PIIE PETERSON INSTITUTE FOR INTERNATIONAL ECONOMICS

WORKING PAPER

18-5 Productivity and Pay: Is the Link Broken?

Anna Stansbury and Lawrence H. Summers

June 2018

Abstract

Since 1973 median compensation in the United States has diverged starkly from average labor productivity. Since 2000, average compensation has also begun to diverge from labor productivity. These divergences lead to the question: Holding all else equal, to what extent does productivity growth translate into compensation growth for typical American workers? We investigate this, regressing median, average, and production/nonsupervisory compensation growth on productivity growth in various specifications. We find substantial evidence of linkage between productivity and compensation: Over 1973–2016, one percentage point higher productivity growth has been associated with 0.7 to 1 percentage points higher median and average compensation growth and with 0.4 to 0.7 percentage points higher production/nonsupervisory compensation growth. These results suggest that other factors orthogonal to productivity have been acting to suppress typical compensation even as productivity growth has been acting to raise it. Several theories of the cause of this productivity-compensation divergence focus on technological progress. These theories have a testable implication: Periods of higher productivity growth should be associated with periods of faster productivity-pay divergence. Testing this over the postwar period in the United States, we do not find substantial evidence of co-movement between productivity growth and either the labor share or the mean/median compensation ratio. This tends to militate against pure technology-based theories of the productivity-compensation divergence. Together these results suggest that faster future productivity growth is likely to boost median and average compensation growth close to one-for-one.

JEL codes: J3, J24, E2, E24

Keywords: Labor Productivity, Wages, Compensation, Income Distribution, Labor Share

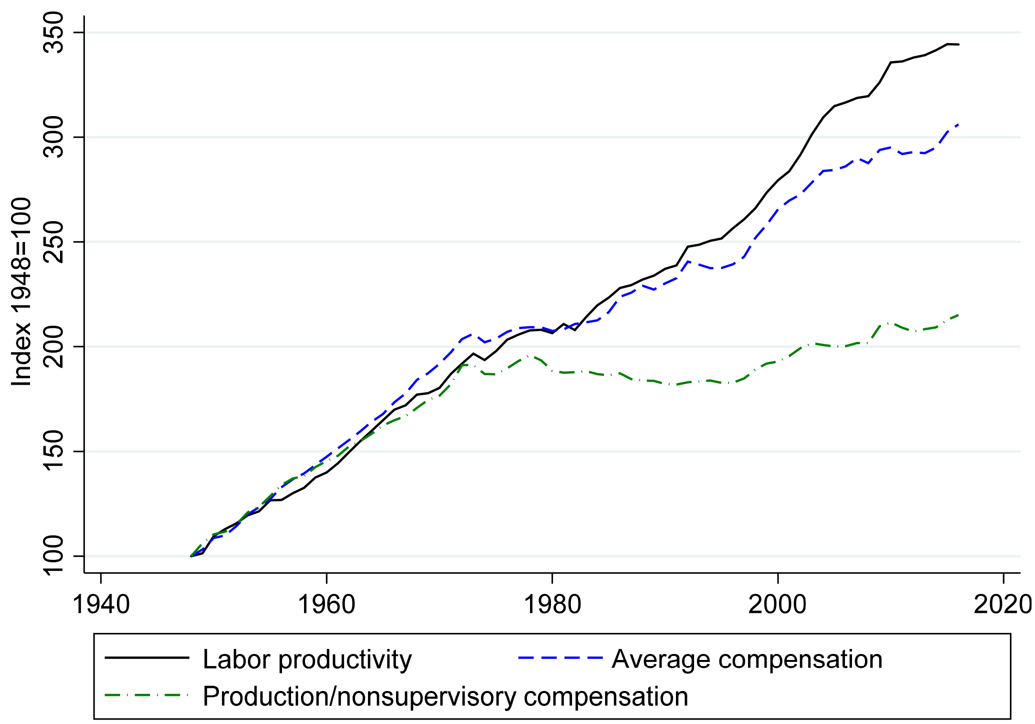
Anna Stansbury is a PhD candidate in economics at Harvard University. **Lawrence H. Summers** is the Charles W. Eliot University Professor at Harvard University. In addition to serving as the 71st Secretary of the US Treasury in the Clinton administration, Summers served as director of the White House National Economic Council in the Obama administration, as president of Harvard University, and as the chief economist of the World Bank.

Note: We thank Jared Bernstein, Josh Bivens, John Coglianese, Jason Furman, Egor Gornostay, Larry Katz, John Komlos, Robert Lawrence, Eben Lazarus, Larry Mishel, Adam Posen, Jaana Remes, Jim Stock, and Jeromin Zettelmeyer for comments, as well as participants of the Peterson Institute for International Economics (PIIE) conference on "The Policy Implications of Sustained Low Productivity Growth" in November 2017 and pre-conference in July 2017. Thanks also to Philipp Schellhaas for excellent research assistance. An earlier version of this paper was published as a NBER working paper. A revised version is forthcoming in PIIE conference volume *Facing Up to Low Productivity Growth*, edited by Adam S. Posen and Jeromin Zettelmeyer.

Introduction

After growing in tandem for nearly 30 years after the second world war, since 1973 an increasing gap has opened between average labor productivity and the typical American worker's compensation: over 1973-2016 median compensation grew by only 11% in real terms, and production/nonsupervisory workers' compensation grew by only 12%, compared to a 75% increase in labor productivity. Since 2000 average compensation has also begun to diverge from labor productivity (Figure 1) [1].

Figure 1: Labor productivity, average compensation and production/nonsupervisory compensation 1948-2016



Source: BLS, BEA, Economic Policy Institute, authors' calculations.
Further details on data sources and calculation can be found in "Data" section.
Note: Labor productivity: total economy real output per hour
Average compensation: total economy real compensation per hour, CPI-U-RS deflation
Production/nonsupervisory compensation: real compensation per hour, production and nonsupervisory workers, CPI-U-RS deflation

[1] We discuss our compensation measures in more detail on pages 10-11.

What does this stark divergence imply for the relationship between productivity and typical compensation? A range of views are compatible with the data presented in Figure 1.

On one end of the spectrum, it is possible that productivity growth has delinked from typical compensation, casting doubt on the common aphorism that “a rising tide lifts all boats”. Factors may be blocking the transmission mechanism from productivity to pay such that increases in productivity growth do not systematically translate into increases in typical workers’ compensation (we refer to this view as “strong delinkage” going forward).

On the other hand, just as two time series apparently growing in tandem does not mean that one causes the other, two series diverging may not mean that the causal link between the two has broken down. Rather, other factors may have come into play which appear to have severed the connection between productivity and compensation. As such productivity growth may have been acting to raise pay, while at the same time other orthogonal factors have been acting to reduce it (we refer to this view as “strong linkage” going forward).

Between these two ends of the spectrum is a range of possibilities where some degree of linkage exists between productivity and typical compensation.

A number of authors have questioned where the American economy currently sits on this linkage-delinkage spectrum. Harold Meyerson for example wrote in American Prospect in 2014 that “for the vast majority of American workers, the link between their productivity and their compensation no longer exists”. The Economist wrote in 2013 that “unless you are rich, GDP growth isn't doing much to raise your income anymore.”

The productivity-compensation divergence has also led to questions as to the extent to which faster productivity growth would boost typical incomes. Bernstein (2015) for example writes that "Faster productivity growth would be great. I'm just not at all sure we can count on it to lift middle-class incomes." Bivens and Mishel (2015) write "although boosting productivity growth is an important long-run goal, this will not lead to broad-based wage gains unless we pursue policies that reconnect productivity growth and the pay of the vast majority".

Establishing where the productivity-typical compensation relationship falls on the linkage-delinkage spectrum is important not only to gain a better understanding of the mechanisms causing middle income stagnation and the productivity-pay divergence, but also to design the most effective policy solutions.

We estimate the extent of linkage or delinkage by investigating the co-movement of productivity growth and typical compensation growth, using the natural quasi-experiment provided by the fact that productivity growth fluctuates through time. Under the strongest linkage view, marginal increases in productivity growth will translate one-for-one into increases in typical worker compensation even without any changes to policy. Under the strongest delinkage view, given the current structure of the economy marginal increases in productivity growth will not translate into increases in typical workers' pay[2]. In between these views is a transmission of productivity growth to compensation growth which is positive but less than one.

The majority of debate on the productivity-pay divergence has focused on the divergence between productivity and *typical* workers' pay (median or production/nonsupervisory workers).

[2] Finding support for "delinkage" would not necessarily imply that productivity growth can never translate into pay. It would most likely imply that given the current structure of the economy, the transmission mechanism from productivity growth to typical pay is blocked – but that with certain reforms transmission could be restored.

Yet it is also possible to define "linkage" and "delinkage" views for the gap between *average* compensation and labor productivity, which has grown since about 2000 as the labor share has started to fall. We investigate the evidence on the linkage-delinkage question for both typical and average compensation.

We find that periods of faster productivity growth over the last seven decades have in general coincided with faster real compensation growth for the typical American worker[3]. Since 1973 our regressions suggest that a one percentage point increase in productivity growth has been associated with between two thirds and one percentage point higher real compensation growth for the median worker, with almost none of the coefficient estimates significantly different from one and all significantly different from zero. For average production/nonsupervisory compensation, a one percentage point increase in productivity growth has been associated with 0.4-0.7 percentage points higher real compensation growth.

For average compensation, since 1948 and since 1973 a one percentage point increase in productivity growth has been associated with between 0.7 and one percentage points higher real compensation growth. Coefficients in most specifications are significantly different from zero. Since 2000, the coefficient estimates are slightly lower, in the range of 0.4-0.8 depending on the specification.

Overall, this evidence suggests that the relationship between *median compensation* and productivity since 1973 has been very substantial and close to one-for-one even while the two series have diverged in levels. For *production/nonsupervisory compensation*, the evidence

[3] A strong relationship between productivity growth and median compensation growth can be compatible with divergence of the series in levels if other factors which have been suppressing median compensation are orthogonal to productivity growth.

suggests that there is substantial linkage between productivity growth and the compensation growth of production/nonsupervisory workers, but that this linkage is likely less than one-for-one. Since median compensation and production/nonsupervisory compensation grew by the same amount in levels the difference in these coefficient estimates is interesting and bears further investigation. For *average compensation*, there has been substantial and close to one-for-one linkage in the relationship with productivity over the postwar period, with an open question as to whether the degree of that linkage has fallen somewhat since 2000.

Overall therefore, the evidence is supportive of substantial linkage between productivity and both typical and average compensation. Rather than the link having broken down, it appears that it is largely factors *not* associated with productivity growth that have caused typical and average compensation to diverge from productivity.

What are these factors causing the divergence between productivity and typical pay? A large body of research has worked on understanding both the divergence between median and average pay (a manifestation of rising income inequality) and the divergence between average pay and productivity (the falling labor share). Explanations include technological progress, education and skills, globalization, labor market institutions like unions, and market power. The technology-focused theories have a testable implication: if technological change is the primary driver of the divergence, and assuming that more rapid technological change causes faster productivity growth, periods of faster productivity growth should coincide with faster growth in the productivity-pay divergence.

To test this, we examine the co-movement of labor productivity with the labor share and with the mean-median compensation ratio. The data tends not to be strongly supportive of a pure technology hypothesis for the productivity-pay divergence: we find little evidence of a significant relationship between productivity growth and changes in the labor share for any period except since 2000, and no evidence of a relationship between productivity growth and changes in the mean-median ratio.

Our paper proceeds as follows. We first discuss definitions of the productivity-compensation divergence, informed by previous literature on the subject. We then describe our data and empirical approach, present our baseline results, and discuss robustness, testing under alternate specifications and considering the effect of productivity mismeasurement. We next show regressions for different deciles of the US wage distribution and for other OECD countries. We finally examine the co-movement of productivity growth with the pay-productivity divergence and its implications for technology-based theories of the pay-productivity divergence.

Existing work, definitions & measurement

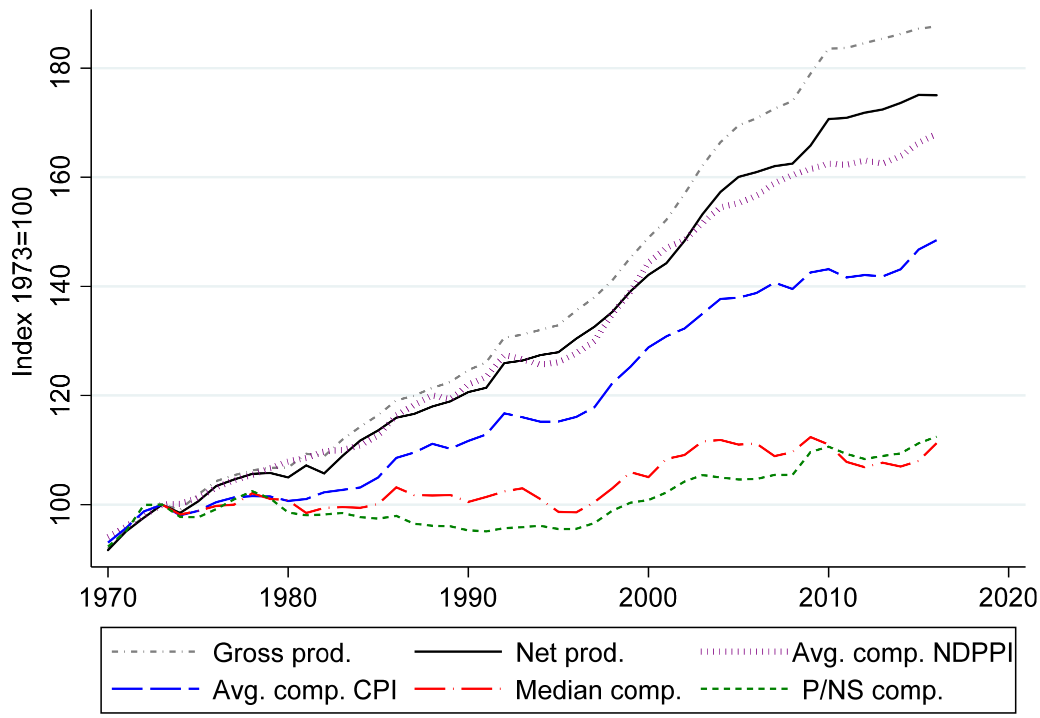
The divergence between median compensation and productivity can be decomposed into various components, as shown in Figure 2 (which is similar to those in Bivens and Mishel 2015 and Lawrence 2016)[4]. Gross labor productivity has grown faster than net labor productivity because of rising depreciation[5]; net labor productivity has grown faster than average compensation deflated by a producer price index (PPI) as the labor share has fallen; average compensation deflated by a PPI has grown faster than average compensation deflated by a consumer price

[4] Pessoa and Van Reenen (2013), Fleck, Glaeser and Sprague (2011), and Baker (2007) have demonstrated similar divergences.

[5] The importance of this fact in the productivity-compensation divergence is discussed in among others Baker (2007), Sherk (2013), Bivens and Mishel (2015) and Lawrence (2016).

index (CPI) as the consumer and producer price indices have diverged[6]; and average compensation has grown faster than median compensation as income inequality in the top half of the distribution has risen. In addition, median compensation has grown faster than median wages as non-wage benefits have increased their share of total compensation (not shown on the graph).

Figure 2: Productivity-compensation divergence decomposition, total economy, 1973-2016



Source: BLS, BEA, Economic Policy Institute, authors' calculations.
Further details on data sources and calculation can be found in "Data" section.
Note: Avg. comp. NDPPI referes to average compensation deflated by the NDP price index.
Avg. comp. CPI refers to average compensation deflated by the CPI-U-RS.
P/NS comp. refers to average production/nonsupervisory worker compensation.
Median and P/NS compensation are deflated by the CPI-U-RS.
All compensation measures refer to compensation inclusive of non-wage benefits.

---

[6] This is analyzed with reference to the productivity-compensation divergence in, among others, Lawrence and Slaughter (1993), Bosworth and Perry (1994), Feldstein (2008), Sherk (2013) and Lawrence (2016). According to the BLS this divergence is partly because the CPI uses Laspeyres aggregation and the GDP deflator uses Fisher ideal aggregation. In addition, the CPI includes import prices, and does not include goods and services purchased by businesses, governments or foreigners (Church 2016). There is extensive work on the divergence between different deflators including Triplett (1981), Fixler and Jaditz (2002), McCully, Moyer and Stewart (2007), Bosworth (2010).

A number of papers have investigated the degree to which the productivity-pay divergence has occurred, and there has been debate about the appropriate measures of compensation and productivity to use. These depend on the question being asked.

One possible line of inquiry is the ***divergence between productivity and the typical worker's compensation***. Bivens and Mishel (2015) document this, comparing net total economy labor productivity with two measures of typical worker compensation: median compensation and average production/nonsupervisory compensation, deflated by consumer price deflators. They argue that production/nonsupervisory compensation is both a good measure of typical compensation in itself, representing trends for about 80% of the private sector workforce, and a good proxy for trends in median compensation before 1973 (a period for which median compensation data is not available). Baker (2007), Pessoa and Van Reenen (2013), and Dew-Becker and Gordon (2005) have carried out similar analyses, using production/nonsupervisory compensation, median compensation, and median household income respectively.

Another line of inquiry is the ***divergence between productivity and average compensation***. This is conceptually equivalent to the decline in the labor share[7]. Feldstein (2008) compares labor productivity in the nonfarm business sector to average nonfarm business sector compensation as deflated by a producer price deflator over 1948-2006. When investigating consumers' experienced rise in living standards as in Bivens and Mishel (2015), a consumer price deflator is appropriate; however, as Feldstein (2008) argues, when investigating factor income shares a producer price deflator is more appropriate because it reflects the real cost to firms of employing workers. Bosworth and Perry (1994) and Lawrence and Slaughter (1993)

[7] In the special case of Cobb-Douglas technology, this also tests the marginal productivity theory of labor (whether workers are paid their marginal product by firms).

previously carried out similar analyses. Lawrence (2016) analyzes this divergence more recently, comparing average compensation to *net* productivity, which is a more accurate reflection of the increase in income available for distribution to factors of production. Since depreciation has accelerated over recent decades, using gross productivity creates a misleadingly large divergence between productivity and compensation. Lawrence finds that net labor productivity and average compensation grew together until 2001, when they started to diverge i.e. the labor share started to fall. Many other studies also find a decline in the US labor share of income since about 2000, though the timing and magnitude is disputed (see for example Grossman et al 2017, Karabarbounis and Neiman 2014, Lawrence 2015, Elsby Hobijn and Sahin 2013, Rognlie 2015, Pessoa and Van Reenen 2013).

In this paper we are concerned with the divergence of productivity from *both* typical compensation and from average compensation. In each case, we want to ask the question: ***to what extent does labor productivity growth feed through into typical or average worker compensation?*** We have chosen the measures of compensation and productivity which are most appropriate for the particular questions we are asking.

For **productivity**, we use net total economy output per hour: total economy since we wish to capture trends affecting all workers, and net (rather than gross) to reflect only the extra output which is available for distribution to factors of production.[8]

[8] Productivity is difficult to measure accurately for the entire economy: it comprises government and non-profit institutions, whose output is difficult to measure since it is usually not traded on markets. Nonfarm business sector productivity is likely to be better measured than total economy productivity, but only captures 75 percent of GDP and only has a gross measure of productivity available. We repeat our baseline regressions with nonfarm business sector productivity and find little change to our results (available on request).

For **typical compensation**, we focus on median compensation. We also report results for average production/nonsupervisory compensation, both as an interesting measure in itself and because it enables us to analyze the pre-1973 period (as in Bivens and Mishel 2015).

Median compensation is the measure which is most clearly interpretable as showing trends for middle income workers. It captures trends for the middle of the income distribution, while average production and nonsupervisory compensation captures the average trend for production and nonsupervisory employees, who compose roughly 80% of the private sector workforce. Median compensation is consistently lower than average production/nonsupervisory compensation (for example in 2015 median hourly compensation was $22.04 and average production/nonsupervisory compensation was $26.61). Since the average production/nonsupervisory compensation figure is a mean, it can be skewed by large changes at the top or bottom of its distribution. In addition, there is some evidence that the average production/nonsupervisory compensation measure does not cover all workers that it is intended to,[9] and that this group may be growing over time (Barkume 2007).

While the two series cover different workers, they move in a similar fashion over most of 1973-2016, with an exception during the 1980s where real production/nonsupervisory compensation falls significantly more than median compensation. We speculate that this may have been driven partly by the substantial fall in incomes for the lowest end of the distribution which would have pulled down the average production/nonsupervisory measure, and partly by

[9] Abraham, Spletzer and Stewart (1998) and Champagne, Kurmann and Stewart (2015) suggest that many service sector establishments surveyed for the CES (from which production/nonsupervisory wages are calculated) interpret the "production and non-supervisory" category to include hourly-paid and/or non-exempt workers (under the Fair Labor Practices Act), but to exclude other types of salaried or exempt worker even if they are non-supervisory.

the reduction in well-paid blue-collar jobs and increase in middle-income white-collar jobs (the former covered in the production/nonsupervisory measure, the latter possibly missed).

For **average compensation**, we look at mean total economy compensation.

We deflate all our compensation series using consumer price deflators to reflect the changes in standards of living experienced by workers.[10]

We estimate the linkage between productivity and compensation with a regression approach similar to that in Feldstein (2008). Feldstein investigated the linkage between productivity and average compensation by regressing the change in log of average compensation on the current and lagged change in log of productivity, finding a close to one-for-one relationship. We use a similar approach to investigate the linkage between typical compensation and productivity, and to update Feldstein's estimates of the linkage between average compensation and productivity.

Empirical estimation

At the simplest level, a linear model can relate productivity and typical or average compensation growth[11] as shown in equation (1) below. Under the strongest "linkage" view, β=1, and under the strongest "delinkage" view, β=0. β between 0 and 1 suggests a point on the linkage-delinkage spectrum. This is a partial model, since many other factors affect compensation growth besides

[10] We deflate with the CPI-U-RS. We also repeated our baseline regressions with compensation deflated by the PCE and NDP price index and found little change to our results (available on request).
[11] We use the change in logged values of compensation and productivity, rather than their levels, as compensation and productivity are both non-stationary unit root processes but their first differences appear to be stationary (as suggested by Dickey-Fuller tests).

productivity. As long as these other factors are orthogonal to productivity growth, they will not affect estimation of β.

$$compensation\ growth_t = \alpha + \beta\ productivity\ growth_t \qquad (1)$$

We can estimate β using the substantial variation in productivity and compensation growth rates since 1948. We look at three different concepts for compensation: median, production/nonsupervisory, and average compensation. For brevity – since we run the same tests for all three measures – we refer to them as "compensation" below.

In our baseline specification (equation 2), we regress the three-year moving average of the change in log compensation on the three-year moving average of the change in log labor productivity and the current and lagged three-year moving average of the unemployment rate[12].

$$\frac{1}{3}\sum_0^2 \Delta \log comp_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \qquad (2)$$

It is not immediately clear over what time horizon any productivity-compensation relationship would hold most strongly. It will depend on both the wage setting process and on the degree to which productivity changes are correctly perceived and anticipated. If firms on average change pay and benefits infrequently, or if it takes some time for firms and workers to discern the extent to which an increase in output is due to a rise in productivity rather than other factors, productivity increases will translate into compensation only with a lag. On the other hand, if firms and workers correctly anticipate that there will be a productivity increase in the near future,

[12] To account for the autocorrelation introduced by the moving average specification we use Newey-West heteroskedasticity and autocorrelation robust standard errors. For our moving average regressions, we specify a lag length of twice the length of the moving average.

the rise in compensation may precede the actual rise in productivity. Taking this uncertainty into account, we also present results for regressions without a moving average, and with two-, four- and five-year moving averages. We repeat our regressions with a distributed lag specification with up to four years of lagged productivity and find results similar to those in our moving average regressions (results available on request).

We control for the level of unemployment for two reasons. First, the level of unemployment itself is likely to affect bargaining dynamics: a higher unemployment rate should enable employers to raise compensation by less than they otherwise would have for a given productivity growth rate, as more unemployed workers are searching for jobs. In addition, unemployment is likely to reflect broader cyclical economic fluctuations which may affect compensation in the short term: higher unemployment may reflect a downturn, which could mean lower pay rises for a given rate of productivity growth. If unemployment is also related to changes in productivity growth – for example, if the least productive workers are likely to be laid off first – then excluding unemployment would bias the results. By controlling for the current and one-year lagged moving average of the unemployment rate we allow for both the level and the change in unemployment to affect compensation growth. We use the unemployment rate of 25-54 year-olds to avoid capturing effects of demographic shifts such as an ageing population; using the total unemployment rate instead has almost no effect on our results.

Data

We primarily use publicly available data from the Bureau of Labor Statistics (BLS), Bureau of Economic Analysis (BEA) and the Economic Policy Institute State of Working America Data

Library, as well as the BLS Total Economy Productivity dataset which is available on request from the BLS.[13]

Our measure of labor productivity for the total economy is calculated by dividing Net Domestic Product, deflated by the Net Domestic Product price index, by the total hours worked in the economy, following Bivens and Mishel (2015). Average compensation for the total economy is from the BLS total economy productivity dataset and deflated by the CPI-U-RS. Our median and production/nonsupervisory compensation series are from the Economic Policy Institute State of Working America Data Library. These are constructed from median wages from the CPS-ORG and average production/nonsupervisory wages from the BLS CES respectively, and deflated by the CPI-U-RS. They are then adjusted to include non-wage compensation using the average real compensation/wage ratio. This is calculated from BEA national income and product accounts data on the composition of workers' compensation, with all components of compensation deflated by the PCE except health and life insurance which are deflated by the PCE health care index (further details are available in Bivens and Mishel 2015).[14]

Our analysis of different percentiles of the wage distribution uses data on real wages from the Economic Policy Institute State of Working America Data Library. The data is constructed from the CPS-ORG and deflated by the CPI-U-RS.

For our analysis of the other major advanced economies, for all countries except Germany we use OECD data on unemployment, labor productivity per hour, and average compensation per hour, deflated by the consumer price index for the country in question. For

[13] For a more detailed list of data sources, see the Working Paper version of this chapter (Stansbury and Summers 2017)

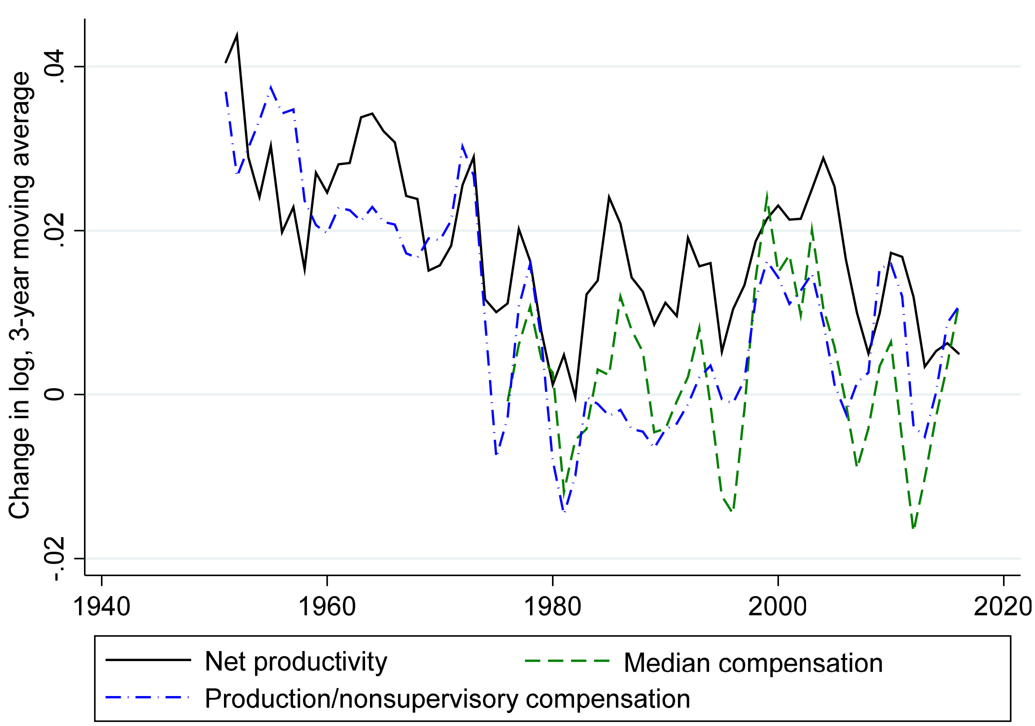
[14] We are grateful to Larry Mishel and Josh Bivens for providing us the raw data alongside the publicly available versions.

Germany pre- and post-reunification, we use data on hourly labor productivity, hourly compensation and unemployment from the German Federal Statistical Office.

Baseline results

Figures 3 and 4 illustrate the relationship between compensation growth and productivity growth in the total US economy, plotting the 3-year moving average of productivity growth with median, production/nonsupervisory, and average compensation growth (in change in log form). While median and production/nonsupervisory compensation consistently grow more slowly than productivity since the 1970s, the series move largely together.

Figure 3: Change in log labor productivity, median compensation and average production/nonsupervisory compensation (3-year moving averages)



Source: BLS, BEA, Economic Policy Institute, authors' calculations.

Further details on data sources and calculation can be found in "Data" section.
Note: Series are three-year backward-looking moving averages of change in log variable.

Figure 4: Change in log labor productivity and average compensation (3-year moving averages)

Source: BLS, BEA, authors' calculations.
Further details on data sources and calculation can be found in "Data" section.
Note: Series are three-year backward-looking moving averages of change in log variable.

Table 1 displays our baseline regression results. The dependent variable is growth in average compensation in columns *a-d*, median compensation in column *e* and production and non-supervisory compensation in columns *f-h*. For average and production/nonsupervisory compensation we show coefficients for the whole postwar period and on either side of 1973[15]. 1973 is often identified as the beginning of the modern productivity slowdown, as well as the date when median and production/nonsupervisory compensation began to diverge from

[15] Since we use 3-year moving averages, we break the regressions such that the last data point in the 1950-1973 regressions is the 3-year moving average of the change in log productivity/compensation for 1972, 1973 and 1974, and the first data point in the 1975-2015 regressions is the 3-year moving average for 1974, 1975 and 1976.

productivity[16]; breakpoint tests also identify a structural break at 1973 for both average and production/nonsupervisory compensation[17]. Since our median compensation data only goes back to 1973, this also makes it easier to compare the results for production/nonsupervisory and median compensation. For average compensation we also show a split from 2000 onwards, as this is the period over which average compensation and productivity began to diverge.

Median compensation: The results in Table 1 suggest that over 1975-2015, the period during which productivity and median compensation diverged in levels, a 1 percentage point increase in productivity growth was associated with a 0.73 percentage point increase in the growth rate of median compensation. The coefficient is strongly significantly different from zero and not significantly different from one. This suggests substantial linkage between productivity and median compensation, and the "strong linkage" hypothesis of a one-for-one relationship between productivity and compensation cannot be rejected.

Production/nonsupervisory compensation: Over 1975-2015, a 1 percentage point increase in productivity growth was associated with a 0.53 percentage point increase in the growth rate of average production/nonsupervisory compensation. The coefficient is significantly different from both zero and one. The result suggests substantial linkage between productivity and production/nonsupervisory compensation, but does not support the "strong linkage" hypothesis of a one-for-one relationship.

Average compensation: Over 1950-2015 and 1975-2015 a one percentage point increase in productivity growth was associated with a 0.74 and 0.77 percentage point increase in the

[16] The Economic Report of the President (2015), Bivens and Mishel (2015), Baker (2007), Bosworth and Perry (1994) are among the authors who identify a break at 1973 when discussing trends in productivity and compensation.
[17] For regressions of the change in log productivity with either average compensation or with production/nonsupervisory compensation, a Wald test is significant at the 0.1% level for a break at 1973.

growth rate of average compensation respectively; the estimates are strongly significantly different from zero and not significantly different from one. Over 2000-2015 the coefficient estimate is smaller at 0.40; it remains significantly different from zero but is also significantly different from one. When testing for significant differences in coefficients between the pre-2000 and post-2000 period, results are mixed: in an unrestricted regression allowing all coefficients to differ between the two periods we find significantly different coefficients on productivity at the 5% level, while a regression allowing the productivity coefficients to differ but restricting unemployment coefficients and the constant to be the same across the whole 1950-2015 period gives a larger coefficient on productivity over 2000-2015 (0.56 rather than 0.4) and the difference between the two periods is non-significant (results shown in Stansbury and Summers 2017, Table A11). Overall these results suggest substantial linkage between productivity and average compensation. The “strong linkage” hypothesis cannot be rejected for most of the period. For the period since 2000 over which the labor share has declined, there is some suggestion that the degree of linkage may have fallen (though “strong delinkage” is still rejected).

Table 1: Compensation and productivity: baseline regressions

Dependent variables are the 3-year moving average of the Δ log compensation	(1a) Average comp 1950-2015	(1b) Average comp 1950-1973	(1c) Average comp 1975-2015	(1d) Average comp 2000-2015	(1e) Median comp 1975-2015	(1f) Production/nonsupervisory comp 1950-2015	(1g) Production/nonsupervisory comp 1950-1973	(1h) Production/nonsupervisory comp 1975-2015
Δ log productivity, 3-year moving average	**0.77*** (0.10)**	**0.58** (0.25)**	**0.74*** (0.14)**	**0.40** (0.14)**	**0.73*** (0.16)**	**0.84*** (0.11)**	**0.69*** (0.19)**	**0.53*** (0.19)**
Unemployment (25-54), 3-year moving average	-0.19 (0.15)	0.36** (0.16)	-0.24* (0.14)	-0.23* (0.12)	-0.15 (0.18)	0.06 (0.25)	0.69* (0.34)	0.09 (0.33)
Lagged Unemployment, 3-year moving average	-0.17 (0.18)	-0.73*** (0.25)	0.02 (0.12)	-0.05 (0.06)	-0.10 (0.15)	-0.40 (0.28)	-0.99*** (0.31)	-0.21 (0.31)
Constant	0.02*** (0.01)	0.03*** (0.01)	0.01*** (0.00)	0.02** (0.01)	0.01 (0.01)	0.01* (0.01)	0.02* (0.01)	0.00 (0.01)
Observations	66	24	41	16	41	66	24	41

F-test: is coefficient on productivity significantly different from 1?								
Test statistic	4.85**	3.00*	3.43	18.5***	2.71	1.95	2.61	5.87**
Prob>F	0.03	0.10	0.07	0.00	0.11	0.17	0.12	0.02

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average. A regression over "1950-2015" implies the first observation is the three-year moving average of the change in logged variable in 1949, 1950 and 1951 and the last observation is the three-year moving average of the change in logged variable in 2014, 2015 and 2016.
F-test null hypothesis: coefficient on productivity is *not* significantly different from one.

Alternate specifications

As a robustness check, we repeat these regressions in a number of other specifications:

- Excluding the unemployment control
- Including a time trend
- Including dummy variables for each decade
- Varying the moving average bandwidth

Table 2 shows a summary of these results for the coefficient on the change in log productivity. The full regressions are shown in Stansbury and Summers 2017, Tables A1-A7.[18]

The results are generally robust across specifications:

The coefficient estimates for **median compensation** are in the range of 0.65 to 1 (for all but the contemporaneous regression), are significantly different from zero at the 1% level and mostly not significantly different from one. (Cells shaded grey have a coefficient that is significantly different from one at the 5% level). This suggests substantial linkage between productivity and median compensation, and the "strong linkage" hypothesis cannot be rejected in almost all of the specifications.

[18] We have also repeated the regressions using distributed lags instead of moving averages, using nonfarm business sector productivity instead of total economy productivity, and deflating the compensation series with the PCE and NDP price index rather than the CPI-U-RS. The overall picture from these regressions is not substantially different from those we present here and in Stansbury and Summers (2017). These results are available on request.

For **production/nonsupervisory compensation** since 1973, the coefficient estimates are in the range of 0.4 to 0.7, significantly different from zero at the 1% level and also significantly different from one. As before this suggests a large degree of linkage between productivity and production/nonsupervisory compensation, but rejects both the "strong linkage" and "strong delinkage" hypotheses. The fact that the coefficients are significantly lower than for median compensation bears further investigation. Average compensation growth for production/nonsupervisory workers does not appear to reflect productivity growth to the same extent as compensation growth for the median worker, although in terms of levels the two series are relatively similar throughout the postwar period[19].

For **average compensation** since 1973, the coefficient estimates are in the range of 0.70 to 0.91, strongly significantly different from zero and mostly not significantly different from one, while over 1999-2016 the estimates are between 0.40 and 0.79 and mostly strongly significantly different from both zero and one. This once again suggests substantial linkage between productivity and average compensation, with some possibility of a reduction in the degree of linkage since about 2000.

Overall, the evidence is largely supportive of the hypothesis that for middle class workers, increases in productivity growth feed through substantially to increases in real compensation growth.

[19] The difference in coverage of the two series and the likely change in this difference over time, as discussed earlier in the paper and in Abraham et al (1998) and Champagne et al (2015), may go some way to explaining this.

Table 2: Coefficients on productivity from various specifications of productivity-compensation regressions

Regression specifications		Average comp				Median comp.	Production/nonsupervisory comp		
		1949-2016	1949-1973	1974-2016	1999-2016	1974-2016	1949-2016	1949-1973	1974-2016
(2a)	Initial regression (Tables 1 and 3)	0.77*** (0.10)	0.58** (0.25)	0.74*** (0.14)	0.40** (0.14)	0.73*** (0.16)	0.84*** (0.11)	0.69*** (0.19)	0.53*** (0.19)
(2b)	Without unemployment	0.96*** (0.08)	0.29 (0.20)	0.79*** (0.17)	0.55*** (0.14)	0.80*** (0.20)	1.00*** (0.11)	0.35* (0.18)	0.58*** (0.17)
(2c)	With time trend	0.68*** (0.16)	0.26 (0.28)	0.73*** (0.14)	0.79*** (0.21)	0.73*** (0.17)	0.73*** (0.17)	0.38 (0.32)	0.51*** (0.15)
(2d)	With decade dummy variables	0.69*** (0.17)	0.38 (0.25)	0.91*** (0.16)	0.57*** (0.08)	1.00*** (0.16)	0.60*** (0.15)	0.45* (0.25)	0.59*** (0.13)
(2e)	Contemporaneous only	0.63*** (0.09)	0.39 (0.23)	0.56*** (0.16)	0.48*** (0.14)	0.33** (0.16)	0.61*** (0.08)	0.24 (0.16)	0.41*** (0.12)
(2f)	2-year moving average	0.73*** (0.11)	0.30 (0.19)	0.70*** (0.15)	0.45** (0.16)	0.72*** (0.17)	0.82*** (0.12)	0.43* (0.24)	0.55*** (0.18)
(2g)	4-year moving average	0.83*** (0.10)	0.72*** (0.18)	0.73*** (0.12)	0.42** (0.14)	0.72*** (0.17)	0.87*** (0.12)	0.95*** (0.20)	0.50*** (0.18)
(2h)	5-year moving average	0.88*** (0.09)	0.78*** (0.26)	0.77*** (0.11)	0.46** (0.17)	0.65*** (0.16)	0.92*** (0.12)	0.99*** (0.29)	0.44*** (0.13)

Newey-West (HAC) standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Cells that are significantly different from one at the 5% level are highlighted in grey. All others are not significantly different from one at the 5% level. Underlying regressions are in Table 1 and Stansbury and Summers 2017, Tables A1-A7. Unless otherwise stated, regressions use 3-year moving averages.

Three additional features of these results are worth noting.

First, estimating only the contemporaneous relationship between productivity growth and compensation (2e), as expected, reduces the magnitude of the estimated coefficient in almost all regressions: insufficient time may be allowed by this specification for firms to pass productivity growth through to workers' compensation.

Second, the coefficient estimates on productivity in the pre-1973 period are not as high as one might expect for both average compensation and production/nonsupervisory compensation, considering that productivity and both compensation measures moved largely together in terms of levels during that period. The coefficient estimates rise significantly as the moving average bandwidth is extended, suggesting that the responsiveness of compensation to productivity growth may have been slower in the earlier period. In addition, the period from 1956-1965 was one of particularly low variation in both compensation and productivity growth which may magnify the effect of noise. The coefficient estimates rise significantly if that period is excluded when running the pre-1973 regressions (to 0.82 for average and 0.80 for production/nonsupervisory compensation in the baseline specification).

Third, the coefficient estimates for production/nonsupervisory compensation are higher for the whole postwar period than for either of the two sub-periods. We prefer to look at the two periods either side of 1973 separately since there is strong evidence of a structural break in the relationship around 1973, and so the strong relationship over the whole period appears to be a combination of two separate and somewhat weaker relationships over the two sub-periods.

Productivity mismeasurement?

There has been substantial debate over the extent to which the productivity statistics are mismeasured (e.g. Feldstein 2017, Groshen et al 2017, Syverson 2017, Byrne, Fernald and Reinsdorf 2016). Mismeasurement may occur, for example, if technological innovations are under-measured, or if quality improvements or new goods and services are hard to value.

The degree of mismeasurement in the productivity statistics should not substantially affect our conclusions. We are comparing real output per hour – labor productivity – to real compensation per hour. Each of these series is calculated from a nominal measure (Net Domestic Product, total compensation) divided by a price deflator and by hours worked. We have no reason to believe that there is substantial mismeasurement in the nominal series, and since both series are divided by the same metric of hours worked, we also need not be concerned that mismeasurement in hours will affect our conclusions. The only major causes for concern with mismeasurement are the price deflators. But since we are investigating the relationship between changes in productivity and changes in real compensation, mismeasurement should not affect our conclusions as long as the *relative* degree of mismeasurement in the price deflators for output and consumption has not changed[20].

The rest of the income distribution

The evidence thus far suggests that median compensation growth, average compensation growth and production/nonsupervisory compensation growth are all strongly positively related to productivity growth. What about other parts of the income distribution?

To answer this question, we estimate the relationship between productivity and wages at each decile of the wage distribution using data from the Economic Policy Institute's *State of Working America Data Library*. The results show substantial differences in the co-movement of productivity and wages by decile (Tables 3 and 4). Wages at the 20th and 40th to 90th percentiles co-move significantly with productivity, with coefficients between 0.3 and 0.7.

[20] This argument is stronger if we deflate both the productivity and compensation series by same price deflator, as in this case the underlying relationship between the two should remain in spite of any mismeasurement. We have repeated our baseline regressions deflating compensation by the NDP price index and do not see substantial differences in our results (available on request).

Table 3: Wage and productivity regression: 10th to 50th percentile wages

Dependent variables are the 3-year moving average of the Δ log wage	(3a) 10th p. wage 1975-2015	(3b) 20th p. wage 1975-2015	(3c) 30th p. wage 1975-2015	(3d) 40th p. wage 1975-2015	(3e) Median wage 1975-2015
Δ log productivity,	**0.34**	**0.69****	**0.18**	**0.37****	**0.60*****
3-year moving average	**(0.39)**	**(0.26)**	**(0.28)**	**(0.16)**	**(0.16)**
Unemployment (25-54),	-1.05*	-0.63*	-0.53	-0.42	-0.43*
3-year moving average	(0.54)	(0.37)	(0.36)	(0.34)	(0.22)
Lag unemployment,	0.29	0.04	-0.04	0.03	0.14
3-year moving average	(0.44)	(0.32)	(0.30)	(0.32)	(0.19)
Constant	0.04***	0.02***	0.03***	0.02***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	41	41	41	41	41
F-test: is coefficient on productivity significantly different from 1?					
Test statistic	2.80	1.48	8.82***	15.3***	5.89**
Prob>F	0.10	0.23	0.01	0.00	0.02

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average.
F-test null hypothesis: coefficient on productivity is *not* significantly different from one.

Table 4: Wage and productivity regressions: 50th to 90th percentile wages

Dependent variables are the 3-year moving average of the Δ log wage	(4a) 60th p. wage 1975-2015	(4b) 70th p. wage 1975-2015	(4c) 80th p. wage 1975-2015	(4d) 90th p. wage 1975-2015	(4e) 95th p. wage 1975-2015
Δ log productivity,	**0.48****	**0.33****	**0.35****	**0.38****	**0.30**
3-year moving average	**(0.19)**	**(0.13)**	**(0.13)**	**(0.17)**	**(0.23)**
Unemployment (25-54),	-0.28	-0.16	-0.18	-0.25	-0.44
3-year moving average	(0.27)	(0.27)	(0.24)	(0.23)	(0.27)
Lag unemployment,	-0.03	-0.09	-0.04	0.05	0.25
3-year moving average	(0.29)	(0.26)	(0.24)	(0.24)	(0.24)
Constant	0.01	0.01**	0.01**	0.01*	0.01
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Observations	41	41	41	41	41
F-test: is coefficient on productivity significantly different from 1?					
Test statistic	7.74***	25.8***	23.6***	13.6***	9.38***
Prob>F	0.01	0.00	0.00	0.00	0.00

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average.
F-test null hypothesis: coefficient on productivity is *not* significantly different from one.

A significant caveat in interpreting these regressions is that these data are for wages not for total compensation. Since benefits have grown faster than wages for much of the postwar period,[21] our wage growth measure underestimates total real compensation growth. It is probable that growth in non-wage benefits is positively correlated with both wage growth and aggregate productivity growth. As a result, our estimates are likely to be biased downwards.

Comparing the coefficient estimates in the median wage and median compensation regressions can help quantify this bias at least for the middle of the distribution. The coefficient in the regression of the median *wage* on productivity is 0.60, compared to 0.73 for the regression of median *compensation* on productivity, suggesting that the bias is quite large, at about 20% of the coefficient size.

Since non-wage benefits make up a vastly different share of total compensation for workers at different points of the wage distribution (see Stansbury and Summers 2017, Figure A1), and these shares have grown differently for different parts of the wage distribution over recent decades (Pierce 2010, Monaco and Pierce 2015), this bias estimate cannot be extrapolated to the entire wage distribution. Evidence from the BLS does suggest however that at least over the periods 1987-1997, 1997-2007 and 2007-2014, the ratio of wage to non-wage compensation grew similarly for the middle of the income distribution, between about the 40th and 60th percentiles (Pierce 2010, Monaco and Pierce 2015). This suggests that we may be able to extrapolate the rough magnitude of the bias at the 50th percentile to the 40th and 60th percentiles, implying that the regression coefficients of 0.37 and 0.48 should be considered lower bounds of

[21] See, among others, Bosworth and Perry 1994, Feldstein 2008, Bivens and Mishel 2015, and Lawrence 2016.

the true relationship between productivity and 40th and 60th percentile compensation respectively, and that the true coefficients could be around 20% higher.

Other countries

In the cross-section, countries with higher labor productivity tend to have higher typical and average compensation. Lawrence (2016) finds a close to one-for one correlation between labor productivity and average manufacturing compensation for 32 countries; and we find a correlation coefficient of 0.8 between 34 OECD countries' labor productivity and their median household equivalized disposable income[22].

Though the cross-country relationship between productivity and compensation is strong, median compensation has diverged from productivity in most OECD countries over the last two decades, with rising mean-median income inequality and a falling labor share[23](Schwellnus, Kappeler and Pionnier 2017, Sharpe and Uggucioni 2017, Nolan, Roser and Thewissen 2016, International Labour Organization 2015). This suggests that in some of these countries there may have been a delinkage of productivity from compensation. To give a sense of whether this might be the case, we repeat our regressions for average compensation for the G7 economies (Table 5). We do not show results for median compensation because most countries lack comparable median hourly compensation data over a sufficiently long time series.

[22] We use 2007 data from the OECD on labor productivity and household equivalized disposable income. Household equivalized disposable income takes into account taxes and social security contributions paid by households as well as the value of government services provided, and as such reflects a country's redistributive policies as well as its underlying labor market dynamics. We use this measure since there is not a good comparable measure of median hourly compensation – which would be our preferred measure – across countries. A scatter plot is shown in Stansbury and Summers (2017), Figure A2.

[23] For comparative international evidence on the labor share decline, see e.g. Cho, Hwang and Schreyer 2017, Karabarbounis and Neiman 2014, Azmat, Manning and Van Reenen 2011, Blanchard and Giavazzi 2003, Bentolila and Saint-Paul 2003.

Table 5: Average compensation and productivity regressions: G7 economies

Dependent variables are the 3-year moving average of the Δ log average compensation	(5a) Canada 1972-2015	(5b) France 1972-2015	(5c) West Germany 1972-1990	(5d) Germany 1993-2015	(5e) Italy 1985-2015	(5f) Japan 1997-2014	(5g) United Kingdom 1996-2015	(5h) USA 1950-2015
Δ log productivity, 3-year moving average	**0.95*** (0.23)**	**0.32** (0.13)**	**0.88*** (0.29)**	**0.23 (0.39)**	**0.42 (0.26)**	**0.20** (0.08)**	**1.55*** (0.22)**	**0.77*** (0.10)**
Unemployment, 3-year moving average	-0.20 (0.20)	-0.62* (0.34)	-1.17*** (0.35)	0.18 (0.34)	-0.79** (0.35)	0.42 (0.34)	-0.41** (0.15)	-0.19 (0.15)
Lag unemployment, 3-year moving average	-0.30 (0.22)	0.15 (0.36)	1.01** (0.40)	-0.64* (0.35)	0.59 (0.37)	-0.84*** (0.15)	-0.23 (0.23)	-0.17 (0.18)
Constant	0.04*** (0.01)	0.05*** (0.01)	0.01 (0.01)	0.04*** (0.01)	0.02* (0.01)	0.01 (0.01)	0.04** (0.01)	0.02*** (0.01)
Observations	44	44	19	23	31	18	20	66
F-test: is coefficient significantly different from 1?								
Test statistic	0.04	27.4***	0.17	3.89*	5.11**	126.1***	6.45**	4.85**
Prob>F	0.84	0.00	0.68	0.06	0.03	0.00	0.02	0.03

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average.
F-test null hypothesis: coefficient on productivity is *not* significantly different from one.

The regressions show a mixed picture. The relationship between average compensation and productivity in Canada, West Germany (pre-reunification), the UK and the USA appear to reflect a strong degree of linkage: coefficients on the change in log of productivity are strongly significant, close to one and not significantly lower than one. Germany post-reunification, France, Italy and Japan have positive but smaller coefficients.

Taken as a whole, these results certainly support the view that productivity growth has positive impacts on average compensation, but they do not support the view that the relationship is necessarily one-to-one. There is to us a surprisingly high degree of variation between different countries, which deserves further exploration.

Technological change and the productivity-compensation divergence

As discussed earlier, the gap between net labor productivity and median real compensation can be thought of in terms of three separate divergences: between mean compensation and productivity (equivalent to a fall in the labor share), between median and mean compensation (one aspect of rising labor income inequality), and between consumer and producer price deflators (Bivens and Mishel 2015).

Several prominent theories focus on technological change to explain the first two of these three divergences: the falling labor share, and rising labor income inequality in the top half of the distribution. In this section, we briefly summarize these theories and test them using short-term fluctuations in productivity growth.

Falling labor share (productivity/mean compensation divergence):

The growing "wedge" between labor productivity and mean compensation is equivalent to a falling labor share of income:

$$\%\Delta \frac{Labor\ productivity}{Mean\ compensation} = \%\Delta \left(\frac{output}{hours\ worked} \Big/ \frac{total\ compensation}{hours\ worked} \right) = \%\Delta \frac{1}{labor\ share}$$

Several theories of this recent labor share decline focus on changes in technology. They include capital-augmenting technological change, enabling the mechanization and automation of production (Brynjolfsson and McAfee 2014, Acemoglu and Restrepo 2016); capital deepening, as a result of falling prices of investment goods together with an elasticity of substitution between labor and capital greater than one (Karabarbounis and Neiman 2014); and labor-augmenting technological change combined with an elasticity of substitution of less than one, leading to a fall in the effective capital-labor ratio (Lawrence 2015). The IMF World Economic Outlook (2017) attributes about half the fall in the labor share in advanced economies to technological progress, with the fall in the price of investment goods and advances in ICT encouraging automation of routine tasks.

Grossman, Helpman, Oberfield and Sampson (2017) argue that the productivity slowdown itself may have reduced the labor share through the effect of slowing technological progress on human capital accumulation.

Other authors argue that technological change is not the primary driver of the decline in the labor share. Non-technology focused theories of the decline in the labor share include offshoring of labor-intensive production tasks (Elsby, Hobijn and Sahin 2013), capital accumulation (Piketty 2014, Piketty and Zucman 2014), reductions of worker bargaining power as a result of changing labor market institutions (Levy and Temin 2007, Solow 2015, Mishel and Bivens 2015, OECD 2012, Bental and Demougin 2010), industrial structure explanations including increased firm concentration in "winner-take-most" markets (Autor et al 2017, see also Furman and Orszag 2018, this volume), increased markups (Barkai 2017), and dynamics of the housing market (Rognlie 2015).

Rising top-half labor income inequality (mean/median compensation divergence): The growing "wedge" between mean compensation and median compensation reflects rising top-half labor income inequality. The 90-50 wage ratio has risen steadily since around 1980; over the same period, top income shares including the top 1% and top 0.1% have rapidly risen[24]. As with the fall in the labor share, a number of pure technology-based explanations of rising labor income inequality have been put forward, including capital-skill complementarity (Griliches 1969, Krusell et al 2000), computerization increasing the pace of skill upgrading (Autor, Katz

[24] See, for example, Goldin and Katz (2007), Lemieux (2008), Autor, Katz and Kearney (2008) and Atkinson, Piketty and Saez (2011) for descriptions of these trends.

and Krueger 1998), routine-biased technological change altering task demand and contributing to the "hollowing out" of middle-skill jobs (e.g. Autor 2010), and automation and the use of robots (e.g. Acemoglu and Restrepo 2017).

Non-technological explanations of rising top-half labor income inequality include slower growth in educational attainment in the face of skill-biased technical change (Goldin and Katz 2007), declining unionization (e.g. Freeman et al 2016, Rosenfeld, Denice and Laird 2016[25]), lower top marginal tax rates (Piketty et al 2014), globalization, including rising trade with China and other low-cost manufacturing hubs (e.g. Autor, Dorn and Hanson 2013), increased low-skill immigration (e.g. Borjas 2003), and the "superstar" effect as globalization or technological change increase market size and returns to being the best (e.g. Rosen 1981, Gabaix et al 2016, Jones and Kim forthcoming).

Implications of technology-based theories of rising inequality

Pure technology-based theories of the falling labor share or rising top-half wage inequality have a testable implication. If the fall in the labor share has been caused by technological change and the mechanism operates over the short to medium term, we should expect the labor share to fall more quickly in periods where labor productivity growth is more rapid, under the natural assumption that the technological change in question also increases labor productivity[26]. Similarly, if the rise in the mean/median compensation ratio has been caused by technological change, we should expect that ratio to rise faster in periods of faster labor productivity growth[27].

[25] In earlier work, Freeman (1993) and DiNardo, Fortin and Lemieux (1996) among others argue that the decline in unionization significantly increased labor income inequality during the 1980s/1990s.

[26] For theories where the mechanism is longer-term we would not expect to observe a short/medium-term relationship between productivity growth and changes in the labor share. One theory to which this may apply is Grossman et al (2017) which operates through changed incentives for human capital accumulation.

[27] Note that the correlation between short- and medium-horizon changes in the mean/median ratio and changes in the labor share is relatively low (around 0.25-0.3) and not significant, making it seem a priori unlikely that the same factor is causing both trends.

Over a medium-term horizon, the opposite has occurred in the US (Table 6). During the productivity boom of 1996-2003, the labor share actually rose, and the mean/median compensation ratio increased less quickly than in the periods of slower productivity growth before and afterwards. Indeed, the period over which the labor share has fallen most and the mean/median ration has risen most in recent decades has been a period of productivity slowdown.

Table 6: Average annual productivity growth and changes in inequality

	Average annual productivity growth	**Annual percentage change in labor share**	**Annual change in mean/median ratio**
1950-1973	2.58%	0.10%	--
1973-1996	1.16%	-0.26%	0.71%
1996-2003	2.33%	0.32%	0.39%
2003-2014	1.15%	-0.34%	0.92%

Data from BLS, Penn World Tables, EPI Data Library

Bivens and Mishel (2017) marshal a variety of evidence in this vein to suggest that the pure technology-based theories for rising US income inequality are weak. They argue that a number of indicators of the pace of automation – productivity growth, capital investment, and IT and software investment – increased rapidly in the late 1990s and early 2000s, a period which saw “the best across-the-board wage growth for American workers in a generation”, while in periods of rapidly widening inequality from 1973-1995 and 2005-present these indicators increased more slowly.

However, these medium-term correlations could mask the underlying relationship. Short-term fluctuations in productivity growth provide us a simple natural quasi-experiment to test the implications of pure technology-based theories of rising income inequality: when productivity growth is faster, the labor share should fall more quickly, and the mean/median compensation ratio should increase more quickly.

We hence run the following regressions[28]:

$$\frac{1}{3}\sum_0^2 \Delta \log labor\ share_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \tag{3}$$

$$\frac{1}{3}\sum_0^2 \Delta \log \frac{mean}{median} compensation_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \tag{4}$$

If pure technology-based theories of rising inequality are correct, we should expect to see a negative and significant coefficient on the change in log productivity in the labor share regressions and a positive and significant coefficient the change in log productivity in the mean/median compensation regressions.[29]

We use the Penn World Tables measure of the labor share, which covers labor compensation for the total US economy as a share of GDP. As raised by Johnson (1954), Kravis (1959) and others, the imputation of self-employed proprietors' income to labor or capital can matter significantly for labor share calculations. The PWT measure imputes mixed income of the self-employed to labor according to the average labor share in the rest of the US economy. This appears to be the most plausible measure for the US, based on the occupational demographics of the self-employed (Feenstra, Inklaar and Timmer 2015, Elsby, Hobijn and Sahin 2013), and is

[28] As with the previous section we also run distributed lag versions of these regressions, and versions with different measures of productivity growth. They do not show substantially different results as compared to the results we present here. They are available on request.
[29] In addition, specific technology-based theories may have specific testable implications. In Stansbury and Summers (2017) we tested the hypothesis that the labor share has fallen because a decline in the relative price of investment goods has led to an increase in the capital-labor ratio (Karabarbounis and Neiman 2014), but were unable to find evidence to support this.

consistent with much of the literature on the labor share[30]. For robustness, we repeated our regressions with the BLS measures of the labor share for the total economy and the nonfarm business sector, as well as a net measure of the labor share.[31] These do not show substantially different results from our baseline results, and are available on request.

Productivity and the labor share: results

Table 7 shows results from our baseline specification (3-year moving average), and Table 8 shows the coefficient estimates on productivity in regressions with varying moving average bandwidths. The majority of specifications show a negative relationship between changes in productivity growth and changes in the labor share, as predicted by technology-based theories of the labor share decline. One would also expect some mechanical negative relationship over short horizons, as a positive unanticipated productivity shock would translate into higher firm income in the current year, but would be unlikely to feed through to worker compensation until future years.

The coefficients tend to be small and insignificant for the postwar period and for the post-1973 period, but are large and strongly significant for the period since 2000 over which the labor share has declined. A Quandt likelihood ratio test identifies a structural break in the relationship

[30] Gollin (2002) discussed three different reasonable methods to impute mixed income when calculating the labor share, of which this labor-share based imputation is one. Recent examples using this approach include Elsby et al (2013), Koh, Santaeulàlia-Llopis, and Zheng (2016), Valentinyi and Herrendorf (2008), Caselli and Feyrer (2007), Gomme and Rupert (2004). Rognlie (2015) and Piketty and Zucman (2014) follow a similar method, assuming that the noncorporate sector has the same net capital share as the corporate sector. Krueger (1999) describes a common convention since Johnson (1954) to impute 2/3 of mixed income to labor, which approximates the US economy-wide labor share: this has been used by Christensen (1971), Abel, Mankiw, Summers and Zeckhauser (1989) and Geerolf (2013) among others.

[31] The BLS imputes the compensation of proprietors under the assumption that their hourly compensation is the same as that of the average employee in each sector (BLS 2008, Giandrea and Sprague 2017). Bentolila and Saint-Paul (2003) use a similar wage-based imputation.. Bridgman (2014) shows that the use of gross rather than net labor shares can have a significant impact on calculations of the US labor share decline.

at 2002, significant at the 1% level. The estimated coefficients for the post-2000 period imply that a one percentage point increase in the rate of productivity growth was associated with between 0.07 and 0.43 percentage points faster decline in the labor share. The labor share began to fall significantly in the early 2000s, falling by a total of 4.5 percentage points or by 6.5% over 2001-2014 (an annual rate of 0.49% per year), while the average annual rate of labor productivity growth over 2001-2014 was 1.3%.

Table 7: Productivity and labor share regressions

Dependent variable: 3-year moving average of Δ log labor share	(7a) 1950-2013	(7b) 1950-1973	(7c) 1975-2013	(7d) 2000-2013
Δ log productivity, 3-year moving average	**-0.10**	**-0.03**	**-0.11**	**-0.43*** **
	(0.11)	**(0.24)**	**(0.18)**	**(0.11)**
Unemployment (25-54), 3-year moving average	-0.51***	-0.49*	-0.47***	-0.20
	(0.14)	(0.26)	(0.16)	(0.16)
Lag unemployment, 3-year moving average	0.27**	0.04	0.28**	0.10
	(0.13)	(0.25)	(0.12)	(0.18)
Constant	0.01***	0.02***	0.01*	0.01
	(0.00)	(0.00)	(0.01)	(0.01)
Observations	64	24	39	14

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average.

Table 8: Coefficients on productivity from productivity-labor share regressions with varying moving average bandwidths

Dependent variable: X-year moving average of Δ log labor share	(8a) 1950-2014	(8b) 1950-1973	(8c) 1975-2014	(8d) 2000-2014
2-year moving average	-0.17*	-0.31	-0.14	-0.43***
	(0.09)	(0.25)	(0.17)	(0.11)
3-year moving average	-0.10	-0.03	-0.11	-0.43***
	(0.11)	(0.24)	(0.18)	(0.11)
4-year moving average	-0.09	0.19	-0.12	-0.34**
	(0.12)	(0.25)	(0.14)	(0.11)
5-year moving average	-0.11	0.08	-0.06	-0.07
	(0.11)	(0.16)	(0.12)	(0.16)

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Independent variable is X-year moving average of change in log productivity.

Regressions include unemployment control.
Underlying regressions are in Table 7 and Stansbury and Summers (2017)

Note, however that the magnitude of the coefficient for the post-2000 period falls substantially as the moving average bandwidth increases (Table 8), in line with the hypothesis that some of the short-term negative relationship between contemporaneous productivity growth and compensation growth could be mechanical, but should disappear over longer bandwidths. Testing for a significant difference between productivity coefficients in the pre-2000 and post-2000 period using unrestricted regressions, we find significant differences at the 5% level for 3-year moving averages, and non-significant differences for 2-, 4- and 5-year moving averages. When restricting the coefficients on unemployment and the constant to be the same over both periods, the difference in productivity coefficients between the pre- and post-2000 period substantially declines and is not significant (results in Stansbury and Summers 2017, Table A12). It's not a priori clear whether one should expect the cyclicality of the productivity-labor share relationship or the constant term to have changed since 2000: if not, the restricted regressions are more appropriate.

Overall the results present a mixed picture. Since there is no apparent relationship between changes in the rate of productivity growth and changes in the labor share before 2000, the results do not tend to support theories which posit a long-term underlying relationship between technology and the labor share. The larger and negative coefficient estimates since 2000 provide some support for theories that attribute the labor share decline to a change in the technology-labor share relationship since 2000, but these estimates are sensitive to the time horizon and methodology used.

Productivity and the mean/median ratio: results

If faster technological progress were responsible for the rising mean/median compensation ratio, one would expect periods of faster productivity growth to be associated with periods of faster increases in the mean/median compensation ratio. As Table 9 shows, there is no significant relationship between productivity growth and changes in the mean/median ratio[32]. This casts doubt on pure technology-based theories of the rising mean/median compensation ratio.

Table 9: Productivity and mean/median compensation regressions

Dependent variable: 3-year moving average of Δ log mean-median compensation ratio	(10a) 1975-2015	(10b) 1975-2015
Δ log productivity, 3-year moving average	**-0.01** **(0.10)**	**0.00** **(0.10)**
Unemployment (25-54), 3-year moving average		-0.09 (0.12)
Lag unemployment, 3-year moving average		0.13 (0.10)
Constant	0.01*** (0.00)	0.01 (0.00)
Observations	41	41

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Notation: the year is listed as the middle year of the moving average.

Implications

Over the last four decades in the US, average compensation growth has been slow and median compensation almost stagnant. Real average hourly compensation rose by 48% between 1973 and 2016, or at an annual rate of only 0.9% per year. Real hourly median compensation rose only 12% in total between 1973 and 2016 (and real average hourly

[32] This relationship also holds with different moving average bandwidths.

production/nonsupervisory compensation by 11%). During the same period hourly labor productivity rose by 75% or 1.3% per year.

In contrast, over the period 1948-1973, average pay for Americans rose both much more quickly and in line with productivity. Real average hourly compensation grew by 2.9% per year. Real hourly production/nonsupervisory compensation – which is likely to have grown at a similar rate to median compensation (Bivens and Mishel 2015) – grew by 2.6% per year. Hourly labor productivity grew by 2.7% per year.

As such, a period of slower productivity growth since 1973 has coincided with a period of even slower pay growth. Productivity has grown relatively slowly, average pay slower still, and median and production/nonsupervisory pay barely at all.

There is a spectrum of possible interpretations of the productivity-pay divergence: at one end of the spectrum, the “strong delinkage” view where productivity growth does not systematically translate into growth in workers' compensation, and at the other end of the spectrum the “strong linkage” view where productivity growth translates one-for-one into compensation growth but a variety of other factors have been putting downward pressure on workers' compensation at the same time.

Our regressions are supportive of substantial linkage between productivity and all three measures of compensation: median, production/nonsupervisory and average. Over 1973-2016, a one percentage point increase in the rate of productivity growth has been associated with an increase in compensation growth of 0.7 to 1 percentage points for median and average compensation, and of 0.4 to 0.7 percentage points for production/nonsupervisory compensation. Almost all specifications strongly reject the “strong delinkage” hypothesis, and the “strong linkage" hypothesis of a one-for-one relationship cannot be rejected for either median or average compensation (while it is rejected for production/nonsupervisory compensation). Evidence on different deciles of the wage distribution also shows large and significant positive co-movement between productivity and wages at the middle deciles.

Overall, our results suggest that productivity growth has been acting to push up typical and average compensation to a significant degree over recent decades. As such other factors are likely to be responsible for the divergence between productivity and pay in the US, suppressing typical workers' incomes even as productivity growth act to increase them.

One of these factors could be technological change. Pure technology-based theories of the fall in the labor share or the rise in mean/median income inequality imply that in periods where productivity growth is faster, productivity and median pay should diverge more rapidly. This can be tested using the natural quasi-experiment of fluctuations in productivity growth. There is little evidence of significant co-movement between productivity growth and the labor share in the US over long periods (since 1948 and since 1973), but we find some evidence of a significantly negative relationship between productivity growth and the labor share since 2000. We find no significant relationship between the mean-median ratio and productivity growth over the last four decades. Taken together these results tend not to provide strong support for purely technology-based theories of either the labor share decline or the rise in mean/median pay inequality. Instead, the factors suppressing median compensation over recent decades are more likely to have been factors that are orthogonal to productivity growth.

We can use the coefficient estimates from our regressions to roughly quantify the degree to which the productivity/median compensation divergence has been the result of a lack of passthrough of productivity growth to median compensation, as opposed to being a result of these other factors suppressing median compensation. Our baseline regression coefficient of 0.73 would suggest that if all else had been equal over 1973-2016, the productivity growth we saw would have resulted in median compensation growing by 51% instead of by 11%. Thus, a lack of passthrough of productivity growth to median compensation can explain 38% of the divergence between the two series, and other factors suppressing median compensation (which are orthogonal to productivity growth) can explain the other 62% of the gap. Using our full range of plausible coefficient estimates (from 0.67 to 1.00), between 0 and 40% of the productivity-median compensation gap can be explained by lack of productivity passthrough, while 60-100% of the gap can be explained by other factors suppressing median compensation. For production/nonsupervisory compensation, 40-50% of the gap with productivity can be explained by lack of productivity passthrough, while 50-60% can be explained by other orthogonal factors suppressing production/nonsupervisory compensation.

The continued significance of productivity growth for compensation growth can be illustrated using some simple counterfactuals. If the ratio of the mean to median hourly compensation in 2016 had been the same as it was in 1973, and mean compensation remained at its 2016 level, median compensation would have been around 33% higher holding all else constant. If the ratio of labor productivity to mean compensation in 2016 had been the same as it was in 1973 (i.e. the labor share had not fallen), average and median compensation would have been 4-8% higher holding all else constant. In contrast, assuming the relationship between compensation and productivity estimated in Table 1 holds, if productivity growth had been as fast over 1973-2016 as it was over 1949-1973 (namely, 2.7% per year, rather than 1.3% per year), median and mean compensation would have been around 41% higher in 2016, holding all else constant.

These point estimates suggest that that the potential effect of raising productivity growth on the average American's pay may be as great as the effect of policies to reverse trends in income inequality. Conversely, they suggest that a continued productivity slowdown should be a major concern for those hoping for increases in real compensation for middle income workers.

Our central conclusion is that the substantial variations in productivity growth that have taken place during recent decades have been associated with substantial changes in median and mean real compensation. If productivity accelerates for reasons relating to technology or to policy, the likely impact will be increased pay growth for the typical worker. Rather than productivity growth failing to translate into pay growth, our evidence suggests that other factors are suppressing typical workers' incomes even as productivity growth acts to increase them.

Productivity growth still matters substantially for middle income Americans. At the same time, the evidence of the past four decades suggests that in the face of rising inequality productivity growth alone may not be enough to raise living standards substantially.

References

Abel, Andrew B., N. Gregory Mankiw, Lawrence H. Summers, and Richard J. Zeckhauser (1989). "Assessing dynamic efficiency: Theory and evidence." *The Review of Economic Studies* 56, no. 1: 1-19.

Acemoglu, Daron, and Pascual Restrepo (2017). "Robots and Jobs: Evidence from US labor markets." *mimeo*.

Acemoglu, Daron, and Pascual Restrepo (2016). “The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment.” NBER Working Paper 22252.

Atkinson, Anthony B., Thomas Piketty, and Emmanuel Saez (2011). “Top incomes in the long run of history." *Journal of economic literature* 49(1): 3-71.

Autor, David (2010). "The polarization of job opportunities in the US labor market: Implications for employment and earnings." *Center for American Progress and The Hamilton Project*.

Autor, David, David Dorn, Lawrence F. Katz, Christina Patterson, and John Van Reenen (2017). *The Fall of the Labor Share and the Rise of Superstar Firms*. No. dp1482. Centre for Economic Performance, LSE.

Autor, David H., David Dorn, and Gordon H. Hanson (2013). "The China syndrome: Local labor market effects of import competition in the United States." *The American Economic Review* 103.6: 2121-2168.

Autor, David H., Lawrence F. Katz, and Melissa S. Kearney (2008). "Trends in US wage inequality: Revising the revisionists." *The Review of economics and statistics* 90.2: 300-323.

Autor, David H., Lawrence F. Katz, and Alan B. Krueger (1998). "Computing inequality: have computers changed the labor market?." *The Quarterly Journal of Economics* 113.4: 1169-1213.

Azmat, Ghazala, Alan Manning, and John Van Reenen (2011). “Privatization and the Decline of Labour's Share: International Evidence from Network Industries,” Economica, 1- 23

Baker, Dean (2007). “Behind the Gap between Productivity and Wage Growth”. Center for Economic Policy and Research Issue Brief, February 2007.

Barkai, Simcha (2016). "Declining labor and capital shares." *Stigler Center for the Study of the Economy and the State New Working Paper Series* 2.

Barkume, Anthony J (2007). “Some New Evidence on Overtime Use, Total Job Compensation and Wage Rates”. *Bureau of Labor Statistics Working Paper 402*.

Bental, Benjamin, and Dominique Demougin (2010). "Declining labor shares and bargaining power: An institutional explanation." *Journal of Macroeconomics* 32.1 : 443-456.

Bentolila, Samuel, and Gilles Saint-Paul (2003). "Explaining movements in the labor share." *Contributions in Macroeconomics* 3.1.

Bivens, Josh and Lawrence Mishel (2015). “Understanding the Historic Divergence between Productivity and a Typical Worker's Pay: Why It Matters and Why It's Real." Washington DC: Economic Policy Institute

Blanchard, Olivier, and Francesco Giavazzi (2003). "Macroeconomic Effects of Regulation and Deregulation in Goods and Labor Markets," The Quarterly Journal of Economics 118, 879-907.

Borjas, George J. (2003). The labor demand curve is downward sloping: Reexamining the impact of immigration on the labor market. *The Quarterly Journal of Economics*, *118*(4), 1335-1374.

Bosworth, Barry, and Dean Perry (1994). “Productivity and Real Wages: Is There A Puzzle?”. Brookings Papers on Economic Activity.

Bosworth, Barry (2010). “Price Deflators, the Trust Fund Forecast, and Social Security Solvency,” Center for Retirement Research Working Paper 2010-12, Boston College.

Bridgman, Benjamin (2014). “Is Labor’s Loss Capital’s Gain? Gross versus Net Labor Shares.” Washington: U.S. Bureau of Economic Analysis

Brynjolfsson, Erik, and Andrew McAfee (2014). “The second machine age: Work, progress, and prosperity in a time of brilliant technologies". WW Norton & Company.

Bureau of Labor Statistics (2008). “Technical Information about the BLS Major Sector Productivity and Costs Measures”, March 11 2008.

Bureau of Labor Statistics (2016). “News Release: Productivity and Costs. First Quarter 2016, Revised". June 7 2016.

Byrne, David M., J. Fernald, and Marshall Reinsdorf (2016). "Does the United States have a Productivity Slowdown or a Measurement Problem." Brookings Papers on Economic Activity March 2016.

Caselli, Francesco, and James Feyrer (2007). "The marginal product of capital." *The quarterly journal of economics* 122.2 : 535-568.

Cho, T., S. Hwang and P. Schreyer (2017) "Has the Labour Share Declined? It Depends," OECD Statistics Working Papers No. 2017/01, OECD Publishing, Paris.

Christensen, Laurits R (1971). "Entrepreneurial income: how does it measure up?." *The American Economic Review* 61.4: 575-585.

Church, Jonathan D. (2016). “Comparing the consumer price index with the gross domestic product price index and gross domestic product implicit price deflator”. Bureau of Labor Statistics Monthly Labor Review, March 2016.

Dew-Becker, Ian, and Robert J. Gordon. (2005) *Where did the productivity growth go? Inflation dynamics and the distribution of income*. No. w11842. National Bureau of Economic Research.

DiNardo, John, Nicole M. Fortin, and Thomas Lemieux (1996). “Labor Market Institutions and the Distribution of Wages, 1973–1992: A Semiparametric Approach.” *Econometrica* 64 (September): 1001–44

Economic Policy Institute (2017). *State of Working America Data Library,* “Wages by Percentile”.

Economic Report of the President (2015). Washington, DC.

Elsby, Michael WL, Bart Hobijn, and Ayşegül Şahin (2013). "The decline of the US labor share." *Brookings Papers on Economic Activity* 2013.2: 1-63.

Feenstra, Robert C., Robert Inklaar, and Marcel Timmer (2015). “The Next Generation of the Penn World Table”. *The American Economic Review* 105.10: 3150-3182

Feldstein, Martin (2008). “Did wages reflect growth in productivity?" *Journal of Policy Modeling* 30(4): 591-594.

Feldstein, Martin (2017). “Underestimating the real growth of GDP, personal income, and productivity”. Journal of Economic Perspectives, Spring 2017 31(2): 145-64.

Fixler, Dennis, and Ted Jaditz (2002). “An Examination of the Difference Between the CPI and the PCE Deflator,” Bureau of Labor Statistics Working Paper no. 361.

Fleck, Susan, John Glaser and Shawn Sprague (2011). "The compensation-productivity gap: A visual essay". Bureau of Labor Statistics Monthly Labor Review, January 2011.

Freeman, Richard B (1993). "How Much Has De-Unionization Contributed to the Rise in Male Earnings Inequality?" In *Uneven Tides: Rising Inequality in America*, edited by Sheldon Danziger and Peter Gottschalk. New York: Russell Sage Foundation

Freeman, Richard B, Han E, Duke B, Madland D (2016). "How Does Declining Unionism Affect the American Middle Class and Inter-generational Mobility?". Federal Reserve Bank, 2015 Community Development Research Conference Publication.

Gabaix, Xavier, Jean-Michel Lasry, Pierre-Louis Lions, and Benjamin Moll (2016). "The dynamics of inequality." *Econometrica* 84, no. 6 : 2071-2111.

Geerolf, Francois (2013). "Reassessing dynamic efficiency". Working paper, UCLA.

Giandrea, Michael D. and Shawn A. Sprague (2017). "Estimating the US labor share". Bureau of Labor Statistics Monthly Labor Review, February 2017.

Goldin, Claudia Dale, and Lawrence F. Katz. (2009) *The race between education and technology*. Harvard University Press.

Gollin, Douglas. (2002). "Getting income shares right". Journal of political Economy, 110(2), 458-474.

Gomme, Paul, and Peter Rupert, 2004. "Measuring Labor's Share of Income," *Federal Reserve Bank of Cleveland, Policy Discussion Paper* no. 04-07.

Griliches, Zvi (1969). "Capital-skill complementarity." *The review of Economics and Statistics* (1969): 465-468.

Groshen, Erica L., Brian C. Moyer, Ana M. Aizcorbe, Ralph Bradley, and David M. Friedman (2017). "How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches." Journal of Economic Perspectives, 31(2): 187-210.

Grossman, Gene M., Elhanan Helpman, Ezra Oberfield, and Thomas Sampson (2017). "The Productivity Slowdown and the Declining Labor Share: A Neoclassical Exploration". NBER Working Paper No. 23853.

IMF (2017) "Understanding the Downward Trend in Labor Income Shares," Chaper 3 in World Economic Outlook April.

International Labour Organization. (2015) Global Wage Report 2014/15: Wage and Income Inequality

Johnson, D. Gale. 1954. "The Functional Distribution of Income in the United States, 1850–1952." Review of Economics and Statistics 36, 2: 175–82.

Jones, Charles I. and Jihee Kim (forthcoming). "A Schumpeterian Model of Top Income Inequality". *Journal of Political Economy*.

Karabarbounis, Loukas and Brent Neiman (2014). "The global decline of the labor share." *The Quarterly Journal of Economics* 129(1): 61-103.

Koh, Dongya, Raül Santaeulàlia-Llopis, and Yu Zheng (2016). "Labor share decline and intellectual property products capital." Working Paper, European University Institute.

Kravis, Irving B (1959). "Relative income shares in fact and theory." *The American Economic Review* 49.5: 917-949.

Krueger, Alan B (1999). "Measuring Labor's Share." *The American Economic Review* 89.2: 45-51.

Krusell, Per, Lee E. Ohanian, José-Víctor Ríos-Rull, and Giovanni L. Violante (2000). "Capital-skill complementarity and inequality: A macroeconomic analysis." *Econometrica* 68.5: 1029-1053.

Lawrence, Robert Z (2016). "Does Productivity Still Determine Worker Compensation? Domestic and International Evidence". Chapter 2 in *The US Labor Market: Questions and Challenges for Public Policy*. American Enterprise Institute Press.

Lawrence, Robert Z (2015). "Recent Declines in Labor's Share in US Income: A Preliminary Neoclassical Account". Working Paper No. w21296. National Bureau of Economic Research.

Lemieux, Thomas. (2008). The changing nature of wage inequality. *Journal of Population Economics*, *21*(1), 21-48.

Levy, Frank, and Peter Temin. (2007). *Inequality and institutions in 20th century America*.

McCully, Clinton P., Brian C. Moyer, and Kenneth J. Stewart (2007). "Comparing the Consumer Price Index and the Personal Consumption Expenditure Price Index," Survey of Current Business, 26-33, Bureau of Economic Analysis.

Mishel, Lawrence and Josh Bivens (2017). "The zombie robot argument lurches on". *Economic* Policy Institute, May 24 2017.

Monaco, Kristen and Brooks Pierce (2015). "Compensation inequality: evidence from the National Compensation Survey," *Monthly Labor Review,* U.S. Bureau of Labor Statistics, July 2015

Nolan, Brian, Max Roser and Stefan Thewissen (2016). "GDP Per Capita Versus Median Household Income: What gives rise to divergence over time?". INET Oxford Working Paper No. 2016-03.

OECD (2012). "Labour Losing to Capital: What Explains the Declining Labour Share?". Chapter 3 in OECD Employment Outlook.

Pessoa, Joao Paolo and John Van Reenen (2013). "Decoupling of Wage Growth and Productivity Growth? Myth and Reality". London School of Economics Centre for Economic Performance Discussion Paper No. 1246.

Pierce, Brooks (2010). "Recent trends in compensation inequality." *Labor in the new economy*. University of Chicago Press. 63-98.

Piketty, Thomas (2014). Capital in the Twenty-First Century. Cambridge, MA: Belknap Press.

Piketty, Thomas, and Gabriel Zucman. (2014). "Capital is Back: Wealth-Income Ratios in Rich Countries 1700–2010." Quarterly Journal of Economics, 129(3): 1255–1310

Rognlie, Matthew (2016). "Deciphering the fall and rise in the net capital share: accumulation or scarcity?." *Brookings papers on economic activity* 2015.1 : 1-69.

Rosen, Sherwin (1981). "The economics of superstars." *The American economic review* 71.5: 845-858.

Rosenfeld, Jake, Patrick Denice, and Jennifer Laird (2016). "Union Decline Lowers Wages of Nonunion Workers." *Washington, DC: Economic Policy Institute*.

Schwellnus, Cyrille, Andreas Kappeler, and P. Pionnier. "The Decoupling of Median Wages from Productivity in OECD Countries." *International Productivity Monitor* 32 (2017): 44-60

Sharpe and Uguccioni (2017) "Decomposing the Productivity-Wage Nexus in Selected OECD Countries, 1986-2013," International Productivity Monitor, Vol. 32, Spring.

Sherk, James (2013). “Productivity and compensation: growing together”. Heritage Foundation Backgrounder #2825 on Labor.

Solow, Robert (2015). “The Future of Work: Why wages aren’t keeping up”. *Pacific Standard Magazine* 11th August 2015.

Stansbury, Anna M. and Lawrence H. Summers (2017), “Productivity and Pay: Is the link broken?” NBER Working Paper No. 24165, December.

Statistiches Bundesamt Deutschland (2016). “Volkswirtschaftliche Gesamtrechnungen: Inlandsproduktberechnung Lange Reihen ab 1970”. Article number 2180150167004.

Syverson, Chad (2017). “Challenges to Mismeasurement Explanations for the US Productivity Slowdown”. *Journal of Economic Perspectives,* 31(2): 165-86.

Triplett, Jack E. (1981). “Reconciling the CPI and the PCE Deflator,” Monthly Labor Review September, 3–15.

Valentinyi, Akos, and Berthold Herrendorf (2008). "Measuring factor income shares at the sectoral level." *Review of Economic Dynamics* 11.4 : 820-835.