adjustment factors for housing. Beginning in 1992, the CPI applied hedonic adjustments to an increasing set of apparel categories: The first set of apparel categories were women’s coats, women’s suits, women’s dresses, women’s footwear, men’s suits, men’s shirts, men’s pants, and men’s footwear. In 1995, the BLS applied hedonic adjustment to women’s tops, girls’ tops, men’s athletic footwear, and women’s athletic footwear. In 1997, hedonic adjustment was added to women’s outerwear. In 2004, boys’ shirts and sweaters were added to the list of apparel categories with a hedonic adjustment. In 2023, men’s underwear and women’s bras were added. The remaining categories with a hedonic adjustment include personal computers and peripheral equipment (1998), televisions (1999), audio equipment (2000), other video equipment (2000), refrigerators and freezers (2000), washers and dryers (2000), microwaves (2000), educational books and supplies (2000), wireless telephone services (2017), smartphones (2018),²³ land-line telephone services (2019),²⁴ internet services (2019), cable and satellite television (2019), watches (2022), ranges and cooktops (unknown date), and photographic equipment (unknown date).

By contrast, the PPI uses hedonic models for quality adjustment for computers (NAICS 334111), microprocessors (NAICS 334413), and broadband internet access (NAICS 517311).

²²See <https://www.bls.gov/cpi/quality-adjustment/>, the links therein, and <https://www.bls.gov/cpi/white-papers/hedonic-quality-adjustments-statistical-agency-perspective.pdf>.

²³Smartphones belong to the “telephone, hardware, calculators, and other consumer information items” consumption category.

²⁴See <https://www.bls.gov/cpi/quality-adjustment/hedonic-price-adjustment-techniques.htm>.

These were introduced in 1991,²⁵ late 2016,²⁶ and 2018,²⁷ respectively.

B Interpolation Methodology

Equation 1 links the two perspectives of price growth. In the right-hand side of Equation 1, we require (a) import shares for each commodity j and (b) the share of each consumption category c that comes from NAICS commodity j . Equation (1) applies detailed PCE categories and detailed NAICS commodities. Unfortunately, the “Detailed” data are present only in certain years—2007, 2012, and 2017—with more aggregated “Summary” data for other years between 1997 and 2023. We first discuss our estimates at producing $m_{t,j}$ —the share of consumption expenditures of detailed commodity j that is imported in year t (Appendix B.1). In this appendix, we then discuss how we compute $s_{t,j \rightarrow c}$ for detailed commodities and consumption categories in each year (Appendix B.2).

When computing TFP mismeasurement, we required information of the use of individual detailed commodities in the production of different downstream industries’ outputs. Again, the “Detailed” versions of the BEA “Use” Tables exist only for 2007, 2012, and 2017, with more aggregated “Summary” data for other years between 1997 and 2023. In Appendix B.3, we describe our methodology to impute commodity flows for each year between 1997 and 2023.

Finally, Appendix B.4 describes how we estimate the contribution of transportation, wholesale, and retail margins in the distribution of each detailed commodity.

B.1 Import Interpolation Methodology

Crosswalk

There are 402 detailed import categories; use j to denote a detailed commodity. For these commodities we have data from 2007, 2012, and 2017 but no other years.

There are 73 summary import commodities categories; use φ to denote a summary category. Of the 73 of these summary commodities two are “Scrap Used and Secondhand Goods and Non-Comparable Imports” and “Rest-of-the-World Adjustment”; we refer to the remaining 71 summary commodities as “normal.” We have data on these commodities from 1997 to 2023.

²⁵See https://fraser.stlouisfed.org/files/docs/publications/cpidr/cpi_199707.pdf.

²⁶See <https://www.bls.gov/ppi/quality-adjustment/ppi-introduces-hedonic-quality-adjustment-for-internet-access-indexes.htm>

²⁷See [Sawyer and So \(2018\)](#).

Each detailed commodity j is part of exactly one aggregate commodity φ . We have constructed a mapping between each detailed commodity j and summary commodity φ by comparing the commodity codes and by checking that the sum of the import volumes of the detailed commodity values from 2017 matched the import volume of the aggregate commodity in 2017.

Interpolation

For $t \notin \{2007, 2012, 2017\}$, we estimate detailed categories' import shares based on the detailed data that was closest in time to the year being estimated.

- 1997-2006 is estimated using the detailed data from 2007;
- 2008-2011 is estimated using the data from 2007 and 2012;
- 2013-2016 is estimated using the detailed data from 2012 and 2017; and
- 2018-2023 is estimated using the detailed data from 2017.

1997-2006 and 2018-2023 If we had only one year of detailed data, we assume that the import proportion of the detailed category changed by the same amount as the import proportion of the aggregate commodity in the same time frame.

That is:

$$m_{j,y+t} = m_{jy} \frac{m_{\varphi,y+t}}{m_{\varphi,y}},$$

where, m_{jy} is the import proportion of the detailed commodity in year y and $m_{\varphi,y}$ is the import share of the aggregate commodity in year y .

To find the data for 2018-2023, we used $y = 2017$ and $t \in \{1, 2, \dots, 6\}$.

To find the data for 1997-2006, we used $y = 2007$ and $t \in \{-1, -2, \dots, -10\}$.

2008-2011 and 2013-2016 Here, we explain the method used for 2008-2011. The equivalent method is used for 2013-2016.

If, as we assumed above, the import proportion of a detailed category changes by the same amount as the import proportion of its aggregate category in the same time frame, then it should be the case that:

$$\frac{m_{j,2012}}{m_{j,2007}} = \frac{m_{\varphi,2012}}{m_{\varphi,2007}}.$$

Since we have the detailed data for 2007 and 2012, we can compare $\frac{m_{j,2012}}{m_{j,2007}}$ and $\frac{m_{\varphi,2012}}{m_{\varphi,2007}}$.

If they are not the same, then we assume that for each year since 2007, one-fifth of the divergence in amount of change happens that year. Thus, the estimation equation becomes:

$$m_{j,2007+t} = m_{j,2007} \frac{m_{\varphi,2007+t}}{m_{\varphi,2007}} \left(\frac{m_{j,2012}}{m_{j,2007}} \frac{m_{\varphi,2007}}{m_{\varphi,2012}} \right)^{t/5}$$

for each $t \in \{1, \dots, 4\}$.

This method fails if $m_{\varphi,2007}$, $m_{\varphi,2012}$, or $m_{j,2007}$ is zero. In those cases we go through the following methods, in the given order, stopping at the first one that fits:

1. If $m_{\varphi,2007} = 0$, then functionally we don't have two import share ratios to compare anymore, so we go back to the one import share ratio method explained above, using the share ratio from 2012.
2. If both $m_{\varphi,2007}$ and $m_{\varphi,2012}$ are zero, then assume that every $m_{j,t}$ from 2008 to 2011 is zero.
3. If $m_{\varphi,2012} \neq 0$ and $m_{j,2007} = 0$ we know that the import proportions were calculated using import volumes (in millions) that were rounded to the nearest integer. So we assume that an import volume of zero has a true import value in $(0, 0.5)$. We set the detailed 2007 import volume to 0.25 to approximate this and recalculate the 2007 detailed import proportion.

Notes on these methods

- There are no cases (excluding rounding error) of $m_{\varphi,2007} = m_{\varphi,2012} = 0$ and the aggregate imports in the years in between being positive. Thus, method 1 does not account for that.
- There are no cases of $m_{\varphi,2007} \neq 0$ and $m_{\varphi,2012} = 0$ (or its 2012-2017 analogue) so we didn't design a method for that scenario.

B.2 PCE Bridge Imputation Methodology

Crosswalk

The PCE Bridge Table combines PCE categories and NAICS commodity codes. We will refer to such combinations as *bridge pairs*. There are 704 detailed bridge pairs and 402 summary bridge pairs. For the detailed bridge pairs, we have data from 2007, 2012, and 2017 but no other years. We have data on the summary bridge pairs for each year from 1997 to 2023.

Each summary bridge pair is composed of some subset of the detailed bridge pairs. Each detailed bridge pair is part of exactly one summary bridge pair. We match the detailed bridge pairs to summary bridge pairs by checking that the sum of the detailed bridge pairs in 2017 exactly matches the value of the summary bridge pair in 2017.

Interpolation

We chose to make the estimations based only on the detailed data that was closest in time to the year being estimated:

- 1997-2006 is estimated using the detailed data from 2007;
- 2008-2011 is estimated using the data from 2007 and 2012;
- 2013-2016 is estimated using the detailed data from 2012 and 2017; and
- 2018-2023 is estimated using the detailed data from 2017.

1997-2006 and 2018-2023 If we have only one year of detailed data, we assume that the value of the detailed bridge pair changes by the same amount as the value of the summary bridge pair in the same time frame.

That is:

$$V_{d,y+t} = V_{d,y} \cdot \frac{V_{\varphi,y+t}}{V_{\varphi,y}},$$

where, $V_{d,y}$ is the value of the detailed bridge pair in year y and $V_{\varphi,y}$ is the value of the summary bridge pair in year y .

To impute $V_{d,y+t}$ for $y+t \in \{2018, \dots, 2023\}$, we use $y = 2017$ and $t \in \{1, 2, \dots, 6\}$. To impute $V_{d,y+t}$ for $y+t \in \{1997, \dots, 2006\}$ we used $y = 2007$ and $t \in \{-1, -2, \dots, -10\}$.

Technically, this method does not work if $V_{\varphi,y} = 0$. In this case, we assume that a value of zero in 2007 implies a value of zero for each preceding year. (Or a value of zero in 2017 implies a value of zero in each succeeding year.) Thus if $V_{\varphi,y} = 0$ we set $V_{d,y+t} = 0$ as well.

2008-2011 and 2013-2016 Here, we explain the method use for $y+t \in \{2008, \dots, 2011\}$. An equivalent method is used for 2013-2016.

For these years, we have detailed data from both before and after the year for which we are trying to impute the entry of the PCE Bridge Table. Since we have both $\frac{V_{d,2012}}{V_{\varphi,2012}}$ and $\frac{V_{d,2007}}{V_{\varphi,2007}}$, we want to use both fractions to provide the best estimate $\frac{V_{d,2007+t}}{V_{\varphi,2007+t}}$. We want $\frac{V_{d,2012}}{V_{\varphi,2012}}$ to play a larger role for years that are closer to 2012 and $\frac{V_{d,2007}}{V_{\varphi,2007}}$ to be more important for

years closer to 2007. We do this by assuming that for each year since 2007, one-fifth of the divergence happened that year.

Thus, the estimation equation becomes:

$$V_{d,2007+t} = V_{d,2007} \cdot \frac{V_{\varphi,2007+t}}{V_{\varphi,2007}} \cdot \left(\frac{V_{d,2012}}{V_{d,2007}} \cdot \frac{V_{\varphi,2007}}{V_{\varphi,2012}} \right)^{t/5} \quad (8)$$

for each $t \in \{1, \dots, 4\}$.

This method fails if $V_{\varphi,2007}$, $V_{\varphi,2012}$, or $V_{d,2007}$ is zero or if the sign of $\frac{V_{d,2012}}{V_{d,2012}}$ is different than the sign of $\frac{V_{\varphi,2007}}{V_{\varphi,2007}}$. In practice, only the sign changes are a problem. This issue occurs very rarely, so when it does it is usually the only case with an issue in its summary bridge pair. Thus, we estimate every other detailed bridge pair in the summary bridge pair. We then subtract their sum from the value of the summary bridge pair and use the remainder as the estimate of the detailed bridge pair in these cases. If there happens to be multiple bridge pairs with this issue in the same summary bridge pair we split the remainder between them based on their relative sizes.

Link to the Measures Used in the Body of the Paper The $s_{t,j \rightarrow c}$ that appear in Sections 2 and 3 are given by V_{dt} divided by the sum of $V_{d't}$ for which consumption category c is the “destination” category. Remember that d denotes a commodity \times consumption category pair.

B.3 Input-Output Use Table Interpolation Methodology

Crosswalk

There are 402 detailed commodity IO codes and 403 detailed distinct industry IO codes. For these categories, we have data from 2007, 2012, and 2017 but no other years.

There are 73 aggregate commodity IO codes and 73 aggregate industry IO codes. We have data on these categories from 1997 to 2023.

Each intersection of an aggregate commodity category and an aggregate industry category is composed of the intersections of some subset of the detailed commodity and some subset of the detailed industry categories. Each detailed intersection is part of exactly one aggregate intersection. We matched the detailed intersections to their aggregate intersections by comparing the commodity codes and by checking that the sum of the detailed intersections from 2017 matched the value of the aggregate category intersection in 2017.

Interpolation

We chose to make the estimations based only on the detailed data that was closest in time to the year being estimated:

- 1997-2006 is estimated using the detailed data from 2007;
- 2008-2011 is estimated using the data from 2007 and 2012;
- 2013-2016 is estimated using the detailed data from 2012 and 2017; and
- 2018-2023 is estimated using the detailed data from 2017

1997-2006 and 2018-2023 If we had only one year of detailed data, we assumed that the use value of the detailed intersection changed by the same amount as the use value of the aggregate intersection in the same time frame. Let φ refer to a combination of a detailed (upstream) commodity \times detailed (downstream) industry, and d to refer to a combination of a summary (upstream) commodity \times summary (downstream) industry. That is:

$$U_{d,y+t} = U_{d,y} \cdot \frac{U_{\varphi,y+t}}{U_{\varphi,y}},$$

where $U_{d,y}$ is the use value of the detailed intersection in year y and $U_{\varphi,y}$ is the use value of the aggregate intersection in year y .

To impute use values for 2018-2023, we let $y = 2017$ and $t \in \{1, 2, \dots, 6\}$. To impute use values for 1997-2006, we let $y = 2007$ and $t \in \{-1, -2, \dots, -10\}$.

Technically, this method does not work if $U_{\varphi,y} = 0$. In this case, we assume that a use value of zero in 2007 means a use value of zero for every earlier year. Thus, if $U_{\varphi,y} = 0$ we set $U_{d,y+t} = 0$ as well.

2008-2011 and 2013-2016 Here, we explain the method used for 2008-2011. The equivalent method is used for 2013-2016.

For these years, we have detailed data from both before and after the year for which we are trying to impute the use value. Since we have both $\frac{U_{d,2012}}{U_{\varphi,2012}}$ and $\frac{U_{d,2007}}{U_{\varphi,2007}}$, we want to use both fractions to provide the best estimate $\frac{U_{d,2007+t}}{U_{\varphi,2007+t}}$. We want $\frac{U_{d,2012}}{U_{\varphi,2012}}$ to play a larger role for years that are closer to 2012 and $\frac{U_{d,2007}}{U_{\varphi,2007}}$ to be more important for years closer to 2007. We do this by assuming that for each year since 2007, one-fifth of the divergence happens each year.

Thus, the estimation equation becomes:

$$U_{d,2007+t} = U_{d,2007} \cdot \frac{U_{\varphi,2007+t}}{U_{\varphi,2007}} \cdot \left(\frac{U_{d,2012}}{U_{d,2007}} \cdot \frac{U_{\varphi,2007}}{U_{\varphi,2012}} \right)^{t/5} \quad (9)$$

for each $t \in \{1, \dots, 4\}$.

This method fails if $U_{\varphi,2007}$, $U_{\varphi,2012}$, or $U_{d,2007}$ is zero. In these problematic cases we apply one of the two following methods:

1. If $U_{\varphi,2007} = 0$ or $U_{d,2007} = 0$, we set $U_{d,2007+t} = 0$ for each $t \in \{1, \dots, 4\}$.
2. If $U_{\varphi,2012} = 0$, but $U_{d,2007} \neq 0$ and $U_{d,2017} \neq 0$, we estimate $U_{d,2007+t} = 0$ using a modified version Equation 9 with the 2017 values replacing the 2012 values and $t/10$ replacing of $t/5$.

The method also fails if the sign of $\frac{U_{d,2012}}{U_{d,2007}}$ is different than the sign of $\frac{U_{\varphi,2007}}{U_{\varphi,2012}}$. In practice this only occurs for two of the farming-government intersections and in both cases the detailed values are very small so we set $U_{d,2007+t}$ to zero.

Link to the Measures Used in the Body of the Paper The $\gamma_{t,i \rightarrow j}$ that appear in Section 3 are given by U_{dt} divided by the gross output of industry j in year t . Remember that d denotes an upstream commodity \times downstream industry pair.

B.4 PCE Bridge Margin Assignment

The PCE Bridge Table reports both producer's value and purchaser's value, which adds the transportation, wholesale, and retail costs to the producer's value. We refer to these as the transportation, wholesale, and retail margins. We would like to be able to assign the value in these margins to the commodities they come from, however, each of the three margins is made up of multiple commodities.

We do not have data on what commodities each industry uses only for its finished products, but the use tables do give each industry's use of the margin commodities as part of their intermediate inputs.

We make the assumption that the relative shares of intermediate inputs in the commodities that make up each margin category is predictive of their relative shares within the margin. For example, Truck Transportation is the majority of the transportation type intermediate inputs for Grain Farming and we expect the same to be true for its share of Grain Farming's transportation margin.

First, we compute the share of each commodity within its margin type in the BEA's Use Table (using the interpolated detailed use values). Next, for each commodity-margin

combination in the PCE Bridge Table, we multiply the use table shares by the margin value. This gets rid of the margins and leaves all values in the PCE Bridge Table assigned to some commodity.

Since there generally are multiple commodities in each PCE category, this procedure usually results in there being multiple of each of the margin type commodities in the PCE Bridge Table. Thus, as a final step, we combine the duplicate commodities via summation.

C Sensitivity to Including Distribution Margins in Equation 1

In this section, we examine the sensitivity of our results in Sections 2 and 3 to our definition of Producer Inflation, where we now include changes in the price of retailing, wholesaling, and transporting goods.

To describe this robustness check, it will be helpful to first describe the structure of the PCE Bridge. Each row within the PCE Bridge Table corresponds to a PCE consumption category (c) by NAICS commodity (j) pair in year t ; for future reference call this $v_{j \rightarrow c, t}$. For each pair, the Bridge Table lists the dollar value of the contribution of commodity (j) to consumption category (c).

In Equation 1, in the body of the paper, $s_{t, j \rightarrow c}$ equals:

$$\frac{v_{t, j \rightarrow c}}{\sum_{j'} v_{t, j' \rightarrow c}} \quad (10)$$

Consider, as an example, NIPA Line 88: “Eggs.” For a single year (2017), the rows associated with this consumption category are given in Table A.2. There are two NAICS commodities that contribute to the Eggs consumption category: “Poultry and Egg Production” (NAICS 11230) and “All Other Food Manufacturing” (NAICS 31199). In terms of Equation 10, $v_{2017, j \rightarrow 88} = \5034 for $j = 11230$ and $\$2237$ for $j = 31199$. As a result, our Producer Inflation measure for the Eggs consumption category would weight Poultry and Egg Production at roughly 70 percent and All Other Food Manufacturing at roughly 30 percent.

In our robustness check, we allow for price changes in distribution margins to enter the Producer Inflation measure. The PCE Bridge Table includes three additional columns, listing the dollar contribution of wholesale, retail, and transportation margins in commodity j to consumption category c . Let $v_{t, \omega; j \rightarrow c}$, $v_{t, \rho; j \rightarrow c}$, and $v_{t, \theta; j \rightarrow c}$ refer to the dollar value of these different margins in the PCE Bridge Table. In the Eggs consumption category, in 2017, transportation accounts for $\$559$ ($v_{2017, \theta; 11230 \rightarrow 88} = \499 ; $v_{2017, \theta; 31199 \rightarrow 88} = \60), the wholesale margin accounts for $\$727$ ($v_{2017, \omega; 11230 \rightarrow 88} = \214 ; $v_{2017, \omega; 31199 \rightarrow 88} = \513), and the retail margin

Commodity Description	Commodity Code	Producers' Value	Transportation Costs	Wholesale Margin	Retail Margin
Poultry and Egg Production	11230	5,034	499	214	2,807
All Other Food Manufacturing	31199	2,237	60	513	1,248

Table A.2: Excerpt from PCE Bridge Table

Notes: This table lists the rows associated with the consumption category of Eggs (NIPA Line, 81) from the 2017 PCE Bridge Table. The dollar figures in the final four columns are all nominal.

accounts for \$4055 ($v_{2017,\rho;11230 \rightarrow 88} = \2807 ; $v_{2017,\rho;31199 \rightarrow 88} = \1248).

While the PCE Bridge Table does not have any further detail on the importance of these distribution margins, we employ the Input-Output Table to infer the importance of detailed distribution channels (e.g., inferring the weight of Auto Wholesalers vs. Machinery Wholesalers; Supermarkets vs. Non-Store Retailers; and Air Transport vs. Pipeline Transport). Using μ to refer to a generic detailed distribution industry and \mathcal{M} the set of detailed distribution industries, let $v_{t,\mu;j \rightarrow c}$ refer to the value of distribution margin μ earned in year t when transporting, wholesaling, or retailing commodity j toward consumption of category c .

Returning to our Egg example, according to the 2017 Use Table (Before Redefinitions), Truck Transportation (NAICS 484) accounted for 73 percent ($=\$1360$ of the $\$1858$) of the transportation inputs used in the production of Poultry and Egg Production, and 75 percent ($=\$970$ of the $\$1290$) of the transportation inputs used in the production of All Other Foods Manufacturing. As a result, we estimate that—toward the Eggs consumption category— $v_{2017,484;11230 \rightarrow 88} = 0.73 \cdot \$499 = \$365$ and $v_{2017,484;31199 \rightarrow 88} = 0.73 \cdot \$60 = \$45$. In words, Trucking Transportation contributes \$410 towards the PCE category of Egg consumption, \$365 through the Poultry and Egg Production commodity and \$45 through the All Other Food Manufacturing commodity.

Having laid out our notation, we consider an alternate definition of Producer Inflation:

$$\Delta \log \tilde{P}_{t,c}^{\text{Producer}} = \sum_j \tilde{s}_{t,j \rightarrow c} \left[(1 - m_{t,j}) \Delta \log P_{t,j}^{\text{GO}} + m_{t,j} \Delta \log P_{t,j}^{\text{Import}} \right], \text{ where} \quad (1')$$

$$\tilde{s}_{j \rightarrow c} = \frac{v_{j \rightarrow c} + \sum_{j'} v_{j,j' \rightarrow c}}{\sum_{j'} (v_{j' \rightarrow c} + \sum_{\mu} v_{\mu,j' \rightarrow c})} \text{ if } j \in \mathcal{M}$$

$$= \frac{v_{j \rightarrow c}}{\sum_{j'} (v_{j' \rightarrow c} + \sum_{\mu} v_{\mu,j' \rightarrow c})} \text{ if } j \notin \mathcal{M}.$$

In the second line within Equation 1', the terms in the numerator account for the two ways

in which commodity j can contribute to consumption category c , the first as a producing industry, the second through distribution margins. For instance, the NAICS commodity of Rail Transportation (NAICS, 482) appears as a producing industry for the Railway Transportation PCE Category (NIPA Line 201) and contributes to the distribution margin of multiple NAICS-Commodity-to-PCE-Category ($j' \rightarrow c$) pairs.

Figure A.1 presents the analogue of Figure 4 using this alternate definition of Producer Inflation. The key takeaway from this figure is that for computers and electronics-related consumption categories, their scatter-points fall even farther from the 45-degree line in Figure A.1 than in Figure 4. The Personal Computers (NIPA Line 49) consumption category is again instructive. Whereas Producer Inflation was -6.8% in Figure 4, it is at -4.4% here. For this consumption category, distribution margins account for 35% to 40% (depending on the year) of the weight in Equation 1'. The industries accounting for most of the distribution margins for Personal Computers consumption include “Professional and Commercial Equipment and Supplies Merchant Wholesalers” (NAICS 4234) and “Motor Vehicle and Parts Dealers” (NAICS 441). Over the 1997 to 2023 period, for these two industries, gross output deflators increased by -0.4% and 2.1%, respectively. Including these terms and those of other distribution industries’ in Equation 1' increases our measure of Producer Inflation up. The same goes for other consumption categories for which Figure 4 indicated deflation. The Producer Inflation measure of Televisions increases by 1.0 percentage points (decreasing by 0.8% annually, instead of by 1.7% annually, as in Figure 4. For Telephones, the difference is 5.1 percentage points (0.8% annual price declines in Figure 4 vs. 6.0% in A.1). Overall, since wholesale, transportation, and retail experienced roughly 2% inflation over the sample period, their inclusion in Producer Inflation will attenuate any observed deflation from non-margin commodities in PCE categories experiencing large price declines.

Figure A.2 next considers the implications of including distribution margins for our estimates of TFP mismeasurement. We follow the same procedure detailed in Section 3 to infer TFP mismeasurement from price gaps between PCE inflation and our Producer Inflation measure. More pronounced output price mismeasurement in Figure A.1 implies greater TFP mismeasurement in Figure A.2. For the 3-digit Computer and Electronic Products Manufacturing industry, TFP mismeasurement is 7.8 percentage points, roughly two percentage points more than in Figure 5. For other manufacturing industries—where price declines are rarer—including distribution margins in our calculations has minimal impact.

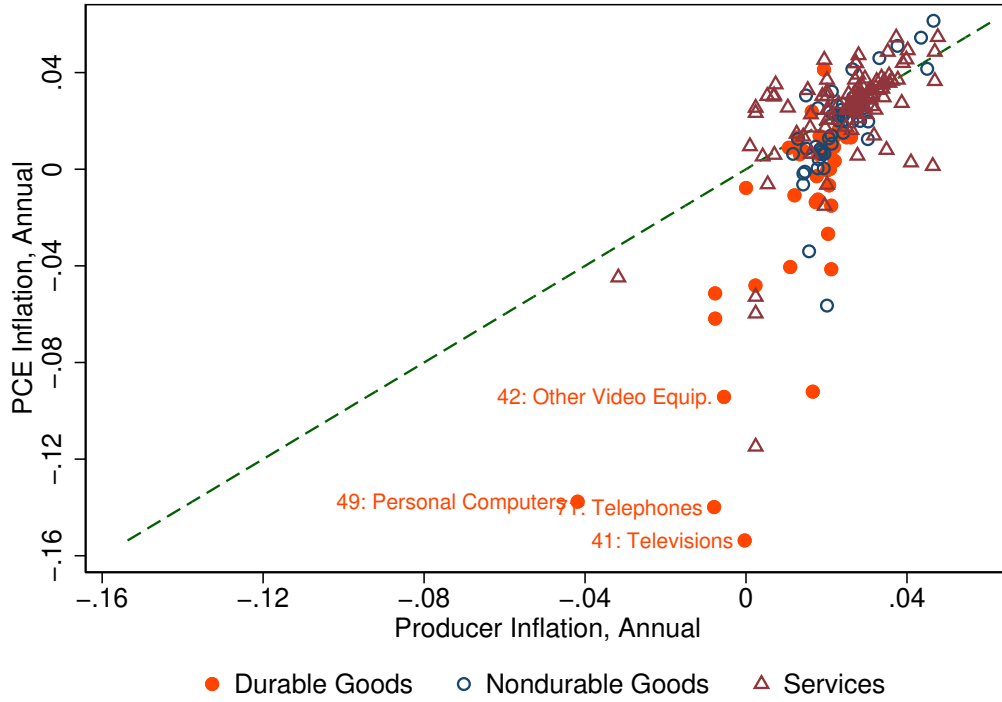


Figure A.1: Two Measures of Inflation Across PCE Categories, 2005–2023

Notes: See the notes for Figure 4. In contrast to that figure, we rely on Producer Inflation measures from Equation 1'.

D Additional Figures and Tables

In this section, we collect figure and tables supplementing those in the body of the paper. Appendix D.1 collects a figure and a table mentioned in Section 1. Appendix D.2 digs deeper into offshoring and production fragmentation in the manufacturing sector. Appendix D.3 evaluates whether our conclusions of TFP mismeasurement in broad sectors are problematic due to the potential non-representativeness of which industries are not observed in the PCE Bridge Table. In Appendix D.4, we assess whether our results are robust to excluding commodities that enter only with small entries in the PCE Bridge Table. In Appendix D.5, we consider an alternate definition of \mathbf{O}_t (see Equation 6) when computing TFP mismeasurement.

D.1 Figures and Tables Supplementing Section 1

Figure A.3 plots the share of manufacturing output attributable to NAICS 334: the Computer and Electronic Products Manufacturing industry. In 1987, this was 9.4%, peaked at 12.3%, and fell to 5.5% by the end of the sample.

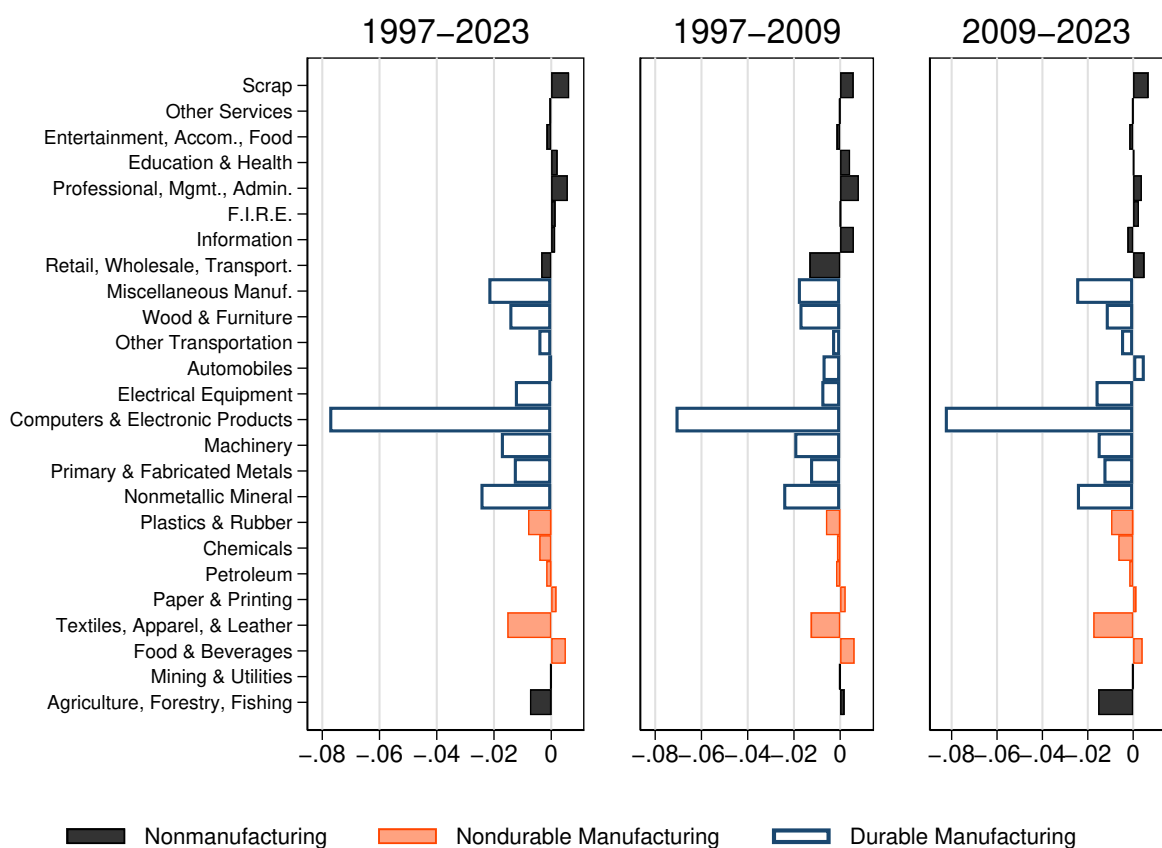


Figure A.2: TFP Mismeasurement

Notes: See the notes for Figure 5. In contrast to that figure, we rely on Producer Inflation measures from Equation 1'.

In Table A.3, we study which 4-digit industries are responsible for the TFP deceleration of the Computer and Electronic Products 3-digit industry. For each of the 4-digit industries, we compute average TFP growth rates and output shares for three subperiods within our sample: 1987 to 1997, 1997 to 2009, and 2009 to 2023. The outstanding pre-2009 growth of this industry is largely due to two 4-digit industries: Computer and Peripheral Equipment Manufacturing (NAICS 3341) and Semiconductors and Other Electronic Components Manufacturing (NAICS 3344). These two industries had the largest slowdown in TFP growth post 2009. The other large industry—Navigational, Measuring, Electromedical, and Control Instrument Manufacturing (NAICS 3345)—had similar TFP growth rates across the three subperiods within the sample. If anything, productivity growth increased for the industries outside of NAICS 3341 and NAICS 3344.

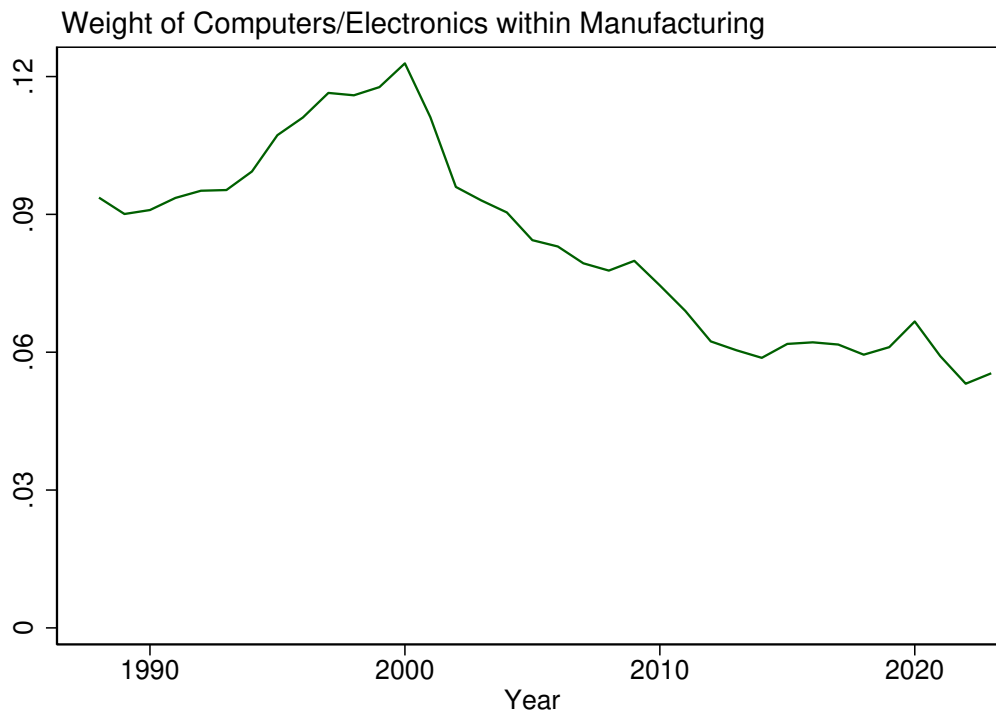


Figure A.3: Share of Sectoral Output of NAICS 334 within Manufacturing

D.2 Imports and Production Fragmentation of Computer and Electronic Products Manufacturing

In this section, we describe changes in the production process for Computer and Electronic Products Manufacturing—the extent to which final private consumption reflects domestic production, the sets of tasks that have been offshored, and the set of tasks that still take place within domestic manufacturers.

Mass market consumer electronics are almost exclusively assembled outside of the United States. While there are exceptions—such as Apple assembling Mac Pros in Austin, Texas or Element Electronics’ production of televisions in Winnsboro, South Carolina—nearly all top-selling televisions, stereos, personal computers, and cell phones are processed and assembled abroad.²⁸

But domestic manufacturing industries still play an import role in the production of computers and other electronic products that are sold to final consumers. Table A.4 lists the ratio of imports of personal consumption expenditures to total personal consumption expenditures. While this increased over the 2000s, there is still a meaningful share of consumer

²⁸See <https://nr.apple.com/d2s4W269s6> and <https://www.prnewswire.com/news-releases/element-electronics-reinvesting-in-american-jobs-220711711.html>.

Industries	TFP Growth			Output Share		
	87-97	97-09	09-23	87-97	97-10	09-23
3341: Computer and Peripheral Equip.	0.142	0.163	0.012	0.229	0.184	0.075
3342: Communications Equip.	0.046	0.027	0.019	0.158	0.173	0.122
3343: Audio and Video Equip.	0.023	0.022	0.030	0.029	0.020	0.011
3344: Semiconductors and Other Electronic Components	0.145	0.080	0.034	0.273	0.308	0.296
3345: Navigational, Measuring, Electromedical, and Control Instruments	0.008	0.002	0.012	0.283	0.295	0.488
3346: Magnetic and Optical Media	0.039	-0.006	-0.005	0.028	0.019	0.008

Table A.3: TFP Growth and Output Shares of 4-Digit Industries Within NAICS 334

Year	1997	2002	2007	2012	2017	2023
Manufacturing (31-33)	0.123	0.165	0.179	0.176	0.162	0.160
Computers and Electronic Products (334)	0.323	0.419	0.469	0.488	0.440	0.464
Computer and Peripheral Equip. (3341)	0.304	0.395	0.441	0.519	0.563	0.594
Communications Equipment (3342)	0.183	0.238	0.266	0.352	0.369	0.389
Audio and Video Equipment (3343)	0.394	0.512	0.573	0.609	0.444	0.468
Semiconductors and Other Electronic Components (3344)	0.232	0.301	0.337	0.302	0.218	0.230
Navigational, Measuring, Electromedical, and Control Instruments (3345)	0.229	0.298	0.333	0.290	0.244	0.258
Magnetic and Optical Media (3346)	0.350	0.454	0.508	0.297	0.122	0.129

Table A.4: Import Share of Personal Consumption Expenditures

electronic goods that are produced by domestic manufacturers. By the end of the sample, 46% of Computer and Electronic Products personal consumption expenditures comes from imports. This is substantially higher than at the beginning of the sample (32%) and higher than the import share for the manufacturing sector as a whole (12% in 1997, 16% in 2023). Yet, even Computers and Peripheral Equipment Manufacturing, the 4-digit NAICS industry with the highest import share, had at least two-fifths of its personal consumption expenditures produced domestically throughout the sample.

How can one reconcile the figures in Table A.4 with paucity of processing and assembly of domestic consumer electronics manufacturers? Table A.5 lists the types of occupations employed in different manufacturing industries, using data from the BLS Occupational Employment and Wage Statistics (OEWS) dataset. Panel A lists the share of employment in five of the largest 2-digit SOC (Standard Occupational Classification) occupation codes for

Panel A: 2002						
Occupation	Mgmt.	Finance	Computers	Engineering	Admin.	Production
Manufacturing (31-33)	0.057	0.025	0.018	0.054	0.099	0.521
Computers and Electronics (334)	0.091	0.053	0.093	0.198	0.112	0.341
Computers (3341)	0.094	0.068	0.202	0.188	0.105	0.233
Communications Equip. (3342)	0.100	0.059	0.082	0.186	0.147	0.314
Audio and Video Equip. (3343)	0.081	0.035	0.026	0.115	0.128	0.476
Semiconductors (3344)	0.079	0.039	0.059	0.201	0.085	0.443
Navigational, Measuring, Elec- tromedical, and Control Instru- ments (3345)	0.102	0.063	0.079	0.232	0.122	0.295
Magnetic and Optical Media (3346)	0.071	0.022	0.137	0.045	0.181	0.232
Panel B: 2023						
Occupation	Mgmt.	Finance	Computers	Engineering	Admin.	Production
Manufacturing (31-33)	0.066	0.050	0.026	0.061	0.076	0.488
Computers and Electronics (334)	0.122	0.092	0.142	0.179	0.070	0.281
Computers (3341)	0.163	0.124	0.293	0.119	0.066	0.110
Communications Equip. (3342)	0.142	0.100	0.169	0.154	0.082	0.222
Audio and Video Equip. (3343)	0.137	0.080	0.087	.	0.099	0.323
Semiconductors (3344)	0.095	0.067	0.074	0.227	0.060	0.380
Navigational, Measuring, Elec- tromedical, and Control Instru- ments (3345)	0.125	0.101	0.141	0.176	0.078	0.269
Magnetic and Optical Media (3346)	0.174	0.119	0.225	.	0.087	0.114

Table A.5: Share of Employment Across Occupations by Manufacturing Industry
Notes: This table lists the share of employment in various manufacturing industries. The column headers are as follows: Mgmt. refers to Management Occupations (SOC 11). Finance refers to Business and Financial Operations Occupations (SOC 13). Computers refers to Computer and Mathematical Occupations (SOC 15). Engineering refers to Architecture and Engineering Occupations (SOC 17). Admin. refers to Office and Administrative Support Occupations (SOC 43). Production refers to Production Occupations (SOC 51). In Panel B, the share of Engineering occupation workers that are in Audio and Video Equipment Manufacturing and Magnetic and Optical Media Manufacturing was not published.

2002. (This is the first year for which the public version of the OEWS used the NAICS classification system.) Slightly more than half of manufacturing employees work in a single 2-digit occupation: Production (SOC 51). By contrast, in Computer and Electronic Products Manufacturing, only one-third of employees work in Production occupations. From 2002 to 2023, the share of production workers declined by about 3 percentage points (from 52% to 49%) for the manufacturing sector and by 6 percentage points for the Computer and Electronic Products Manufacturing industry (from 34% to 28%). For this industry, Management (SOC 11), Finance (SOC 13), Computer Programming (SOC 15), and Engineering and Architecture (SOC 17) collectively account for more than half of its workers, and nearly double the number of workers in production occupations. For this particular industry, domestic manufacturers add value not through their production and assembly of the goods that are consumed but through researching, designing, prototyping, and testing the manufacturing process. The other components of the manufacturing process—namely production and assembly—occur abroad.²⁹

D.3 Industries Missing in the PCE Bridge Table

To compute TFP mismeasurement of a detailed industry (j), it must appear in the PCE Bridge Table for at least one consumption category (c). For instance, while Vegetable and Melon Farming (NAICS 1112) appears in the PCE Bridge Table for the Fresh Vegetables consumption category (NIPA Line 92), Oilseed and Grain Farming (NAICS 1111) does not appear in the PCE Bridge Table. This commodity is sold only to other businesses, not to final consumers.

Figure A.4 plots the share of industries that appear in the PCE Bridge Table, for which we can compute TFP mismeasurement. While Government and Construction industries do not appear in the PCE Bridge, all of the industries producing Food & Beverages (NAICS 311, 312), Textiles, Apparel, and Leather (NAICS 313-316), and Entertainment, Accommodation, and Food (NAICS 71, 72) do. Overall, weighting observations by their gross output, 75% of manufacturing industries and 62% of private (non-governmental industries) appear in the PCE Bridge.

In the remainder of this subsection, we investigate whether industries missing in the PCE Bridge Table are likely to have lower (or higher) estimated mismeasurement. We consider two exercises. First, we look across broad groups of industries, comparing TFP

²⁹These results align with, but are slightly different from, those in Ding et al. (2022) and Fort (2023): These articles document within-firm shifts by which “manufacturing firms” increasingly specialize in establishments performing research and design. Since the OEWS samples establishments, the trends that we document in Table A.5 occur within establishments.

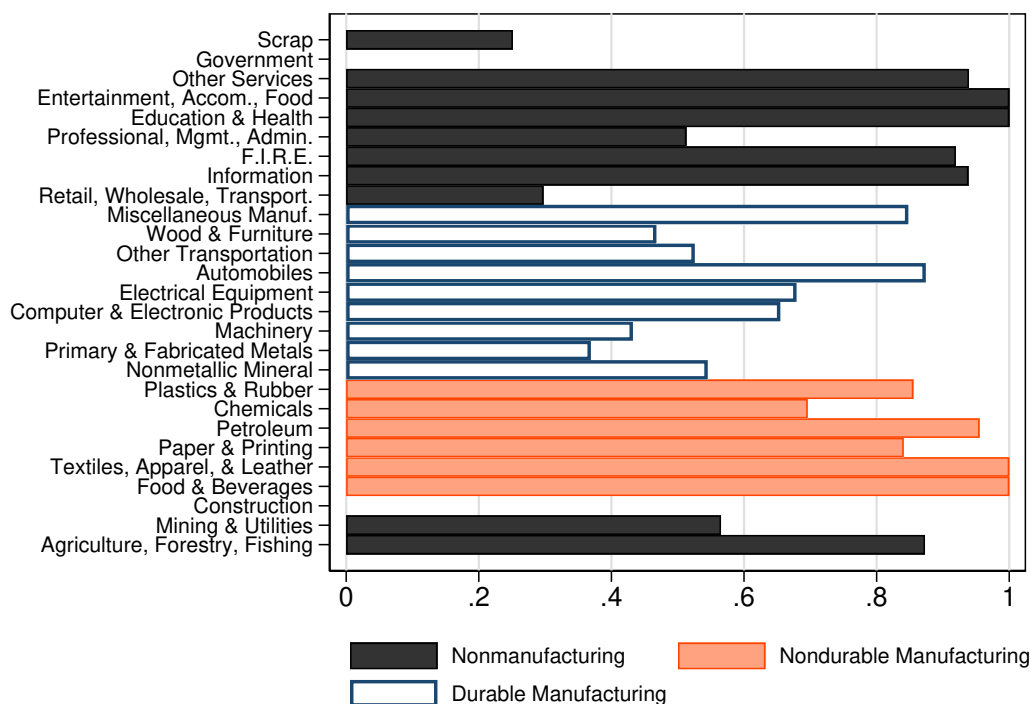


Figure A.4: Share of Industries for Which We Estimate TFP Mismeasurement

Notes: This figure lists the share of grouping of detailed industries for which we can compute TFP mismeasurement. When averaging across industries, we weight according to their gross output in 2017. In computing this figure, we exclude retail, wholesale, and transport industries that appear only through columns D-F of the PCE Bridge Table (see the discussion in Appendix C). Including these industries would increase the entry for the “Retail, Wholesale, and Transport” row from 0.30 to 0.87, increasing the private economy average from 0.62 to 0.78.

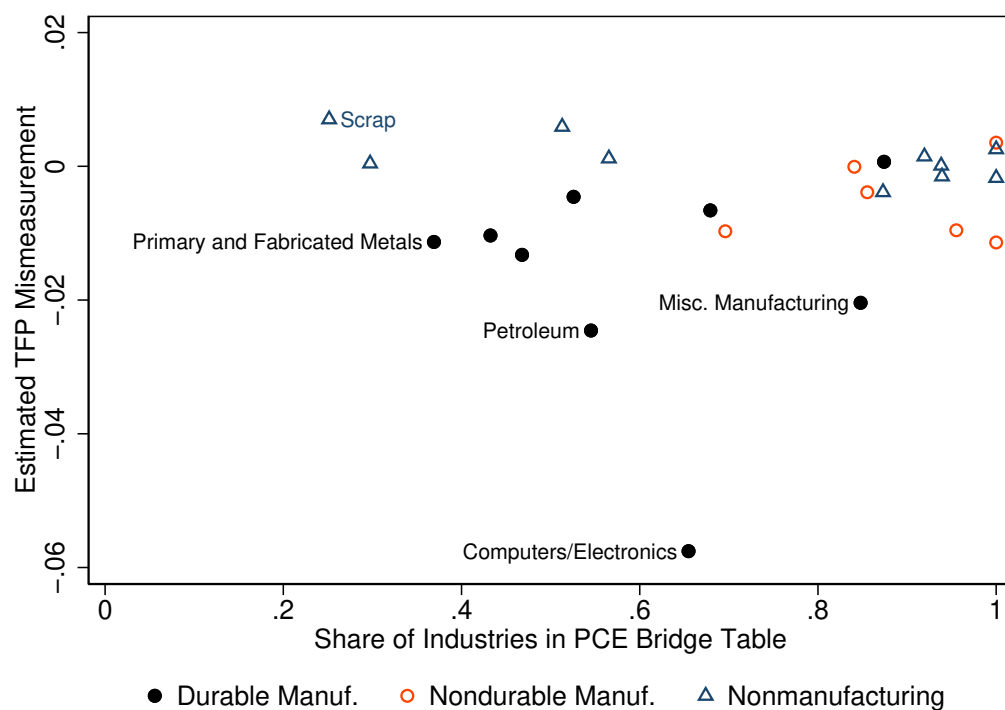


Figure A.5: Share of Industries for Which We Estimate TFP Mismeasurement vs. Average TFP Mismeasurement

Notes: For each of the industries appearing in Figure A.4, excluding “Government” and “Construction,” we relate the share of industries for which we estimate TFP mismeasurement to the average TFP mismeasurement among the industries for which we can compute it.

mismeasurement (among the set of detailed industries for which we can estimate it) to the share of industries appearing in the PCE Bridge Table. The idea behind this exercise is that—if the extent to which gross output deflators understate quality growth is correlated within 2- or 3-digit industries, then we can infer whether we are missing estimates of TFP mismeasurement particularly so in industries where this mismeasurement is likely to be exceptionally high (or exceptionally low.) Figure A.5 presents our comparison. Overall, we find no relationship across the two variables. Weighting observations equally, the correlation is an (insignificant) 0.09; weighting groups of industries according to their gross output (as of 2017), the correlation is 0.03.

While Figure A.5 looks across industry groupings, Table A.6 examines whether there are any differences within industry groupings between those detailed industries that are present or absent in the PCE Bridge Table. We compare industries according to their output prices—either the gross output deflator or our Equation 1 measure of “Producer Inflation.” (We cannot compare industries’ TFP mismeasurement, as we cannot compute this for detailed industries absent from the PCE Bridge Table.)

In more detail, we estimate the following regression:

$$\Delta \log P_j = \beta_J + \beta_1 \cdot \mathbf{1}_{j \in \text{PCE Bridge}} + \varepsilon_j \quad (11)$$

In some regressions, we include fixed effects for the broad industry grouping (i.e., one of the 29 industries listed in Figure 5.) In others, we do not. Table A.6 lists our estimates from Equation 11. Here, we find some differences, but with the sign and significance varying across groups of industries and empirical specifications. Overall, we do not find that industries in the PCE Bridge Table have systematically faster or slower Producer Inflation rates than those that are not represented.

D.4 Dropping Industries with Only Small Entries in the PCE Bridge Table

Another concern, which we examine in this section, is that our estimates of TFP mismeasurement may be driven by NAICS commodities that appear within the PCE Bridge Table, but only marginally so. Consider, as an example of this potential concern, the NAICS commodity 3274: Lime and Gypsum Products Manufacturing. In 2017, domestic gross output of this commodity was \$8.1 billion. This commodity appears in the PCE Bridge Table once, contributing \$71 million towards the consumption category “Clocks, Lamps, Lighting Fixtures, and Other Household Decorative Items” (NIPA Line 26.) (The three most important NAICS Commodities for this consumption category are 33999, S00402, and 335120: “Used and Secondhand Goods,” “All Other Miscellaneous Manufacturing,” and “Lighting Fixture

Panel A: All Sectors						
Dependent Variable	Producer Inflation				Gross Output Deflator	
In PCE Bridge	-0.004 (0.002)	-0.002 (0.002)	-0.001 (0.004)	0.005*** (0.002)	-0.001 (0.004)	0.005*** (0.002)
Observations	398	398	398	398	398	398
Adjusted R^2	0.009	0.421	-0.001	0.480	-0.002	0.478
Fixed Effect	None	Industry	None	Industry	None	Industry
Weighted	No	No	Yes	Yes	Yes	Yes
Panel B: Durable Manufacturing						
Dependent Variable	Producer Inflation				Gross Output Deflator	
In PCE Bridge	-0.010** (0.003)	-0.008** (0.003)	-0.005 (0.003)	0.001 (0.004)	-0.005 (0.003)	0.002 (0.003)
Observations	151	151	151	151	151	151
Adjusted R^2	0.050	0.437	0.006	0.466	0.001	0.453
Fixed Effect	None	Industry	None	Industry	None	Industry
Weighted	No	No	Yes	Yes	Yes	Yes
Panel C: Nondurable Manufacturing						
Dependent Variable	Producer Inflation				Gross Output Deflator	
In PCE Bridge	-0.002 (0.003)	0.003* (0.001)	0.003 (0.004)	0.002 (0.002)	0.004 (0.005)	0.004 (0.003)
Observations	80	80	80	80	80	80
Adjusted R^2	-0.008	0.344	-0.008	0.566	-0.002	0.557
Fixed Effect	None	Industry	None	Industry	None	Industry
Weighted	No	No	Yes	Yes	Yes	Yes
Panel D: Nonmanufacturing						
Dependent Variable	Producer Inflation				Gross Output Deflator	
In PCE Bridge	-0.002 (0.005)	0.006*** (0.002)	-0.002 (0.005)	0.006** (0.002)	-0.002 (0.005)	0.006*** (0.002)
Observations	167	167	167	167	167	167
Adjusted R^2	-0.003	0.401	-0.000	0.430	-0.001	0.429
Fixed Effect	None	Industry	None	Industry	None	Industry
Weighted	No	No	Yes	Yes	Yes	Yes

Table A.6: Differences in Output Prices between Industries Present or Absent in the PCE Bridge Table

Notes: Each column by panel presents the results from a separate regression. The first four columns have the Producer Inflation measure (defined in Equation 1) as the dependent variable. The final two columns have gross output deflator inflation as the dependent variable. An observation is a detailed industry. The standard errors are clustered at the more aggregated industry level (i.e., each of the clusters is one of the 29 industries listed in Figure 5.)

Manufacturing,” respectively.) Our estimate of TFP mismeasurement for this commodity comes from comparing its price index to that in an only loosely related consumption category. More generally, we may doubt our estimates of TFP mismeasurement for commodities that have a small contribution in the PCE Bridge Table, relative to their total gross output.

In the panels of Figure A.6, we consider the impact of removing commodities with small contributions to the PCE Bridge Table. The left panel reproduces our baseline results. The middle panel removes detailed commodities for which the total value in the PCE Bridge Table relative to its gross output is less than 0.25. In the right panel, we increase that threshold to 0.50.

In the main, our conclusions are robust across these three panels. In our baseline specification, TFP growth was understated by 1.7 percentage points in the durable goods sector, understated by 0.4 percentage points in the nondurable goods sector, and overstated by 0.1 percentage points in nonmanufacturing sectors. In the middle and right panels, TFP growth in the durable goods manufacturing sector is understated by 1.8 percentage points. In both the middle and right panels, nondurable goods’ TFP growth is understated by 0.4 percentage points and overstated by 0.1 percentage points in nonmanufacturing industries. For the Computer and Electronic Products Manufacturing industry, TFP growth is understated by 5.8 percentage points in the left and middle panels and 6.2 percentage points in the right panel.

D.5 TFP Mismeasurement with Alternate Definition of \mathbf{O}_t

In this section, we assess the robustness of our conclusions in Section 3 to our definition of \mathbf{O}_t . This matrix was necessary for translating price mismeasurement at the PCE category level to price mismeasurement at the NAICS commodity level.

In the body of the paper, we defined:

$$\begin{aligned}\mathbf{O}_{t,jc} &\equiv 1 \text{ if } v_{t,j \rightarrow c} = \max_{c'} v_{t,j \rightarrow c'} \text{ and} \\ &\equiv 0 \text{ otherwise .}\end{aligned}$$

In words, for each NAICS commodity (j) we searched for the PCE consumption category c that has the largest value in the PCE Bridge Table. As an example, consider NAICS Commodity 336111 (Automobile Manufacturing). This appears twice in the PCE Bridge Table. As of 2017, it contributes \$14.87 billion in the consumption of New Domestic Autos (NIPA Line 7) and \$5.23 billion in the consumption of New Foreign Autos (NIPA Line 8.) According to this first definition, for the row associated with $j = 336111$, $\mathbf{O}_{t,jc}$ would be equal to 1 for the column associated with NIPA Line 7, and 0 otherwise. In essence, we infer price

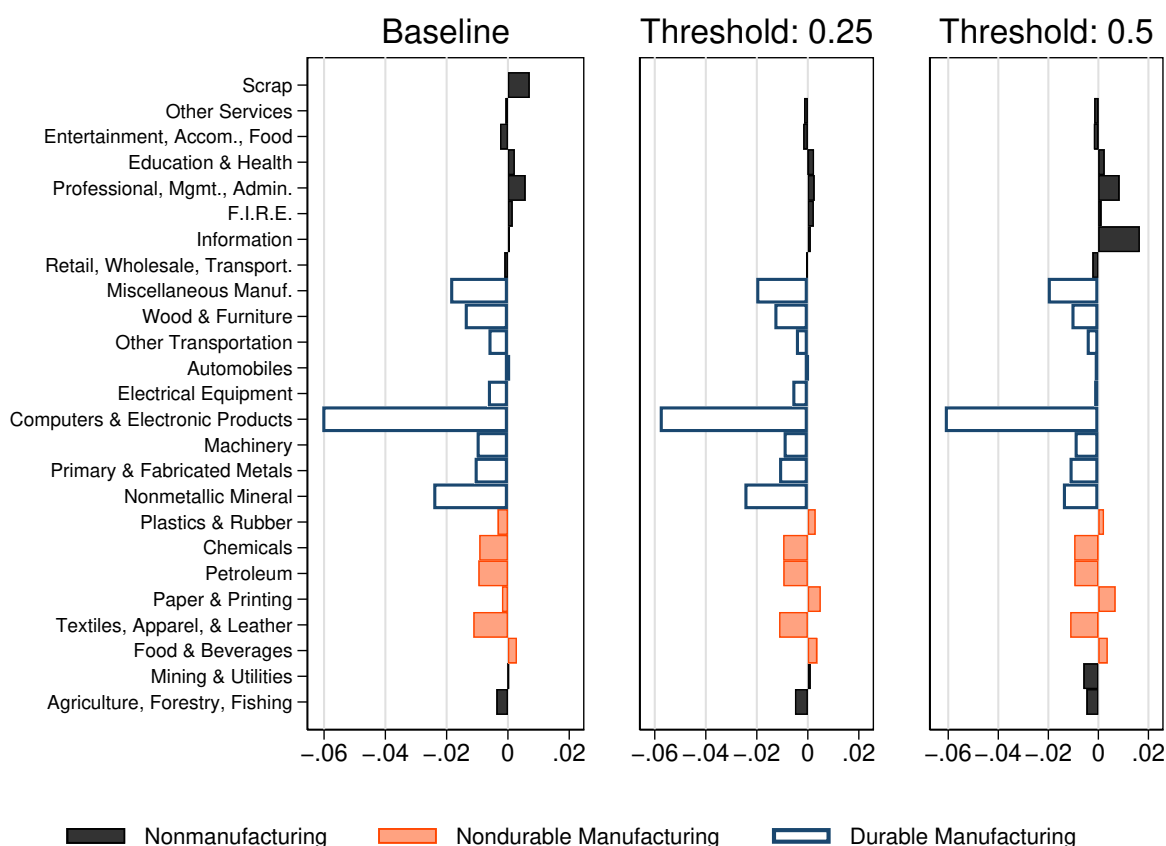


Figure A.6: Sensitivity to Dropping Commodities with Only "Small" Entries in the PCE Bridge Table

Notes: The left panel recapitulates the left panel of Figure 5. The middle panel drops detailed industries for which the sum of its entries in the 2017 PCE Bridge Table is less than 25% of the its gross output in the same year. The right panel drops detailed industries for which the sum of its entries in the 2017 PCE Bridge Table is less than 50% of the its gross output in the same year. Entries for "Scrap" are missing for these panels, as there are no detailed industries meeting this threshold. Of the 255 detailed industries represented in the left panel, 156 are included in the middle panel, and 130 in the right panel.

mismeasurement of Automobile Manufacturing from price mismeasurement in New Domestic Autos.

In this section, we consider an alternative definition for $\mathbf{O}_{t,jc}$. We set:

$$\mathbf{O}_{t,jc} \equiv \frac{v_{t,j \rightarrow c}}{\sum_{c'} v_{t,j \rightarrow c'}} . \quad (12)$$

Here, we infer an industry's price mismeasurement as a weighted average of the mismeasurement in all of the PCE consumption categories it is linked to. Returning to our autos example, for the row associated with NAICS 336111, $\mathbf{O}_{t,jc}$ would be equal to 0.739 = $\frac{14.87}{14.87+5.23}$ for the column associated with NIPA Line 7, 0.261 for the column associated with NIPA Line 8, and 0 elsewhere. Here, we infer price mismeasurement of Automobile Manufacturing from a weighted average of price mismeasurement in New Domestic Autos and New Foreign Autos.

Figure A.7 presents our alternate results. TFP mismeasurement is similar to what we had presented in Figure 5. In Figure 5, annual manufacturing TFP growth is understated by 0.7 percentage points. For durable goods, TFP growth is understated by 1.6 percentage points. Both figures are 0.1 percentage points less than the, respectively, 0.8 percentage points and 1.7 percentage points in the baseline specification.

D.6 Sensitivity to Assumptions on the Mismeasurement in Import Price Growth and Relative to Mismeasurement in Gross Output Deflator Growth

In deriving our estimate of TFP mismeasurement in Section 3, we were required to make some assumption on the relative magnitudes of mismeasurement in import price growth and mismeasurement in gross output deflator growth. Without any guidance from the literature on the relative guidance of mismeasurement in the two indices, we had assumed that they were equal to one another: $\Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} = \Delta \log \tilde{\mathbf{P}}_t^{\text{Import}}$. This assumption allowed us to rewrite Equation 6 as:

$$\begin{aligned} \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} = & \mathbf{O}_t \left[\Delta \log \mathbf{P}_t^{\text{PCE}} \right. \\ & \left. - \mathbf{S}_t \left[(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}} \right] \right] . \end{aligned} \quad (13)$$

In this appendix, we consider how our results from Figure 5 would change if mismeasurement in import price growth was proportionate—but not necessarily equal to—mismeasurement in gross output deflator growth. That is, we suppose that $\Delta \log \tilde{\mathbf{P}}_t^{\text{Import}} = \xi \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}}$ for different values of ξ . Since the TFP mismeasurement we infer is smaller for larger values of ξ , our focus is on values of ξ greater than 1.

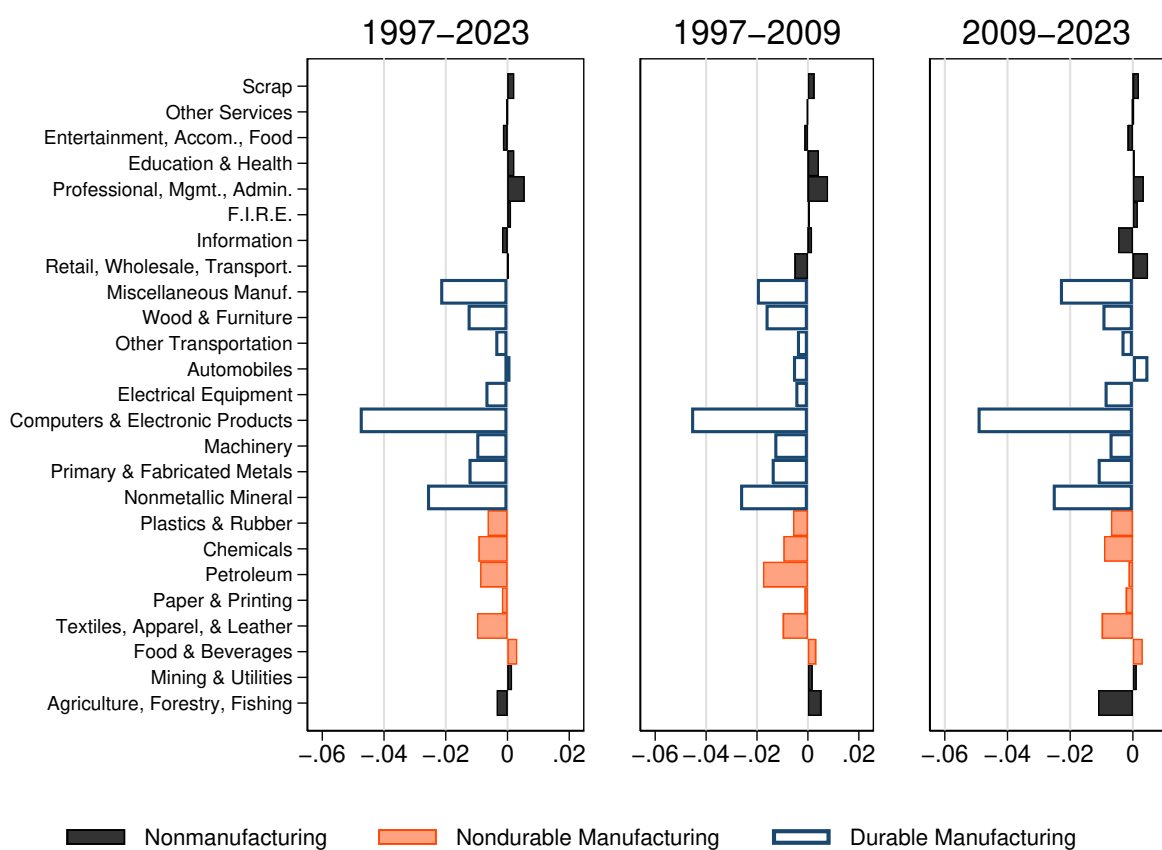


Figure A.7: TFP Mismeasurement

Notes: See the notes for Figure 5. In contrast to that figure, we apply Equation 12 to compute O_t .

When $\xi \neq 1$, Equation 13 generalizes to:

$$(\mathbf{I} - (1 - \xi)\mathbf{M}_t) \Delta \log \tilde{\mathbf{P}}_t^{\text{GO}} = \mathbf{O}_t [\Delta \log \mathbf{P}_t^{\text{PCE}} - \mathbf{S}_t [(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}}]] . \quad (14)$$

In this equation, \mathbf{M}_t is a matrix with entries of the \mathbf{m}_t vector on the diagonal. Off-diagonal entries of \mathbf{M}_t are equal to 0.

This expression for $\Delta \log \tilde{\mathbf{P}}_t^{\text{GO}}$ yields the following expression for $\Delta \log \tilde{\mathbf{A}}_t$:

$$\Delta \log \tilde{\mathbf{A}}_t = -[(\mathbf{I} - (1 - \xi)\mathbf{M}_t)^{-1} - \mathbf{\Gamma}_t] \mathbf{O}_t [\Delta \log \mathbf{P}_t^{\text{PCE}} - \mathbf{S}_t [(\mathbf{1} - \mathbf{m}_t) \circ \Delta \log \mathbf{P}_t^{\text{GO}} + \mathbf{m}_t \circ \Delta \log \mathbf{P}_t^{\text{Import}}]] . \quad (15)$$

In Figure A.8, we plot our estimates of TFP mismeasurement by industry groups for $\xi \in \{1, \frac{5}{4}, \frac{3}{2}\}$. Overall, higher values of ξ lead to smaller estimates of TFP mismeasurement in the manufacturing sector: For $\xi = \frac{5}{4}$, TFP growth in this sector is understated by 0.7 percentage points. For $\xi = \frac{3}{2}$, manufacturing TFP growth is understated by the same amount. The Computer and Electronic Products Manufacturing industry has relatively high import penetration. Accordingly, estimated TFP growth mismeasurement is more sensitive to the choice of ξ than in other industries. Assuming $\xi = \frac{3}{2}$, we estimate that TFP growth is understated by 4.4 percentage points (as opposed to 5.8 percentage points when $\xi = 1$).

In sum, when inferring TFP mismeasurement, we were compelled make some assumptiuo

E Contrasting ICT Industries to All Others

Throughout the paper, our focus has been on the productivity of the manufacturing sector. We have argued that measured productivity growth in manufacturing was considerably higher than elsewhere up to the late 2000s and considerably slower since then. We have also argued that productivity growth is mismeasured specifically in manufacturing. Our choice to focus on the manufacturing sector, and the special role that Computer and Electronic Products Manufacturing played within it, is premised on standard industry classifications, which group industries according to their production processes. In this appendix, we consider an alternate perspective of grouping industries: We contrast industries related to information and communication technologies to all other industries.

In the body of the paper and in the appendix, we have highlighted three distinctive features of Computer and Electronic Products Manufacturing. First, Section 1 and Appendix D.1 documents that two four-digit industries—Computers and Peripheral Equipment Manufacturing (NAICS 3341) and Semiconductor and Other Electronic Component Man-

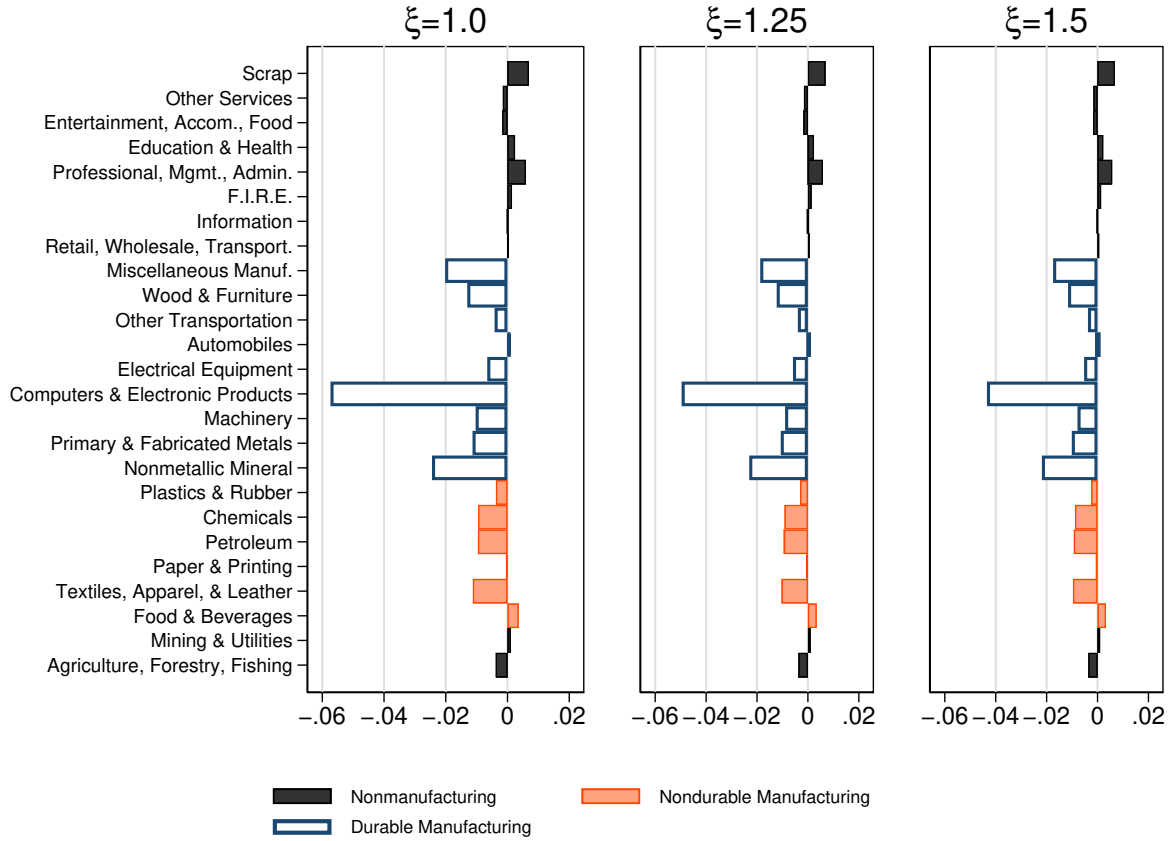


Figure A.8: TFP Mismeasurement

Notes: See the notes for Figure 5. In contrast to that figure, we apply Equation 15 to compute $\Delta \log \tilde{\mathbf{A}}_t$.

ufacturing (NAICS 3344)—account for the remarkable growth of the manufacturing sector between 1987 and 2009 and the deceleration since. Furthermore, Sections 2 and 3 illustrate that TFP growth in Computer and Electronic Products Manufacturing (NAICS 334) is understated by nearly six percentage points. Finally, in Appendix D.2 we have highlighted that production occupations comprise a meaningful share of workers in all manufacturing industries (albeit with a lower share in Computer and Electronic Products Manufacturing).

In this appendix, we examine ICT-related outside of manufacturing. We ask three questions:

- Which industries have production processes, as measured by the occupations of the workers they employ, similar to those within Computer and Electronic Products Manufacturing?
- Which industries, akin to Computer and Electronic Products Manufacturing, play an outsized role in their sectors’ productivity growth trajectory?
- Which industries, if any, have their TFP growth understated due to undercounted quality growth?

In addition to in the manufacturing sector, information-and-communication-related industries reside in the wholesale, retail, information, and professional service sectors. In wholesale, the two related industries are Professional and Commercial Equipment and Supplies Merchant Wholesalers (NAICS 4234, hereafter “Professional and Commercial Equipment Wholesalers”) and Household Appliances and Electrical and Electronic Goods Merchant Wholesalers (NAICS 4236, hereafter “Household Appliances and Electronics Wholesaling”). In retail, the single related industry is Electronics and Appliance Stores (NAICS 4431.) Within the information sector, several industries provide services related to information and communications technologies: Software Publishers (NAICS 5112), Data Processing, Hosting, and Related Services (NAICS 5182), Wired and Wireless Telecommunications Carriers (NAICS 5171), Wireless Telecommunications (NAICS 5172), Satellite, Telecommunications Resellers, and All Other Telecommunications (NAICS 5174, 5179), Internet Publishing and Broadcasting and Web Search Portals (NAICS 5193).³⁰ Finally, we include Computer Systems Design and Related Services (NAICS 5415), an industry in the professional, scientific, and technical services sector.

Table A.7 presents occupation profiles for ICT-related industries outside of manufacturing. The only industries with any meaningful share of production workers are those in the wholesaling sector. Similar to Computer and Electronic Products Manufacturing, these

³⁰In information, NAICS industries have changed considerably over the last two decades.

industries had their employees relatively evenly spread across management, finance, computer, engineering, and transportation-and-material-moving occupations. These industries have occupation profiles most similar to Computer and Electronic Products Manufacturing. By contrast, Electronics and Appliance stores had none of their workers in these occupations. Industries in the information and professional services sector had a plurality of their workers either in computer occupations or in repair/maintenance occupations, and less than one percent of their workers in production occupations.

Figure A.9 presents the productivity growth rates for all 4-digit wholesale industries in addition to Electronics and Appliance Stores (in retail), Software Publishers (in information), Telecommunications Carriers (in information), Data Processing and Internet Publishing (in information), and Computer Systems Design and Related Services (in professional services). Unfortunately, the BLS Productivity dataset does not contain TFP for most of these industries. We plot labor productivity instead. Similar to Computer and Electronic Products Manufacturing, both wholesale industries follow a late-2000s productivity deceleration. Software Publishers' labor productivity follows an even more extreme deceleration, but one which occurred slightly earlier. The other retail, information, and professional service industries followed a different pattern, with labor productivity first increasing then decreasing in the first three industries and essentially unchanged in Computer Systems Design. In sum, the industries with productivity declines most similar to Computer and Electronic Products Manufacturing are those which wholesale ICT goods.

These two industries, by themselves, account for much of the wholesale sector's productivity growth since 1987. To show this, in Figure A.10 we plot labor productivity for the wholesale sector as well as the contribution of all wholesale industries with the exception of the two ICT-related industries. To ease comparison, we also plot labor productivity in the manufacturing sector. Akin to Figure 2, Professional and Commercial Equipment Wholesaling and Household Appliances and Electronics Wholesaling represent the majority of the sector's productivity trajectory. By contrast to manufacturing, the wholesale sector's productivity continued to grow in the 2010s. Also in contrast to Figure 2, industries in wholesale outside of NAICS 4234 and NAICS 4236 had positive productivity growth throughout the sample.³¹

In a final exercise, we report TFP mismeasurement for ICT-related industries. For our benchmark exercise (described in Figure 5), we cannot identify mismeasurement for ICT-related wholesale, retail, and professional service industries. While TFP mismeasurement

³¹Part of the difference, here, has to do with the fact that we are considering a different productivity measure-labor productivity instead of TFP. Between 1987 and 2023, manufacturing labor productivity growth exceeds TFP growth by 1.4 percentage points. For wholesale, the difference is 2.3 percentage points.

Panel A: 2002						
Occupation	Mgmt.	Computers	Sales	Admin.	Maint.	Prod.
Professional and Commercial Equip. (4234)	0.078	0.145	0.241	0.227	0.112	0.050
Household Appliances and Electronics (4236)	0.100	0.029	0.265	0.270	0.074	0.063
Electronics and Appliance Stores (4431)	0.053	0.061	0.477	0.167	0.133	0.014
Software Publishers (5112)	0.132	0.501	0.088	0.124	0.005	0.003
Wired Telecommunications (5171)	0.076	0.077	0.103	0.277	0.293	0.003
Wireless Telecommunications (5172)	0.088	0.079	0.268	0.359	0.082	0.006
Telecommunications Resellers (5173)	0.077	0.079	0.156	0.298	0.267	0.001
Cable and Other Program Distrib. (5175)	0.056	0.032	0.086	0.362	0.362	0.002
Other Telecommunications (5179)	0.125	0.106	0.077	0.190	0.220	0.007
Internet Service Providers (5181)	0.138	0.378	0.076	0.249	0.022	.
Data Processing, Hosting (5182)	0.095	0.297	0.049	0.379	0.012	0.015
Other Information Services (5191)	0.056	0.049	0.018	0.415	0.017	.
Computer Systems Design (5415)	0.111	0.532	0.058	0.142	0.018	0.008
Panel B: 2023						
Occupation	Mgmt.	Computers	Sales	Admin.	Maint.	Prod.
Other Durable Goods Wholesalers (4230A1)	0.100	0.023	0.221	0.153	0.049	0.080
Professional and Commercial Equip. (4234)	0.122	0.129	0.218	0.162	0.089	0.038
Electronics and Appliance Stores (4492)	0.048	0.020	0.615	0.118	0.123	0.003
Software Publishers (5132)	0.170	0.456	0.104	0.079	0.002	0.002
Telecommunications (5170)	0.073	0.160	0.178	0.149	0.297	0.001
Computing Infrastructure Providers (5182)	0.153	0.393	0.100	0.153	0.004	0.006
Web Search Portals (5192)	0.149	0.365	0.115	0.108	0.002	.
Computer Systems Design (5415)	0.148	0.506	0.070	0.073	0.008	0.003

Table A.7: Share of Employment Across Occupations In Selected Wholesale, Retail, and Information Industries

Notes: This table lists the share of employment in various nonmanufacturing industries. The column headers are as follows: Mgmt. refers to Management Occupations (SOC 11). Computers refers to Computer and Mathematical Occupations (SOC 15). Sales refers to Sales and Related Occupations (SOC 41). Admin. refers to Office and Administrative Support Occupations (SOC 43). Maint. refers to Installation, Maintenance, and Repair Occupations (SOC 49). Prod. refers to Production Occupations (SOC 51). In Panel A, the shares of Production occupation workers that are in the Internet Service Providers and Other Information Services industries was not published. In Panel B the share of Production occupation workers that are in the Web Search Portals industry was not published.

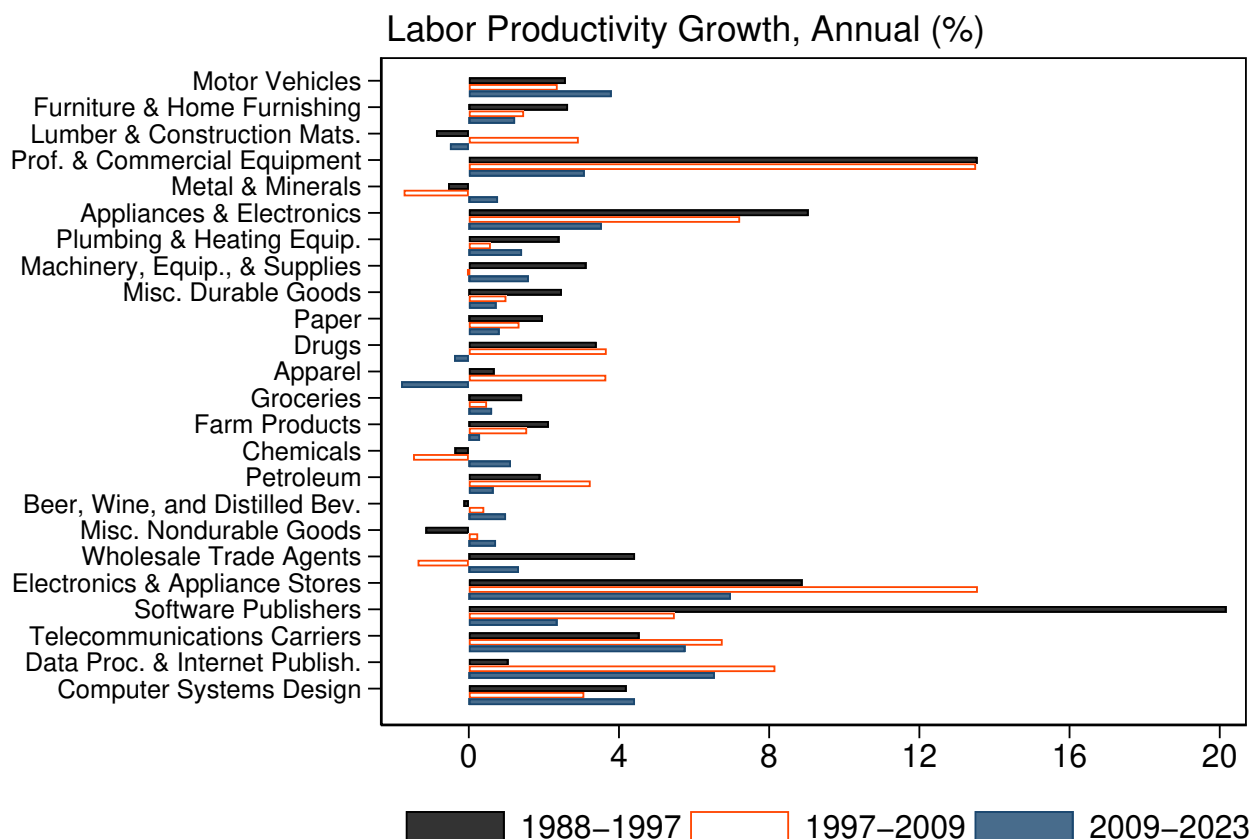


Figure A.9: Annual TFP Growth Rate for Selected Nonmanufacturing Industries

Notes: This figure plots labor productivity growth for each of the 19 4-digit industries within the wholesale sector. Additionally it plots labor productivity growth for Electronics & Appliance Stores (NAICS 4431, in retail), Software Publishers (NAICS 5112, in information), Telecommunications Carriers (NAICS 517, in information), Data Processing, Internet Publishing, & Related Services (NAICS 5182, in information), Computer Systems Design Services (NAICS 5415, in professional services.)

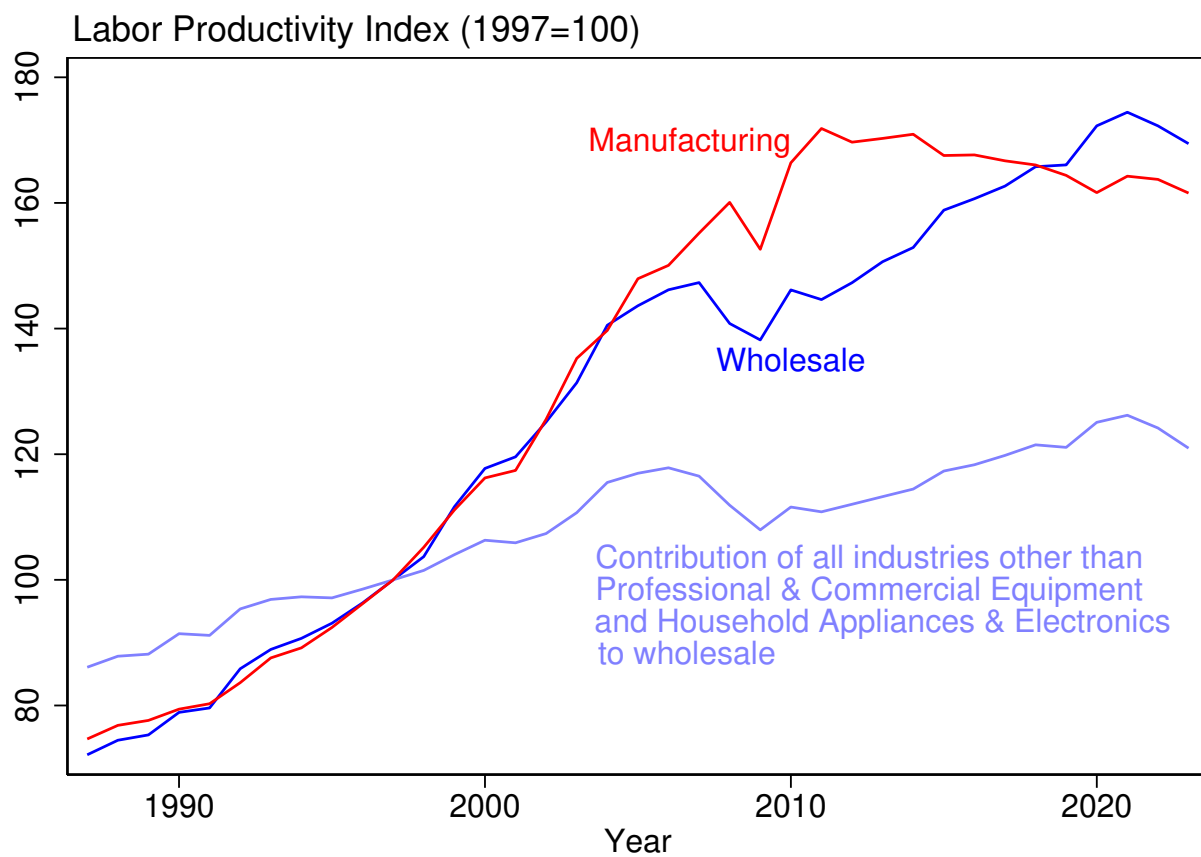


Figure A.10: Labor Productivity for Manufacturing, Wholesale, and Wholesale Excluding Professional & Commercial Equipment and Household Appliances & Electronics

for the broader information sector is close to zero (see Figure 5), this sector includes industries like Motion Picture and Video Industries; Newspaper, Periodical, Book, and Directory Publishers; and others that have no connection to information-and-communication technologies. Instead, we consider the specific industries related to ICT information services. Within the information sector, Software Publishers' TFP growth is understated by 3.3%. Satellite, Telecommunications Resellers, and All Other Telecommunications' TFP growth is understated by 3.5%. But other ICT industries have much smaller TFP mismeasurement: 1.6 percentage points for Wireless Telecommunication Carriers and 0.0 percentage points for Data Processing. It is *overstated* for Internet Publishing and Broadcasting (1.6 percentage points) and Wired Telecommunications Carriers (2.5 percentage points). Summing up these seven detailed commodities, TFP growth is understated, by less than two percentage points.

In sum, in this appendix, we have searched for industries that resembled the distinctive features of the Computer and Electronic Products Manufacturing industry that we highlighted in the paper. We searched for industries that (a) had at least some production occupation workers, (b) productivity decelerating in the late 2000s, and (c) TFP mismeasurement. Two industries in the wholesale sector—Professional and Commercial Equipment Wholesalers (NAICS 4234) and Household Appliances and Electronics Wholesaling (NAICS 4236) match the first two criteria. We could, unfortunately, not estimate TFP mismeasurement for these industries. Software Publishers also had a deceleration in productivity, but one which occurred earlier than for industries that manufactured or wholesaled ICT goods. Our framework suggests that Software Publishers' TFP growth is understated, but is less than the mismeasurement for Computer and Electronic Products Manufacturers' TFP growth.