Labor Share Decline and Intellectual Property Products Capital*

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Abstract

We study the behavior of the US labor share over the past 65 years. We find that intellectual property products (IPP) capital accounts entirely for the observed decline of the US labor share, which is otherwise secularly constant for traditional capital (i.e., structures and equipment). The decline of the labor share reflects the fact that the US is undergoing a transition to a more IPP capital-intensive economy. This result has essential implications for the US macroeconomic model.

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1 Introduction

The constancy of the labor share (LS), one of the great fantasies of contemporary macroeconomics, has finally gone: The LS declines. Updated with the most recent national income and product accounts (NIPA) data after the 2013 Bureau of Economic Analysis (BEA) comprehensive revision, the US aggregate LS decreases from 0.68 in 1947 to 0.60 in 2013 (panel (a) of Figure 1). Compared with the LS implied by the pre-revision data (Elsby, Hobijn, and Sahin, 2013, Karabarbounis and Neiman, 2014a, Piketty and Zucman, 2014), the up-to-date LS shows a prolonged secular decline that started much earlier, in (at least) the late 1940s, doubling the size of the decline of the pre-revision LS from roughly 4 to 8 LS points, and still continues (panel (b) of Figure 1). These findings shatter the alleged constancy of the LS (Kaldor, 1957, Prescott, 1986), which is nothing short of "a bit of a miracle" in Keynes' colorful language.

After carefully analyzing the national income and fixed assets data from the 1999 and 2013 BEA revisions that capitalize intellectual property products (IPP), we show that the secular decline of the LS is entirely driven by the recognition and the increasing importance of IPP capital in national income. That is, the decline of the LS is strictly a measurement issue related to aggregate capital. The introduction of IPP capital to the existing types of traditional capital (i.e., structures and equipment) has revised significantly the behavior of the measured aggregate capital income and affected the implication it has on factor shares. The faster growing investment in IPP and its higher depreciation rate, relative to traditional capital, give rise to a significant component of aggregate capital income, the IPP depreciation, which accounts for two thirds of the LS decline. The rising net IPP capital income accounts for the remaining one third of the LS decline.

The introduction of IPP capital in national accounts is a substantial improvement on the measurement of aggregate capital and output. While the IPP is (and has always been) part of the US economy (Corrado, Haltiwanger, and Sichel, 2005a, Akcigit, Celik, and Greenwood, 2013), it is only after the changes in the BEA accounting rules, which expand the definition of capital, that the effects of IPP capital on the LS emerge. The 11th comprehensive revision of NIPA in 1999 recognized business and government expenditures for software as fixed investment. After the most recent 14th comprehensive revision in 2013, the BEA now treats expenditures by business, government and nonprofit institutions serving households (NPISH) for R&D, and expenditures by private enterprises for the creation of entertainment, literary and artistic originals (henceforth, artistic originals) as investments in various forms of durable capital and no longer, as previously done, as expenditures in intermediate nondurable goods (for the private sector) or as final consumption (for the government sector).These two newly recognized forms of investment (R&D and artistic originals), combined with software (recognized since 1999), form a class of

intangible assets, the so-called IPP. This re-classification of capital implies an upward revision of all previous estimates of the private sector GDP, which mostly reflects the increase in the consumption of fixed capital generated by the higher depreciation of these new assets.[1] Overall, these revisions capture the increasingly important role of IPP in the US economy: The share of IPP in aggregate investment has increased from 8% in 1947 to 26% in 2013; see also McGrattan and Prescott (2014).[2]

To investigate the effects of IPP capital on the behavior of the LS—in an accounting sense—we compare two LS constructs. First, we construct the aggregate LS using the post-2013 BEA revision data that includes income from both IPP capital and traditional capital. Second, we construct a traditional LS that includes only income from traditional capital. The comparison between the aggregate LS and the traditional LS yields the main result of our paper. While the aggregate LS exhibits the prolonged secular decline described earlier, the traditional LS is absolutely trendless. In other words, the increase in IPP capital income over time accounts for the entire secular decline in the LS that started in the late 1940s. The decline in the LS simply reflects an ongoing shift to a more IPP capital-intensive economy.

Our results have essential implications for the US macroeconomic model. While the long-standing aggregate Cobb-Douglas production function is consistent with the trendless long-run behavior of the traditional LS, this is clearly not the case anymore with IPP capital in the picture. The explicit consideration of IPP capital generates a secular decline of the LS and the US model should incorporate these new facts. In terms of the aggregate production function, we show that a re-interpretation of the traditional capital-augmenting technical change as a form of IPP capital deepening offers a consistent reading of the new facts. This IPP capital deepening mechanism—a modeling choice guided by our accounting result that attributes the LS decline to IPP capital—implies that capital and labor must be more than Cobb-Douglas substitutes. While our result for an elasticity of substitution between capital and labor larger than one is consistent with the recent evidence in Karabarbounis and Neiman (2014a), we fully attribute this finding to IPP capital. Indeed, our framework embeds the Cobb-Douglas paradigm as a special case in which IPP capital is omitted from both the aggregate production function and the national income accounts.

[1] The net IPP capital income was already incorporated in measured output prior to these BEA revisions, even though the factor that contributed to it was not recognized. That is, the measured output from proprietors and corporate firms using IPP capital (e.g., software or higher-quality and newer inputs developed through R&D) already included the net returns from the use of IPP (Fraumeni and Okubo, 2005). For example, Amazon's software engineers are constantly finding a more efficient way to organize production: what to order, at which price to sell and where to ship. The increase in sales and revenue from using newer versions of the in-house software is already present in the measured profit (BLS, 1989).

[2] This shift in aggregate investment toward IPP is of considerable size and does not show signs of deceleration. Excluding residential investment accentuates this shift: The investment in IPP grows from 11% of nonresidential aggregate investment by 1947 to 32% by 2013.

The rest of the paper is organized as follows. First, we compare the properties of IPP capital versus traditional capital in Section 2. Second, we show that the decline of the LS is driven by the inclusion of IPP capital in national accounts in recent BEA revisions in Section 3. Third, we discuss the implications of our results for the US model in Section 4. We conclude in Section 5.

2 IPP Capital versus Traditional Capital

IPP capital can differ from traditional capital along three channels: The flow of investment, its price, and the depreciation rate. We investigate these channels for both types of capital in this section. In terms of flows, both IPP and traditional investment have grown exponentially over the past 65 years but at different rates. IPP investment shows a faster growth than traditional investment. Traditional investment increased by a factor of 6 between 1947 and 2013, while IPP investment increased by a factor of 25 (panel (a) of Figure 2). The logged series of investment imply a linear annual growth of 4.9% for IPP investment and 2.7% for traditional investment. This differential in growth rates implies a compositional change in aggregate investment. The share of IPP in aggregate investment has grown almost linearly from 8% in 1947 to 26% in 2013 (panel (b) of Figure 2).[3,4]

The price of IPP investment and that of traditional investment show strong similarities (panel (c) of Figure 2). While the price of investment in IPP is uniformly lower than that in traditional capital, both dropped by a similar amount of 52% and 40% respectively between 1947 and 2013, with a clear acceleration after the mid-1970s in both cases. In the case of IPP capital, the acceleration is largely driven by software, as the prices of the other components of IPP (i.e., R&D and originals) are fairly constant over the entire period.[5] In the case of traditional capital, the

[3]IPP investment comes largely from the private sector. From the late 1940s to the mid-1960s, private and government IPP investment moved in tandem and rose slowly from 4 to 8% of aggregate investment. Since the mid-1960s, the private IPP investment has accelerated to reach 20% of aggregate investment by 2013, while the government IPP investment remains somewhat steady around 6%. Further details can be found in Section 4 of the longer version of this paper (available online).

[4]The growing relative importance of IPP investment is valid regardless of whether we include the housing sector or not. While in reporting these shares we have included residential investment in aggregate investment, we find that excluding residential investment further increases the IPP investment share to 10% in 1947 and to 32% in 2013.

[5]The BEA provides series of the price of investment in IPP as well as series of the price of investment in the components of IPP. The BEA measures R&D price changes using an input-cost approach with a productivity adjustment. In terms of artistic originals, BEA develops an input cost index for each type of entertainment originals. See BEA (2013) for more details. We utilize BEA's price indices for fixed investment in structures, equipment and IPP. We construct the series of the price of traditional investment using a standard Törnqvist aggregate of the price index of structures and equipment that closely follows Ríos-Rull, Schorfheide, Fuentes-Albero, Kryshko, and Santaeulàlia-Llopis (2012). We document our data construction in online Appendix A.1.4. Note that both series plotted are relative to the price of consumption. The prices of investment in IPP components can be found in panel (c) if Figure B-1 in online Appendix B.

acceleration is driven by equipment (Greenwood, Hercowitz, and Krusell, 1997).

The depreciation rate of IPP and traditional capital are plotted in panel (d) of Figure 2. The depreciation rate of IPP is much higher—reflecting the higher rate at which IPP becomes obsolete—and grows over time.[6] It starts at 15% per year in 1947 and grows to 21.4% in 2013. The increase in IPP depreciation is due to a compositional change within IPP in which software, the IPP component with the highest depreciation rate averaging 34% in the 2000s, increases its share in IPP investment from 4% in the 1960s to 40% in the 2000s.[7] The depreciation rate of traditional capital is steady around 4% for the entire period.

A complementary approach to understand the difference between IPP and traditional investment is through the effects that IPP has on the current BEA measure of aggregate investment that includes both IPP and traditional investment. Figure 3 shows the effects of IPP on aggregate investment, its price and depreciation rate. Panel (a) shows aggregate investment and traditional investment. The ratio between aggregate and traditional investment increased from 1.08 in 1947 to 1.36 in 2013, showing the increasing importance of IPP in aggregate investment. We also compare the price of aggregate investment, that incorporates both IPP and traditional investment, with the price of traditional investment in panel (b). Both series have declined since the 1950s in a very similar fashion, dropping by 40% from 1947 to 2013. The price of aggregate investment is slightly lower than the price of traditional investment. The ratio between the former and the latter is roughly 1.00 in the 1960s and around 0.97 since the 2010s. In other words, the fall in the price of investment is not driven by IPP. Finally, the difference between depreciation rates of aggregate capital and traditional capital is shown in panel (c) of Figure 3. IPP has a large effect on the aggregate depreciation rate. The depreciation rate of aggregate capital is uniformly higher than that of traditional capital and this differential grows over time. The aggregate depreciation rate increased from 4% in 1947 to 5.2% in 2013, while the traditional depreciation rate stayed at roughly 3.8% through the entire period. This implies that the ratio of aggregate to traditional

[6] BEA's estimates of the depreciation of R&D assets are from a forward-looking profit model using firm-level and establishment-level data from certain R&D intensive industries (see online Appendix A.2). The estimates of the depreciation of artistic originals is based on analyses of profits over a typical product life-cycle for various forms of entertainment originals assets. For more details on BEA's treatment, see BEA (2013). Given BEA's estimates of the current-cost depreciation and net stock of capital by type of assets retrieved from the Fixed Assets Tables, we construct the depreciation rate of a type of capital by dividing the current-cost depreciation of that capital by its current-cost net stock of capital. For our data construction, see online Appendix A.1.2.

[7] Software is the IPP capital with the highest depreciation rate starting at around 30% per year in the early 1960s and reaching 34% per year in the 2000s. The depreciation rate of R&D capital is roughly 17% per year and the depreciation rate of artistic originals capital has been roughly 14% since the 1970s; see panel (d) of Figure B-1 in online Appendix B. Further, while R&D accounts for around 80% of total IPP investment in the early 1960s, this share declined to a steady 50% in the 2000s; see panel (b) of Figure B-1 in online Appendix B. In contrast, the share of software investment in IPP increased from an average of 4% in the 1960s to a steady average of 40% since the 2000s. Artistic originals account for about 10% throughout the entire sample.

depreciation rate increased from 1.05 in the late 1940s to 1.25 in the 2010s.

3 The Effects of IPP Capital on Measured Labor Share

In this section we describe the data and the construction of the aggregate LS. Then, we show that the decline of the aggregate LS is purely a measurement issue driven by the inclusion of IPP capital in national income.

3.1 The US Labor Share, 1947-2014

We use the standard definition of LS in growth and business cycle theory from Cooley and Prescott (1995) which corresponds to the aggregate (or "economy-wide basis") measure proposed in Kravis (1959) and recently discussed in Elsby, Hobijn, and Sahin (2013).[8] Following this approach, to split the income for which the attribution to either capital or labor is ambiguous, we attribute to capital income the same proportion of the ambiguous income as the proportion of unambiguous capital income to unambiguous income.[9] We apply this definition to the entire economy as a natural benchmark to study the factor distribution of the income of the US economy. More precisely, we define

1. Unambiguous Capital Income (UCI) = Rental Income + Corporate Profits + Net Interest + Current Surplus Government Enterprises
2. Unambiguous Income (UI) = UCI + Depreciation (DEP) + Compensation of Employees (CE)
3. Proportion of Unambiguous Capital Income To Unambiguous Income: $\theta = \frac{\text{UCI}+\text{DEP}}{\text{UI}}$.
4. Ambiguous Income (AI) = Proprietors' Income + Taxes on Production − Subsidies + Business Current Transfers Payments + Statistical Discrepancy
5. Ambiguous Capital Income (ACI) = $\theta\times$ AI.

Then, capital income is computed as

$$\text{Capital Income} = \text{UCI} + \text{DEP} + \text{ACI},$$

[8] Our data and all the results of our analysis are available in this permanent link: US Factor Shares.

[9] This definition of LS is also used in Gomme and Rupert (2004, 2007) and in Ríos-Rull and Santaeulàlia-Llopis (2010). As in Ríos-Rull and Santaeulàlia-Llopis (2010), we do not include land, which we regard as inaccurately measured. Further, the flow of funds accounts, the original source for land capital and its rents, no longer publish the series, as also noted by Gomme and Rupert (2007). We can, however, add consumer durable goods to the computation of the LS, under the assumption of the same net rate of return to consumer durables as to other forms of capital (see Cooley and Prescott (1995)). The results of our exercise do not change with this addition.

which we use to construct our benchmark LS as

$$\text{Labor Share} = 1 - \text{Capital Share} = 1 - \frac{\text{Capital Income}}{Y},$$

where aggregate output, Y, is the gross national product (GNP), that is, the sum of total unambiguous and ambiguous income, i.e., $Y = \text{UCI} + \text{DEP} + \text{CE} + \text{AI} \equiv \text{GNP}$.

Panel (a) in Figure 1 shows the time series of the aggregate LS constructed from the post-2013 revision data. Clearly, it exhibits a relentless secular decline starting in the late 1940s. The LS begins at 0.68 in 1947 and reaches a historical low at 0.60 in 2013, a decline of 8 LS points.

To put our paper in perspective, it is important to note that the recent debate about the secular decline of the LS (e.g., Elsby, Hobijn, and Sahin (2013), Karabarbounis and Neiman (2014a), and Piketty and Zucman (2014)) has relied on evidence from the pre-2013 revision data.[10] For the purpose of comparison, we present in the same figure our benchmark LS and its pre-2013 revision equivalent (panel (b) of Figure 1). Since both series of LS follow the same definition, the difference in their behaviors results strictly from the difference in the data inputs, or the 2013 BEA revision on the data. The first observation is that the 2013 BEA revision shifts the LS down and brings forward the decline from the late 1970s to the late 1940s. Second, our benchmark LS exhibits a much stronger decline than its pre-revision equivalent. Precisely, the pre-2013 revision data imply a decline of the LS from 0.68 in 1947 to 0.64 in 2013, a decline of 4 LS points, as compared to the decline of 8 LS points from the post-2013 revision data. Fitting a linear time trend to our post-2013 LS yields a secular decline of 7.2 LS points, while this number is 4.4 LS points using the pre-2013 revision data.The 2013 BEA revision doubles the size of the LS decline previously studied in the literature.

To assess the effects of IPP capital on the measured behavior of the LS, we compare the following two constructions of the LS. First, the aggregate LS, LS, computed with the current BEA national income accounting that includes capital income from both IPP capital and traditional capital. Second, a traditional LS, LS_T, computed using only capital income from traditional

[10] There are several remarks to be made. First, Elsby, Hobijn, and Sahin (2013) focus on LS constructs provided by the Bureau of Labor Statistics (BLS), which we discuss in online Appendix D. Second, Karabarbounis and Neiman (2014a) focus on the corporate LS — see our discussion in Appendix D.1 — although these authors also provide estimates for the aggregate economy using national income data and Penn World Tables data. Third, while our analysis, as in Elsby, Hobijn, and Sahin (2013) and Karabarbounis and Neiman (2014a), focuses on the gross LS, Piketty and Zucman (2014) study the decline of the net LS. Piketty and Zucman (2014) construct a LS for the US that starts at the level of 0.80 in 1974 and decreases to 0.71 in 2010. For that sample period, our benchmark LS declines from 0.67 to 0.61. The larger LS decline found by these authors is most likely due to the difference in the data sources, in particular, as argued in Bonnet, Bono, Chapelle, and Wasmer (2014), to the use of market prices for housing capital. Instead, our LS construct is strictly based on BEA national income data.

capital. Dropping time subscripts, the aggregate LS under the current BEA accounting is

$$LS = 1 - \frac{R_{IPP}k^x_{IPP} + R_T k^x_T}{y}, \tag{1}$$

where k^x_j is the stock of capital j and R_j the gross return to capital j for $j \in \{IPP, T\}$. This way, the capital income generated from IPP capital is $R_{IPP}k^x_{IPP}$ and that from traditional capital is $R_T k^x_T$. The traditional LS that does not include IPP capital is:

$$LS_T = 1 - \frac{R_T k^x_T}{y - R_{IPP}k^x_{IPP}}, \tag{2}$$

where capital income is generated only from traditional capital. Note that if we remove IPP from capital income (i.e. the numerator), we also need to adjust output (i.e. the denominator).

By definition, the aggregate LS specified in (1) is the current post-2013 BEA revision measure of the LS described earlier in this section using Figure 1, which exhibits a large and prolonged secular decline. To compute the traditional LS in (2), we must remove the IPP capital income from each and all of the national income items. Unfortunately, BEA does not provide information on the amount of IPP capital income separately for each national income item, except for depreciation. That is, we cannot use BEA data to directly retrieve $R_{IPP}k^x_{IPP}$. However, we can resolve this situation from an aggregate perspective with the separate series of k^x_{IPP}, k^x_T, R_{IPP} and R_T. The capital series k^x_{IPP} and k^x_T are directly provided by the BEA. The series for the rates of return, R_{IPP} and R_T, are recovered from observables using a standard investment model with two types of capital, traditional and IPP, as we describe next.

3.2 The Rate of Return from an Investment Model

Consider a competitive-markets environment with one final consumption-good sector produced from an aggregate production function with two capital inputs, IPP and traditional, respectively $j \in \{IPP, T\}$, and labor input h_t.[11] The production function,

$$y_t = f(k_{IPP,t}, k_{T,t}, h_t; \Omega_t),$$

exhibits constant returns to scale (CRS) and Ω_t represents technological parameters. Importantly, absolutely no further requirement on its shape is assumed in addition to CRS.

[11] We provided an analogous three-sector model in the Appendix to the longer version of the paper (available online), where structures, equipment, and IPP capital are treated as separate capital goods. Our results under that framework are similar to those obtained with the two-sector model studied in this section.

Investments in capital j is given by:

$$x_{j,t} = v_{j,t} i_{j,t},$$

where v_j is the inverse of the price of investment j in terms of consumption. The separate production of each of these investment goods, x_j, is linear in their respective investments, i_j, with its corresponding technical change, v_j. Their associated law of motions for capital are:

$$k_{j,t+1} = x_{j,t} + (1 - \delta_{j,t}) k_{j,t}, \tag{3}$$

where δ_j is the depreciation rate for capital j.

The Bellman equation of a representative firm's investment problem:

$$V(k_{IPP}, k_T; \Omega) = \max_{k_{IPP}, k_T, l} f(k_{IPP}, k_T, h; \Omega) - wh - \sum_{j=\{IPP,T\}} \frac{x_j}{v_j} + \frac{1}{1+r'} V(k'_{IPP}, k'_T; \Omega'),$$

where the production costs are in labor wages w for the labor input h and in investment j for each type of capital good. Let the net return to capital, or the interest rate, be denoted as r_t, which is common across capital types. Note that in this recursive formulation the primes denote next period values. The investment decision of the firm (i.e., the FOCs for each type of capital j) implies that the gross return to capital, or the marginal product of capital, for capital j is:

$$R'_j = \frac{1}{v_j}(1 + r') - \frac{1}{v'_j}(1 - \delta'_j), \tag{4}$$

where the only unknown is the net return (or interest rate), r, because we know the series for v_j and δ_j from the data. That is, optimal investment implies that R_j is a function of the series of r, v_j, and δ_j, and hence, once we find r we also find R_j. It is important to note that to derive the gross return to capital in (4) we do not need to impose (and have not imposed) any functional form on the production function.

We find r by exactly matching the model LS to the aggregate LS series from the data,

$$LS = 1 - \frac{R_T(r, v_T, \delta_T) k^x_T + R_{IPP}(r, v_{IPP}, \delta_{IPP}) k^x_{IPP}}{y}, \tag{5}$$

in which r is the only unknown per year because the rest of series in (5), that is, LS, y, k^x_{IPP}, v_{IPP}, δ_{IPP}, k^x_T, v_T, and δ_T, are directly retrieved from the data. If we plug r back to (4), we find R_j for each j.

Finally, we can investigate (in a purely accounting sense) the effects of IPP capital on LS by computing the traditional LS free of IPP capital income specified in (2) and compare it with the aggregate LS specified in (1) that incorporates both IPP and traditional capital income and that we described in Section 3.1.

3.3 Quantitative Results

Our main result is shown in Figure 4. There we plot the aggregate LS that incorporates both IPP and traditional capital income and the traditional LS that includes only traditional capital income. In striking contrast to the aggregate LS (blue line), the traditional LS (orange line) is trendless over the past 65 years; the respective linear trends plotted in Figure 4 are for the 1947-2010 period. If we fit a linear trend to the traditional LS from 1947 to any endpoint between 2008 and 2013, the estimated trend is not significantly different from zero.[12,13] That is, the observed decline of the LS is simply a measurement issue entirely driven by the introduction of IPP capital in national accounts.[14,15]

To assess the evolution of IPP capital intensity, we decompose the capital share of income into that generated by IPP and traditional capital in Figure 5. Consistent with our main result, the traditional capital share of income remains steady around 30.6% through the entire sample period. At the same time, the capital share of IPP is what explains the secular rise in the capital share of income by linearly increasing from 1.6% in the late 1940s to 6.6% in 2013. That is, the

[12]Precisely, a linear trend from 1947 to 2008, at the onset of the Great Recession, yields a nonsignificant slope of -0.000401; a linear trend from 1947 to 2012 yields a negative but nonsignificant slope of -0.001454.

[13]We further note that large and persistent cyclical fluctuations of LS, however, survive our scrutiny of IPP capital. Simple visual inspection of Figure 4 suggests that IPP capital does not change the cyclical properties of the LS. Hence, while IPP capital can explain the secular decline of LS, the cyclical behavior of LS does not seem much altered by it and remains unexplained; see a recent discussion in Koh and Santaeulàlia-Llopis (2014).

[14]In Appendix C, we extend our analysis to the historical sample period 1929-2013 for which national income data are available and reach the very same result.

[15]Our results are robust to the definition of the LS (see Appendix D) and to industry analysis (see Appendix E). First, by focusing on the corporate LS, we largely mitigate the concerns raised in Gomme and Rupert (2004, 2007) and Karabarbounis and Neiman (2014a). Again, applying to the corporate sector the same methodology we have implemented on the entire economy, we find that IPP capital completely accounts for the decline in the corporate LS. Second, we find similar results with the LS provided by the Major Sector Multifactor Productivity Division of the BLS, the "Assest Basis" LS definition suggested in Elsby et al. (2013). Third, at the industry level, there is also a strong and negative correlation between the LS and IPP capital intensity. Of the three industries whose output is expanding relative to the rest of the economy, the service and information industry, which combined account for 35% of total output in 2013, have experienced a substantial decline in LS and an increase in IPP capital intensity. In addition, the four major industries whose output share declines (i.e., manufacturing of durable and nondurable goods, retail trade and wholesale trade) also display a decline in LS and an increase in IPP capital intensity. In particular, both durable and nondurable manufacturing, which have experienced the largest declines in LS also experience the largest increase in IPP capital. Manufacturing would not have experienced any decline since the mid-1980s in the absence of IPP capital.

US is going through a transition to a more IPP capital-intensive economy.[16]

To externally validate our results, in panel (a) of Figure 6, we plot the traditional LS against the aggregate LS computed from the vintage BEA data released in 1998 (i.e., before IPP investment made it into national accounts) available at the Archives Library of the St. Louis FED, and the aggregate LS computed in Gomme and Greenwood (1995) who also implemented a definition of LS similar to ours using data before any IPP items entered the national accounts as investment.[17] The results are straightforward. Our traditional LS aligns very well with the LS series from the vintage data that do not incorporate IPP capital. All three series without IPP capital suggest a trendless LS, pointing to IPP as the main source of the decline of the LS.

To put our analysis in the context of the most recent debate of the decline (Elsby, Hobijn, and Sahin, 2013, Karabarbounis and Neiman, 2014a, Piketty and Zucman, 2014), which is motivated by the pre-2013 revision data that only includes software as IPP capital, we ask if incorporating software capital alone accounts for the decline of US LS in the pre-2013 revision data. The answer is yes. To see this, we add to traditional capital income the income from software capital. This produces the green line in panel (b) of Figure 6; note that this line is virtually identical to the actual aggregate LS implied by the pre-2013 revision data (i.e. the magenta line in panel (b) of Figure 6). Conversely, if we took the pre-2013 revision data—invariably used in previous studies to document the decline of the US LS—and removed software capital in those data, we would obtain a trendless LS (i.e. the orange line that purges national income from IPP capital). That is, again, IPP (software) capital explains the LS decline in the pre-2013 revision data.

3.4 A Decomposition of the Effects of IPP Capital on Labor Share

The price of aggregate investment falls with traditional capital (mainly through equipment) and is barely affected by the introduction of IPP prices, see Section 2. In this context, our finding that the traditional LS, which is trendless, coexists with a fall in the price of traditional investment is fully consistent with the traditional-capital frameworks in Greenwood, Hercowitz, and Krusell (1997) and Krusell, Ohanian, Ríos-Rull, and Violante (2000). Clearly, our finding also implies

[16] BEA investment accounts leave out other recognized sources of IPP such as brand equity and organizational capital (Corrado, Hulten, and Sichel, 2005b, 2009). If we focus on the corporate sector, we find that BEA IPP capital represents 11.0% of total capital in the late 1990s, while this figure is 29.4% in McGrattan and Prescott (2005). In terms of capital income shares, we find that BEA IPP capital accounts for 5.7% of total income in the 2000s, while this figure is 7.6% in McGrattan and Prescott (2010). These comparisons confirm the notion that BEA captures a fraction, i.e., roughly two thirds of total IPP. To address this issue, at least partially, we extend the BEA accounts to incorporate advertising capital, an important dimension of brand equity. We find that incorporating advertising capital shifts the LS down by around 0.015-0.017 LS points from 1947 to 2010 but does not strengthen (or alleviate) the decline of LS. See the longer version of this paper (available online).

[17] We would like to thank Paul Gomme for sharing their vintage data with us.

that the falling price of investment cannot be behind the LS decline, a result that is consistent with Elsby, Hobijn, and Sahin (2013). The LS decline must then come from a combination of IPP investment (and its stock) and IPP depreciation.

To explore the quantitative role of IPP depreciation in LS behavior, we can reformulate the IPP capital income in (4) as

$$R_{IPP,t}k^x_{IPP,t} = \left(\frac{1+r_t}{v_{IPP,t-1}} - \frac{1}{v_{IPP,t}}\right) k^x_{IPP,t} + \frac{\delta_{IPP,t}}{v_{IPP,t}} k^x_{IPP,t},$$

where the first product is IPP capital income net of depreciation and the second is IPP depreciation. Then, we compute the aggregate LS setting IPP depreciation equal to zero. The resulting LS is shown in Figure 7. We find that the total IPP depreciation accounts for roughly 65% of the total decline of the LS, and the remaining is attributed to net IPP capital income.

4 Implications for the US Model

While the long-standing aggregate Cobb-Douglas production function is consistent with the trendless long-run behavior of the traditional LS, this is no longer the case with IPP. The empirical evidence explicitly shows that IPP capital generates a secular decline of the aggregate LS, and the US model should incorporate these new facts. To do so, we move away from the traditional Cobb-Douglas paradigm.

We propose the notion that IPP capital and traditional capital are complementary with some degree ρ and specify the aggregate production function as

$$Y_t = A_t \left(\alpha_k \left(\left(K_{IPP,t}^{\frac{\rho-1}{\rho}} + K_{T,t}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \right)^{\frac{\sigma-1}{\sigma}} + \alpha_h H_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{6}$$

Before explaining the technological parameters governing (6), we can conveniently rewrite it as

$$Y_t = A_t \left(\alpha_k \ (C_t K_{T,t})^{\frac{\sigma-1}{\sigma}} + \alpha_h H_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{7}$$

where

$$C_t = \left(\left(\frac{K_{IPP,t}}{K_{T,t}} \right)^{\frac{\rho-1}{\rho}} + 1 \right)^{\frac{\rho}{\rho-1}}, \tag{8}$$

explicitly depends on IPP capital; and note that for a given ρ we can directly identify C_t from

data on IPP and traditional capital. We can further rewrite our production function as

$$Y_t = \left(\alpha_k \ (B_t K_{T,t})^{\frac{\sigma-1}{\sigma}} + \alpha_h \left(A_t H_t\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{9}$$

which is the familiar shape of the aggregate production function posed in Acemoglu (2002, 2003) where A_t is labor-augmenting technical change and B_t is traditional capital-augmenting technical change. Distinctively, in our case, the traditional capital-augmenting technical change, $B_t = C_t A_t$, is determined by the IPP capital deepening (with respect to traditional capital) as described by (8). In the three equivalent formulations (6), (7) and (9), σ is the elasticity of substitution between aggregate capital and labor.

It is well-known that the long-run dynamics of factor income shares are jointly determined by the elasticity of substitution and the technical change ratio, $C_t = B_t/A_t$. Our contribution here is to explicitly interpret this ratio as a form IPP capital deepening given by (8). This formulation is guided by our main result in Section 3 that IPP capital is the source behind the secular decline of the LS. To assess the implications of these new facts for the US model, i.e., for the value of σ, we estimate this elasticity in two steps.

First, note that we can estimate the elasticity of substitution between IPP capital and traditional capital, ρ, using the ratio of the first order conditions of K_{IPP} and K_T, which is,

$$\ln \frac{R_{IPP,t} K_{IPP,t}}{R_{T,t} K_{T,t}} = \frac{\rho - 1}{\rho} \ln \frac{K_{IPP,t}}{K_{T,t}}, \tag{10}$$

where IPP and traditional capital and their associated gross returns, $R_{IPP,t}$, and $R_{T,t}$, are constructed as in Section 3.2. We find an OLS estimate for ρ of 5.787 significantly different from one. IPP and traditional capital are more than Cobb-Douglas substitutes (Table 1). Using this ρ, we can measure C_t by plugging the data series for IPP and traditional capital in (8).[18]

Second, having recovered C_t, we can estimate the elasticity of substitution between traditional

[18] Importantly, by directly recovering C_t we circumvent the identification impossibility theorem posed in Diamond, McFadden, and Rodriguez (1978) regarding the joint identification of C_t and σ without having to resort to ad-hoc shapes for the behavior of C_t. The empirical literature almost invariably avoids this impossibility by assuming an ad-hoc shape (e.g., a linear trend in log) for C_t (Antràs, 2004, Chirinko et al., 2011). In such a context, the ad-hoc linear trend identifies the differential growth between traditional capital- and labor-augmenting technical change, B_t/A_t. In our framework, however, $C_t = B_t/A_t$ has an explicit interpretation as a technical change driven by IPP capital deepening, which provides a natural alternative guided by the empirical evidence in Section 3. This way, we recognize IPP as the source behind traditional capital-augmenting technical change and the secular decline of the LS.

capital and labor, σ, using the firm's FOCs of capital and labor,

$$\ln \frac{R_{T,t}K_{T,t} + R_{IPP,t}K_{IPP,t}}{w_t H_t} = \ln \frac{\alpha_k}{\alpha_h} + \frac{\sigma - 1}{\sigma} \ln \frac{C_t K_{T,t}}{H_t} \tag{11}$$

where the left hand side is the aggregate capital income to labor income ratio, and the variable term on the right hand side is the aggregate capital to labor ratio.[19] If we focus on the aggregate model where IPP capital is incorporated both in the production function and in the national income, we find an OLS estimate for σ of 1.137 for the full sample and of 1.139 for the 1975-2010 sample (first row in Table 2).[20] In both cases, σ is significantly larger than one. This is due to the fact that both the aggregate capital income to labor income ratio and the aggregate capital to labor ratio grow over time, and hence $\frac{\sigma-1}{\sigma} > 0$ is required in (11). The increase in aggregate capital income to labor income ratio (panel (a) of Figure 8) is directly related to the decline of the aggregate LS. The fact that the aggregate capital to labor ratio grows is determined by the presence of traditional capital deepening (i.e., the ratio $\frac{K_{T,t}}{H_t}$ grows) enhanced by IPP capital deepening through C_t (panel (b) of Figure 8).

In contrast, if we were to use the traditional model that omits IPP capital deepening from the production function (i.e., $C_t = 1$) and from the national income (i.e., $R_{IPP,t}K_{IPP,t} = 0$), the estimated σ is not significantly different from one (second row in Table 2), and we cannot reject the Cobb-Douglas specification of the production function. This is because the traditional capital to labor ratio grows (panel (b) of Figure 8), while the traditional capital income to labor income ratio is trendless (panel (a) of Figure 8)—an empirical consequence of the trendless traditional LS in Section 3.3. This implies that, in the IPP-free scenario, σ must be equal to one to satisfy (11) which delivers the traditional Cobb-Douglas paradigm.

To sum up, we reconcile our empirical finding that IPP capital generates the LS decline (Section 3) with a model of IPP capital deepening. IPP capital deepening implies that aggregate capital and labor must be more than Cobb-Douglas substitutes to explain the decline of the LS. This way, our result adds evidence in favor of a σ larger than one as recently suggested by Karabarbounis and Neiman (2014a). In our case, we fully attribute this finding to IPP capital. To see this, note that our framework embeds the traditional Cobb-Douglas paradigm as a special

[19] All variables related to capital are constructed as described in Section 3.2. Labor income is computed as $w_t H_t = LS_t \times Y_t$. The aggregate hours H_t are constructed from BLS data series "Civilian Employment" (LNS12000000) and "Nonfarm Business Sector: Average Weekly Hours" (PRS85006023, 2009=100) by taking the actual 2009 value of "Average Hours" (LNS12005054) to generate a non-indexed average hours of work. Alternative constructions of aggregate hours using CES or CPS data do not change the results.

[20] In our estimation, an implicit normalization, $K_{T,0} = K_{IPP,0} = H_0 = Y_0 = C_0 = 1$, is assumed, and the points of normalization remain unchanged for the estimation with and without C_t. See Klump and de La-Grandville (2000) for a discussion on the importance of CES normalizations.

case in which IPP capital is omitted from both the aggregate production function and the national income accounts.

5 Conclusion

Two main findings stand out from our analysis. First, the LS decline is a phenomenon that started in the late 1940s and doubles the size of the previous estimates. The length and size of this decline wrecks the balanced growth path hypothesis (or Kaldor facts). Second, IPP capital fully explains the decline in the LS. These empirical findings emerge from recent improvements in the measurement of aggregate capital (and its income) in national accounts. It is all in the measurement. While the well-known Kaldor facts are based on measures of traditional capital associated with a trendless LS, the recent capitalization of IPP in national accounts—gradually incorporated by the 1999 and 2013 BEA revisions—provides a better and a more accurate picture of the US economy, one in which IPP capital generates a secular decline of the LS.

Our results have essential implications for the US macroeconomic model. The long-standing aggregate Cobb-Douglas production function, which is consistent with the long-run behavior of the trendless traditional LS, is clearly not consistent with the aggregate LS that incorporates IPP capital. The explicit consideration of IPP capital generates a secular decline of the LS and the US model should incorporate these new facts. It is this ongoing shift to a more IPP capital-intensive US economy and its implications for the factor distribution of income that should be modeled. We show that a framework with IPP capital deepening, in which capital and labor are more than Cobb-Douglas substitutes, is entirely consistent with the new facts.

While we have focused on the secular behavior of US data, multi-country analysis poses interesting challenges for future research. We also confirm the presence of large and persistent cyclical fluctuations in factor shares that are not altered by IPP capital and that, hence, still beg for an explanation. Finally, while we have not attempted to link LS and economic inequality (see recent discussions in Bridgman (2014), Krusell and Smith (2014) and Karabarbounis and Neiman (2014b)), our result that IPP capital is behind the LS decline suggests that theories that aim at jointly explaining the LS decline and the increase in individual inequality could benefit from explicitly considering innovators and entrepreneurial activities that generate IPP. This leads to our final remark. Considering that IPP is not only an important source of growth (Jones, 2005, Lucas, 2009) but also, as per our results, the main driver of the LS decline, implies that welfare assessments of LS decline should incorporate a growth-inequality tradeoff that has been overlooked by previous studies (e.g., Piketty (2014)).

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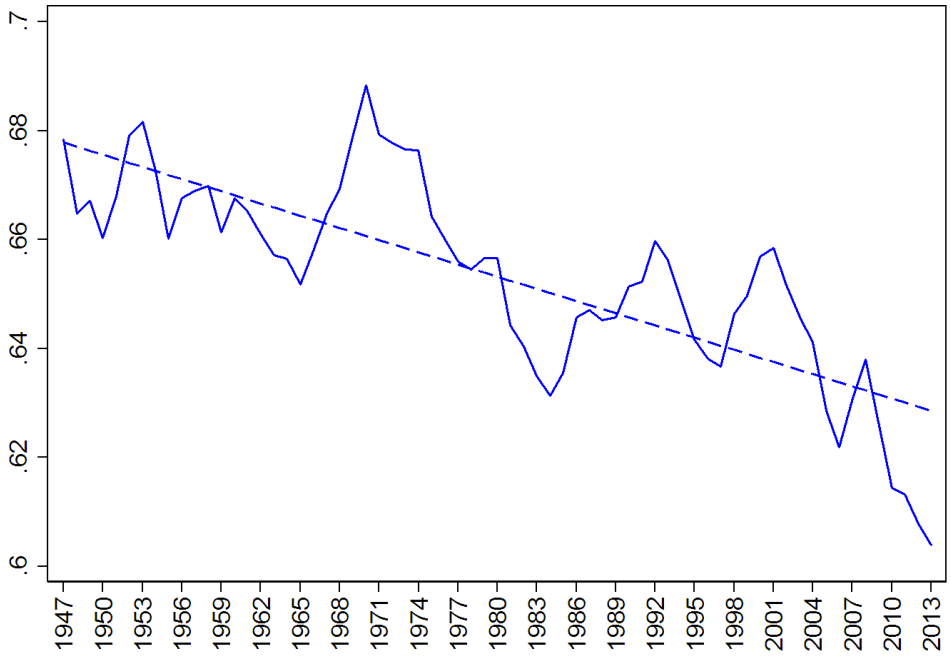
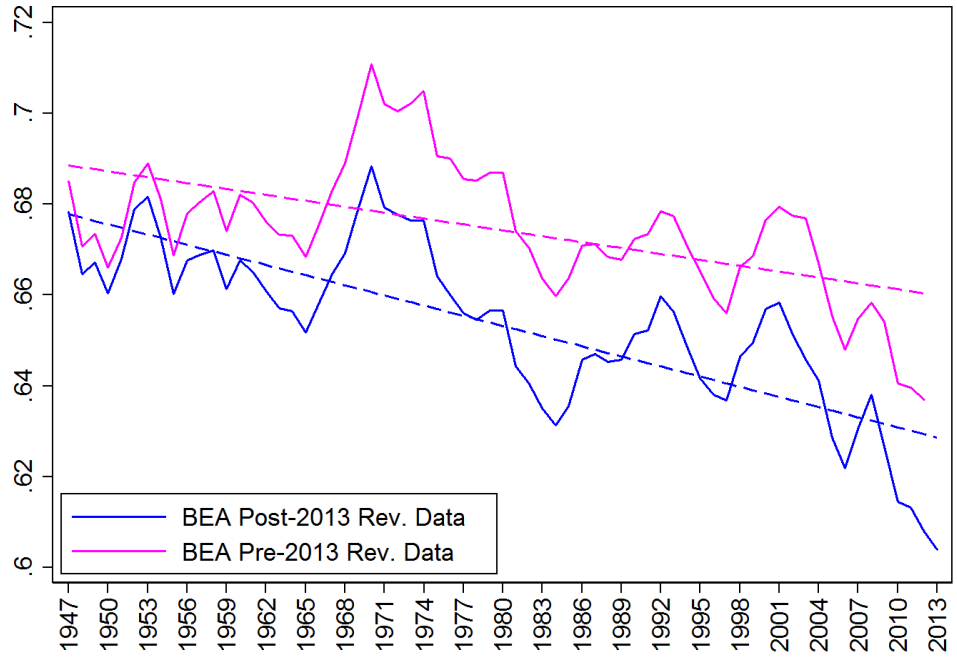
Figure 1: US Labor Share, BEA 1947-2013

(a) Post-2013 BEA Revision

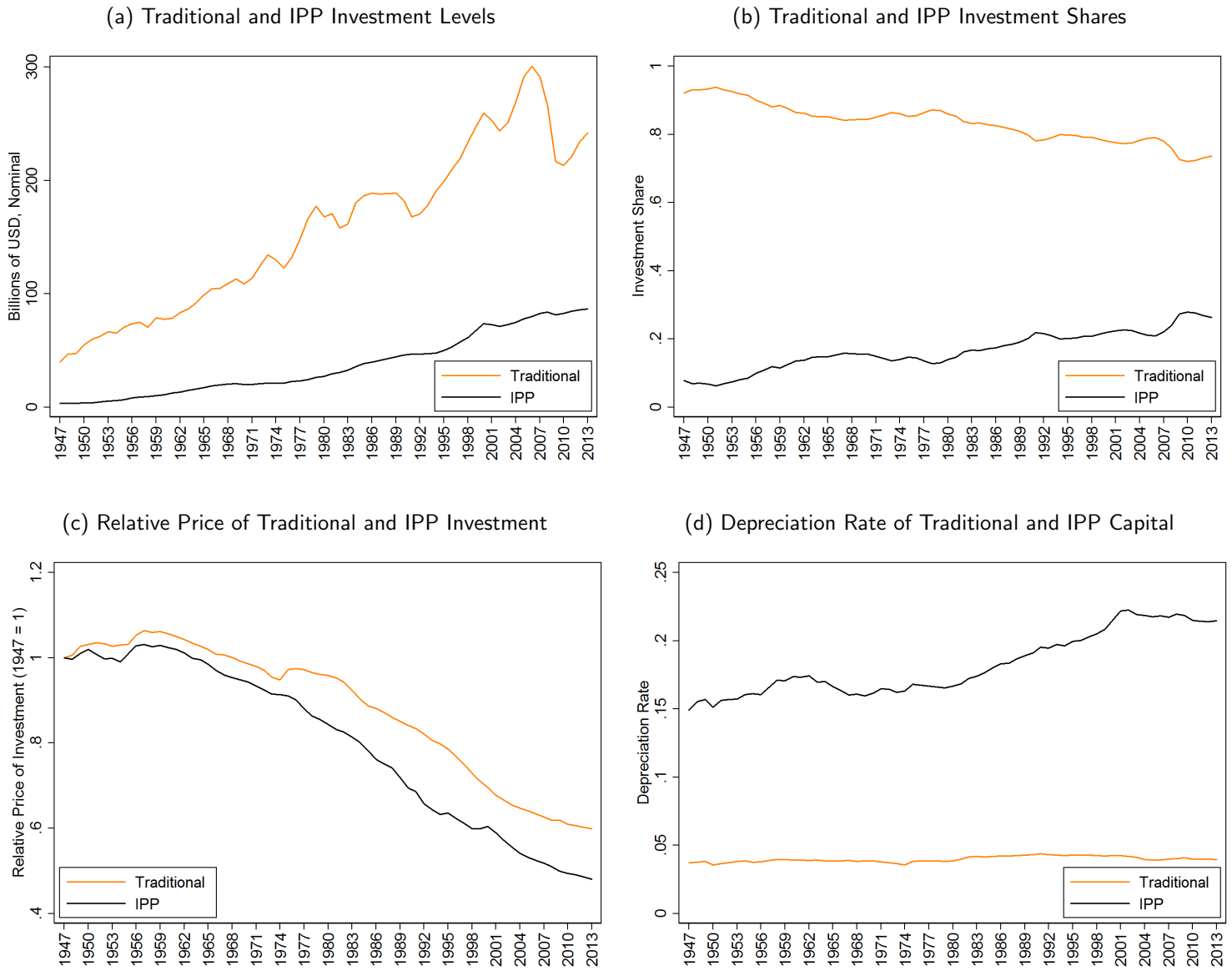


(b) Pre- and Post-2013 BEA Revision



Notes: In panel (a), the labor share of income refers to the aggregate benchmark definition described in Section 3.1 and uses only post-2013 BEA revision data. In panel (b), we plot our benchmark LS together with the LS constructed under the same definition but using the data released before the July 2013 BEA comprehensive revision. The dashed lines are fitted linear trends with an absolute decline of 4.4 percentage points from 1947 to 2013 using pre-2013 revision data and 7.2 percentage points using post-2013 revision data. All variables used in computations are in nominal terms.

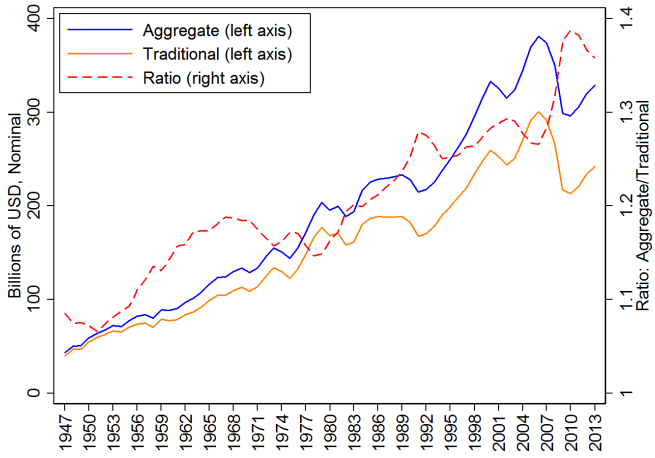
Figure 2: Traditional Capital versus IPP Capital



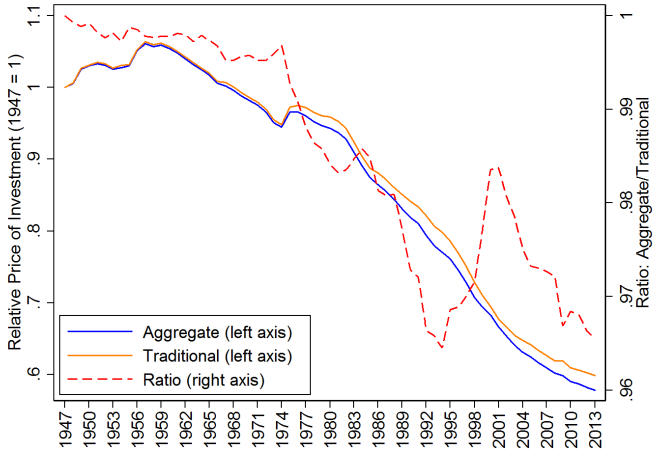
Notes: Traditional capital includes structures and equipment. IPP capital includes software, R&D and artistic originals (see Section 2). The investment shares are in terms of aggregate investment that includes both private and government investment and both residential and nonresidential investment. The construction of aggregate investment, investment price, and depreciation rate is discussed in Section 2.

Figure 3: Effects of IPP on Aggregate Investment, Its Price and Depreciation Rate

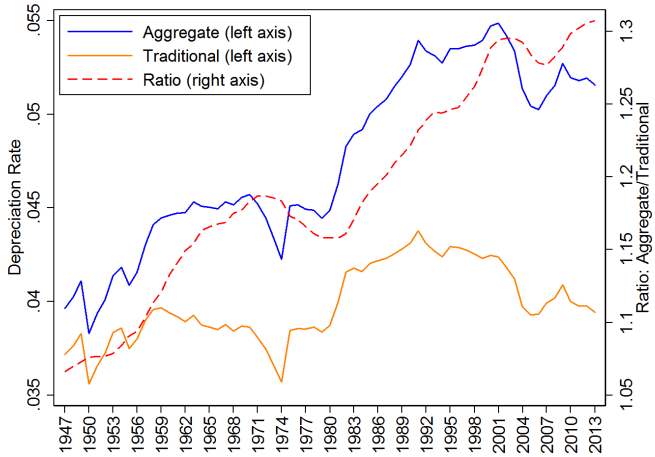
(a) Aggregate Investment



(b) Relative Price of Aggregate Investment

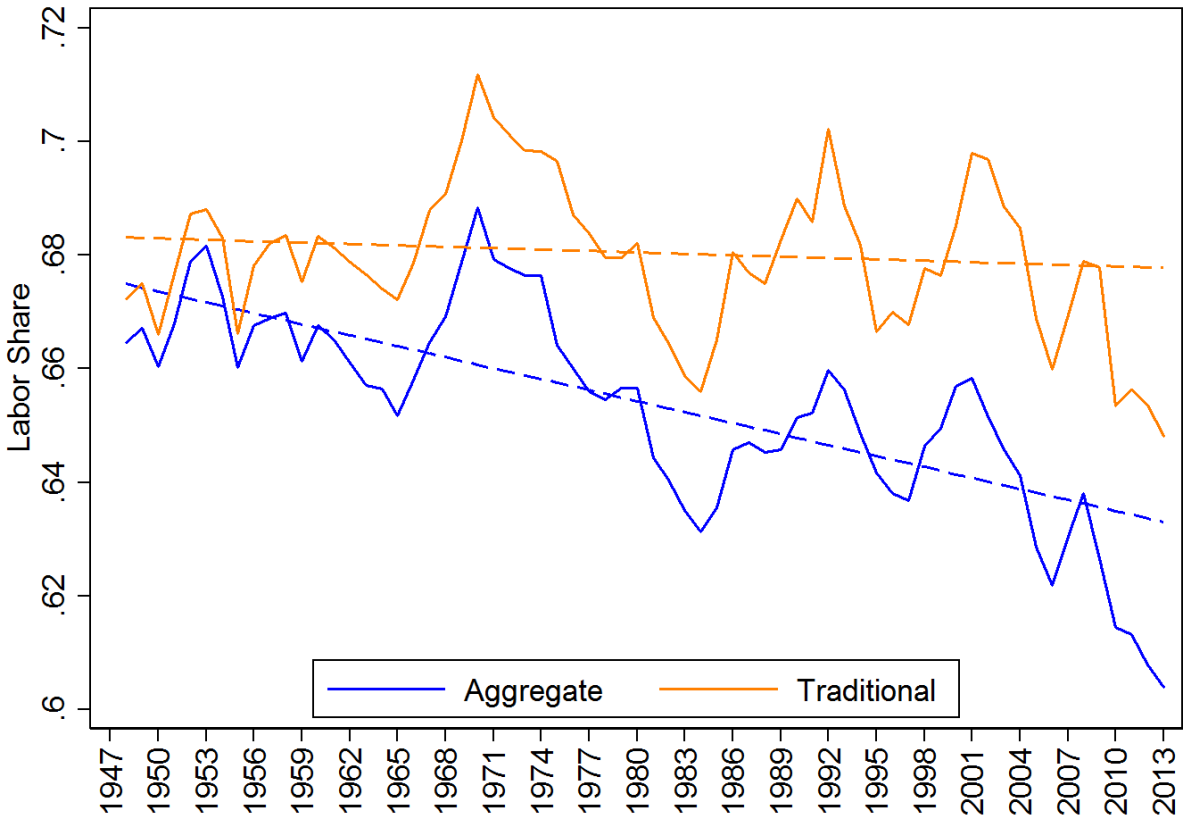


(c) Depreciation Rate of Aggregate Capital



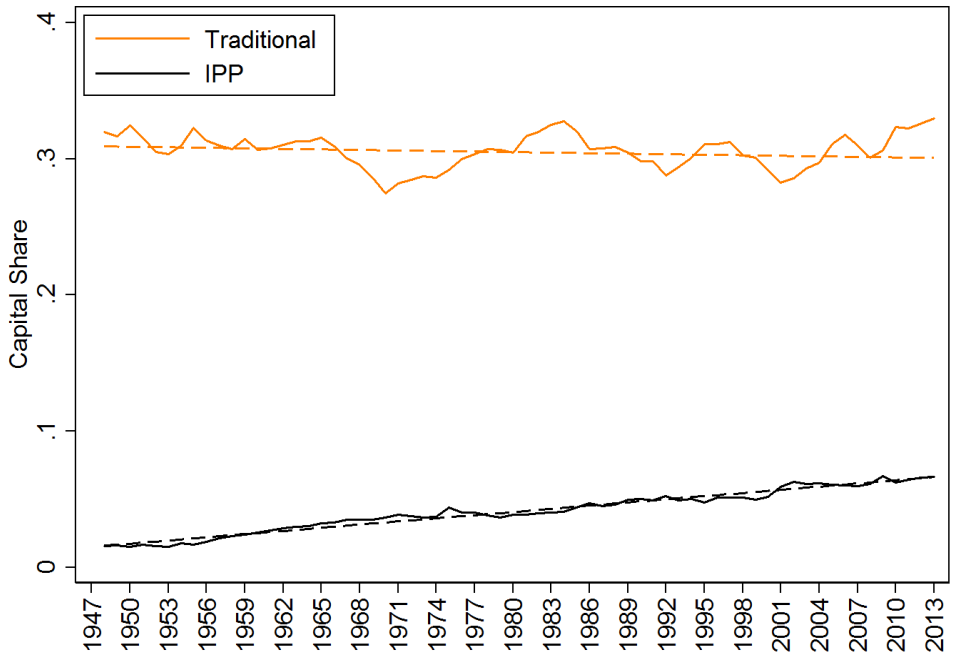
Notes: The construction of aggregate investment, investment price, and depreciation rate for, respectively, panel (a), (b) and (c), is discussed in Section 2. One reads from the left-hand-side axes the levels of investment, relative price of investment and depreciation rate of tradition and aggregate capital (in blue and organge solid lines); and from the right-hand-side axes the ratios of aggregate-to-traditional series (in red dashed lines).

Figure 4: Effects of IPP Capital on Labor Share, US 1947-2013



Notes: The "Aggregate" labor share refers to the benchmark definition described in Section 3.1 (also depicted in panel (a) of Figure 1). The "Traditional" labor share includes only capital income from traditional capital, see Section 3. The underlying linear trend for the "Traditional" labor share is not significantly different from zero. Our data and all the results of our analysis are available in this permanent link: US Factor Shares.

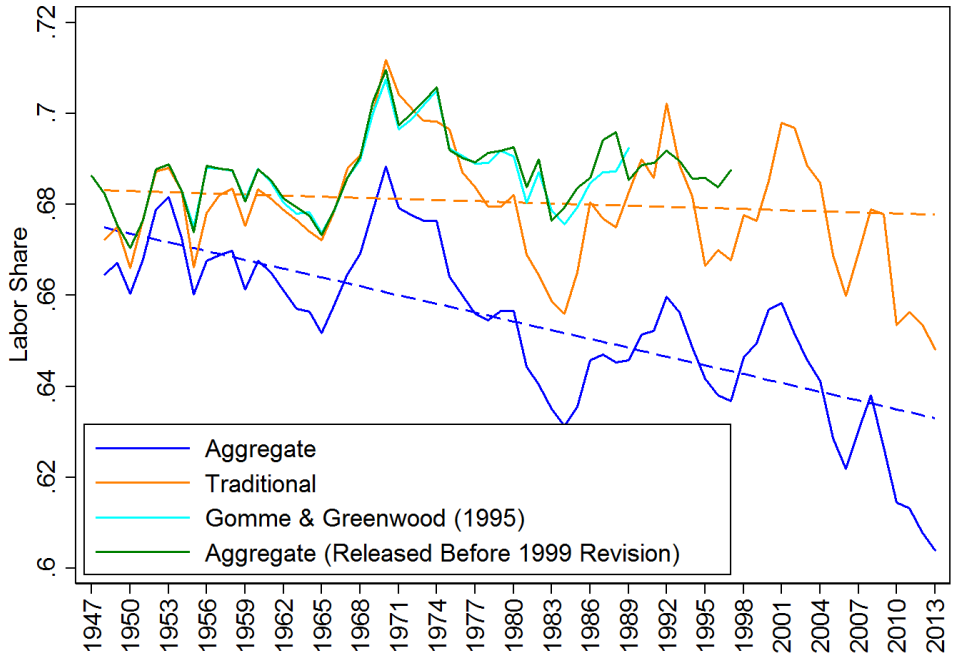
Figure 5: The Capital Share of Income: Traditional and IPP, US 1947-2013



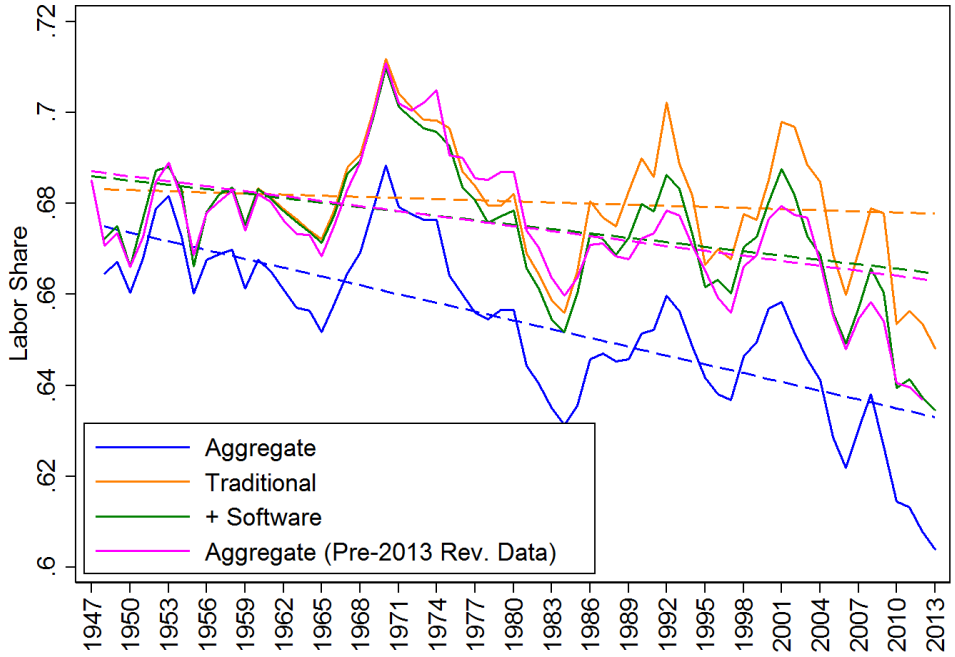
Notes: The capital share of income from IPP capital and traditional capital are computed as described in Section 3.2. The sum of IPP capital income and traditional capital income over output adds up to one minus the aggregate labor share computed in panel (a) of Figure 1. Our data and all the results of our analysis are available in this permanent link: US Factor Shares.

Figure 6: Vintage Labor Share

(a) When IPP Was Not Capitalized, Pre-1999 BEA Revision Era

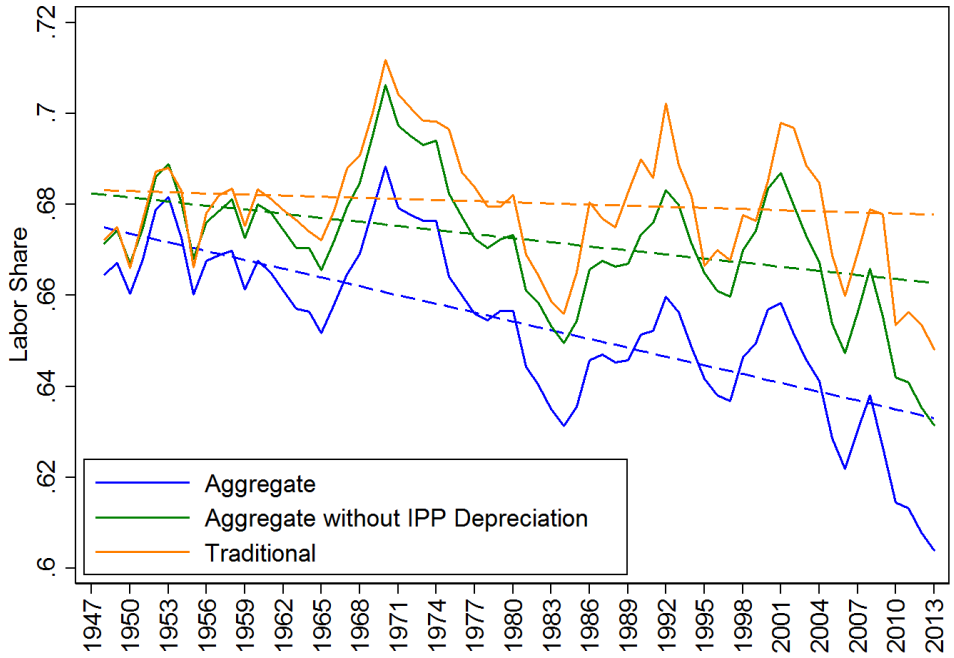


(b) Effects of Software Capital on Labor Share with Pre-2013 BEA Revision Data



Notes: In panel (a), the labor share labeled as "Aggregate" refers to the benchmark definition described in Section 3.1 and uses only post-2013 BEA revision data (also depicted in panel (a) of Figure 1). The labor share labeled "Traditional" refers to the labor share that includes only capital income from traditional capital, see Section 3. The labor share labeled as "Aggregate (Released Before 1999 Revision)" is computed using data released by BEA in 1998 and available at the Archives Library of the St. Louis FED. The labor share constructed in Gomme and Greenwood (1995) using data before software entered the national accounts as investment is also reported. To avoid differences in levels, we normalize the mean of the last two series of labor share to the mean of our "Traditional" labor share. In panel (b), the series labeled "+ Software" takes the traditional labor share as reference and adds software capital. The series labeled as "Aggregate (Pre-2013 Rev. Data)" refers to labor share computed using pre-2013 revision data from BEA which include capitalized software but not other forms of IPP capital. The underlying linear trend for labor share series "+ Software" and "Aggregate (Pre-2013 Rev. Data)" are not significantly different from each other. See Section 3.3 for a discussion.

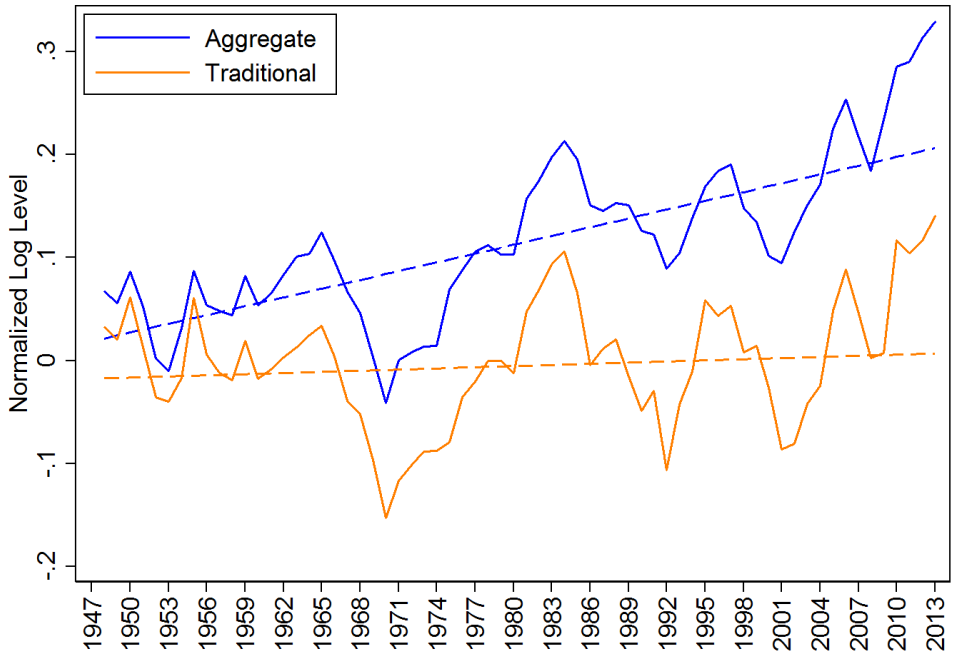
Figure 7: The Role of IPP Depreciation: A Decomposition of the Effects of IPP Capital on Labor Share



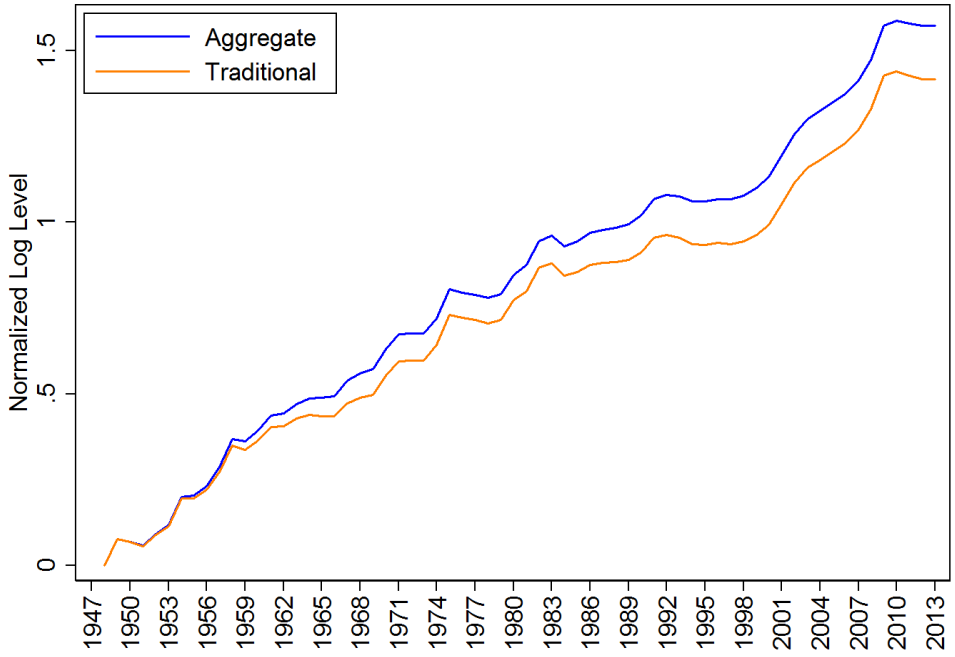
Notes: The reference scenario is the benchmark "Aggregate" labor share which incorporates both traditional and IPP capital. The labor share labeled as "Aggregate without IPP Depreciation" results from only removing IPP capital depreciation from the benchmark labor share. See section 3.4 for a discussion.

Figure 8: The US Capital and Labor

(a) The Capital Income to Labor Income Ratio



(b) The Capital to Labor Ratio



Notes: In panel (a), we plot the capital income to labor income ratio (in logs). The series labeled "Aggregate" includes IPP capital income and traditional capital income, i.e., $\ln \frac{R_{T,t}K_{T,t}+R_{IPP,t}K_{IPP,t}}{w_t H_t}$, while the series labeled "Traditional" includes only traditional capital income, i.e., $\ln \frac{R_{T,t}K_{T,t}}{w_t H_t}$. In panel (b), we plot the capital to labor ratio (in logs). The series labeled "Aggregate" includes IPP capital and traditional capital, i.e., $\ln \frac{C_t K_{T,t}}{H_t}$, while the series labeled "Traditional" includes only traditional capital income, i.e., $\ln \frac{K_{T,t}}{H_t}$. See Section 4 for a discussion.

Table 1: The Elasticity of Substitution Between IPP and Traditional Capital, US 1947-2013

Elasticity ρ	5.787^{***}

Notes: The estimate is for our full sample on our benchmark specification of the production function in (10). We denote significance level at 10 percent with (*), 5 percent with (**) and 1 percent with (***). For the elasticity ρ we report significance with respect to a value of one, that is, we explore whether the elasticity of substitution between IPP and traditional capital is significantly different from unity.

Table 2: The Elasticity of Substitution Between Traditional Capital and Labor, US 1947-2013

	1975-2010	Full Sample
Elasticity σ:		
(a) Aggregate Model	1.139^{***}	1.137^{***}
(b) Traditional Model	1.049	1.034

Notes: In the first column, the estimates are for the sample years in Karabarbounis and Neiman (2014a) and Piketty and Zucman (2014), i.e., from 1975 to 2010. In the second column, the estimates are for our full sample on our benchmark specification of the production function in (11). We denote significance level at 10 percent with (*), 5 percent with (**) and 1 percent with (***). We report significance with respect to a value of one, that is, we explore whether the aggregate production function is significantly different from Cobb-Douglas.