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PRODUCTIVITY AND PAY:
IS THE LINK BROKEN?

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ABSTRACT

Since 1973 median compensation 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: 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 the 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. We do not find substantial evidence of co-movement between productivity growth and the labor share or mean/median compensation ratio. This tends not to provide strong support for pure technology-based theories of the productivity-compensation divergence.

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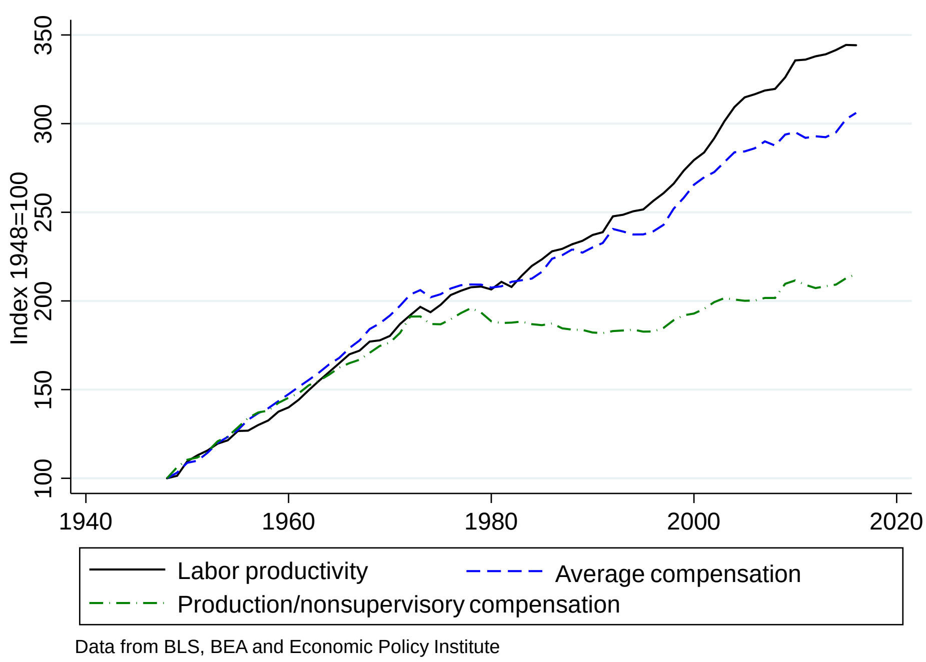
Introduction

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. We illustrate these trends in Figure 1, showing the growth since 1948 in labor productivity, average compensation, and average production/nonsupervisory compensation (proxying for the "typical" worker) [1].

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



[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 it is possible that productivity growth translates directly into increases in typical workers’ pay, but even as productivity growth has been acting to raise pay, 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 in the productivity-typical compensation relationship by investigating the co-movement of growth in productivity and typical compensation, 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 translation of productivity growth to compensation growth which is positive but less than one.

[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 this transmission process could be restored.

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). 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. 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 statistically 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 our estimates suggest that 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 statistically significantly different 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 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 we believe that the evidence is supportive of there being substantial linkage between productivity and typical worker compensation, and between productivity 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, institutions and market power. The technology-focused theories have a testable implication: under the assumption that more rapid technological progress causes faster productivity growth, if the primary cause of the productivity-pay divergence is technological progress then periods of faster productivity growth should coincide with faster growth in this divergence.

To test this we examine the co-movement of labor productivity with the labor share and with the mean-median compensation ratio. The general tendency in the data is not strongly supportive of a pure technology hypothesis for the productivity-pay divergence: we find little evidence of a significant relationship between the rate of productivity growth and changes in the labor share for any period except the period 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 and measurement issues, 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.

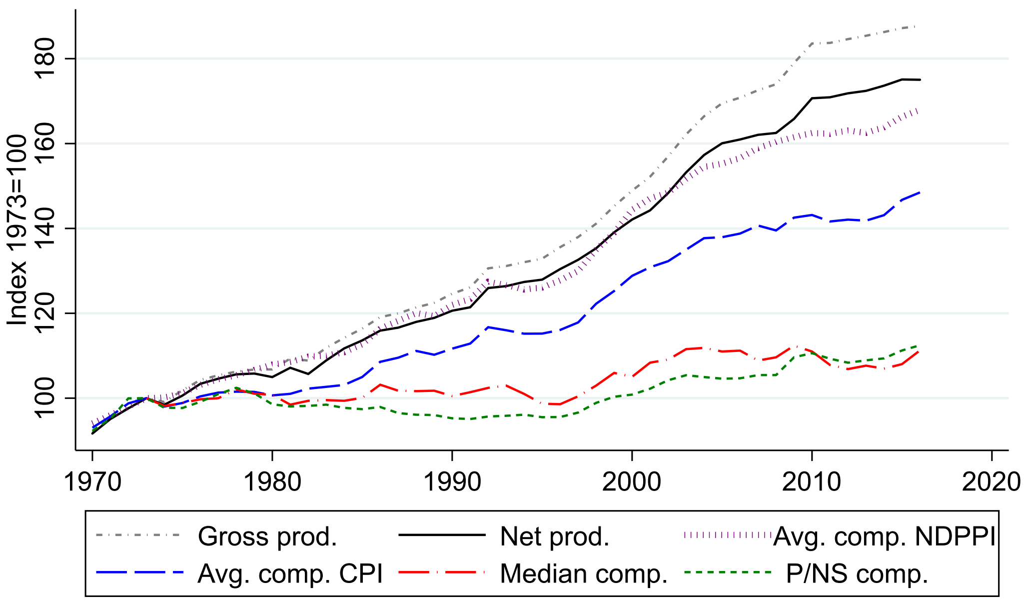
Existing work, definitions & measurement

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)[3]. Gross labor productivity has grown faster than net labor productivity because of rising depreciation[4]; net labor productivity has grown faster than average compensation deflated by a PPI as the labor share has fallen; average compensation deflated by a producer price index (PPI) has grown faster than average compensation deflated by a consumer price

[3] Pessoa and Van Reenen (2013), Fleck, Glaeser and Sprague (2011), and Baker (2007) have demonstrated similar divergences.
[4] 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 "terms of trade" between consumer and producer have diverged[5]; 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 grown as a share of total compensation (not shown on the graph).

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



Data from BLS, BEA and Economic Policy Institute
Avg. comp. NDPPI refers to average compensation deflated by the NDP price index
Avg. comp. CPI refers to average compensation deflated by the CPI
P/NS comp. refers to average production/nonsupervisory worker compensation
Mediand and P/NS compensation are deflated by the CPI

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. The appropriate measures ultimately depend on the question being asked.

[5] 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).

One possible line of inquiry is to study the ***divergence between productivity and the typical worker's compensation***. Bivens and Mishel (2015) document this divergence, comparing net total economy labor productivity with two measures of typical worker compensation: median compensation and average production/nonsupervisory worker compensation, both 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 is also a good proxy for trends in median compensation before 1973 (a period for which median compensation data is not available). Baker (2007) and Pessoa and Van Reenen (2013) have carried out similar analyses, using production/nonsupervisory compensation and median compensation respectively.

Another line of inquiry is to investigate the ***divergence between productivity and average compensation***. This is conceptually equivalent to the decline in the labor share[6]. Feldstein (2008) compares labor productivity in the nonfarm business sector to average nonfarm business sector compensation[7] 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) carried out similar analyses for earlier periods. Lawrence (2016) analyzes this divergence more

[6] 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). With non-Cobb-Douglas technologies, a divergence of workers' wages from their average productivity can occur even while workers are being paid their marginal product.

[7] Using compensation rather than wages is important. The share of compensation provided in non-wage benefits such as health insurance significantly rose over the postwar period, particularly during the 1960s and 1970s, meaning that comparing productivity against wages alone would imply a larger divergence between productivity and workers' pay than has actually occurred.

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 productivity growth feed through into typical/average worker compensation?*** We have chosen the measures of compensation and productivity which are most appropriate for the particular questions we are asking.

For **typical compensation**, we compare net total economy productivity with median compensation. While median compensation is our preferred measure for the typical worker, we also report results for average production/nonsupervisory compensation, both as an interesting measure in itself and since it enables us to analyze the pre-1973 period (as in Bivens and Mishel 2015). We focus primarily on median compensation since it is the measure which is most clearly interpretable as showing trends for middle income workers. Median compensation 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 as discussed by Abraham, Spletzer and Stewart (1998) and Champagne, Kurmann and Stewart (2015), there is some evidence that the average production/nonsupervisory compensation measure does not cover all workers that it is intended to. They 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. This may represent a significant group of middle income workers[8] which is 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 production/nonsupervisory compensation falls significantly more than median compensation in real terms. We speculate that this divergence 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 the reduction in well-paid blue-collar jobs (covered in the production/nonsupervisory measure) and increase in middle-income white-collar jobs (possibly missed out of the production/nonsupervisory measure).

[8] Some examples of occupations where workers are likely to be exempt, salaried, and earn around the median wage: pre-school teachers, several categories of clerk and administrative assistants, medical and equipment technicians.

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.

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 strong and 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 to include the last decade.

Empirical estimation

At the simplest level, a linear model can relate productivity and typical or average compensation growth[9] 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.

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

We can estimate β using the substantial variation in productivity and compensation growth rates since the second world war. We look at three different concepts for compensation: median

[9] 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).

compensation, average production/nonsupervisory compensation, and average compensation. For brevity since we run the same tests for all compensation 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 of real compensation on the three-year moving average of the change in log of labor productivity and the current and lagged three-year moving average of the unemployment rate[10].

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

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, increases in productivity will only translate with a lag into changes in compensation. 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, once again 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, the rise in compensation may precede the actual rise in productivity. As a result of this uncertainty we also present results for regressions without a moving average, and with two-,

[10] 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. For our distributed lag regressions, we specify lag length using the "rule of thumb" lags $=0.75{*}T^{1/3}$ (Stock and Watson 2007).

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 search and 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 setting in the short term: higher unemployment may signal a downturn, which could bring lower firm revenues, profits and 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 the unemployment rate 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 BLS, 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.

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. Our median and production/nonsupervisory compensation series are from the Economic Policy Institute State of Working America Data Library. They construct median wages from the CPS-ORG survey and average production/nonsupervisory wages from the BLS CES, and deflate these by the CPI-U-RS. They then adjust to include non-wage compensation using the average real compensation/wage ratio, which they calculate from BEA NIPA data on the composition of workers' compensation, deflating all components of compensation by the PCE except costs for health and life insurance which are deflated by the PCE health care index (further details are available in Bivens and Mishel 2015). We are grateful to Larry Mishel and Josh Bivens for providing us the raw data alongside the publicly available versions.

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 survey and deflated by the CPI-U-RS. It starts in 1973.

There are some ambiguities with respect to the appropriate choice of compensation and productivity measures. We choose to deflate our compensation series with the CPI-U-RS over the PCE because it is designed to deflate only the consumption of individuals/households, whereas the PCE also includes consumption by non-profits and some purchases of healthcare for individuals by government or employers. It could be argued however that we should use the PCE since it is a chained consumer price index and since its data from establishment surveys may be more reliable (as argued by Lawrence 2016), or that we should use a producer price deflator since if not our regression will pick up differences in price deflators which may be considered to be statistical artefacts rather than real divergences. We repeat our baseline regressions with compensation deflated by the PCE and NDP price index and find little change to our results (available on request).

Productivity is difficult to measure accurately for the entire economy: it comprises government and non-profit institutions, whose output is difficult to conceptualize and 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 our analysis of the other major advanced economies, we only focus on the linkage between average compensation and productivity since there is not good internationally comparable data on median hourly compensation. Unless otherwise specified we use OECD data on labor productivity per hour worked and average compensation per hour worked, deflated by the consumer price index for the country in question, as well as using OECD data on the aggregate unemployment rate. For 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 median, production/nonsupervisory and average compensation growth and of productivity 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)

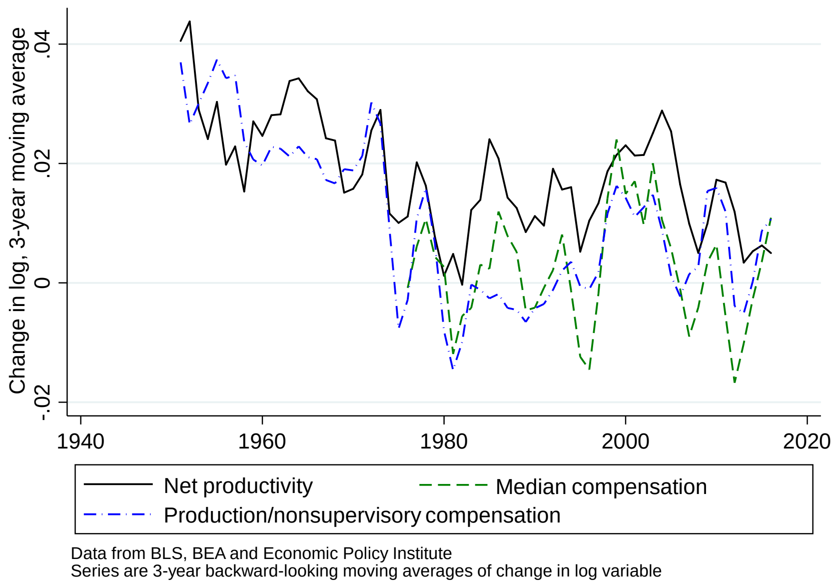


Figure 4: Change in log labor productivity, and average compensation (3-year moving averages)

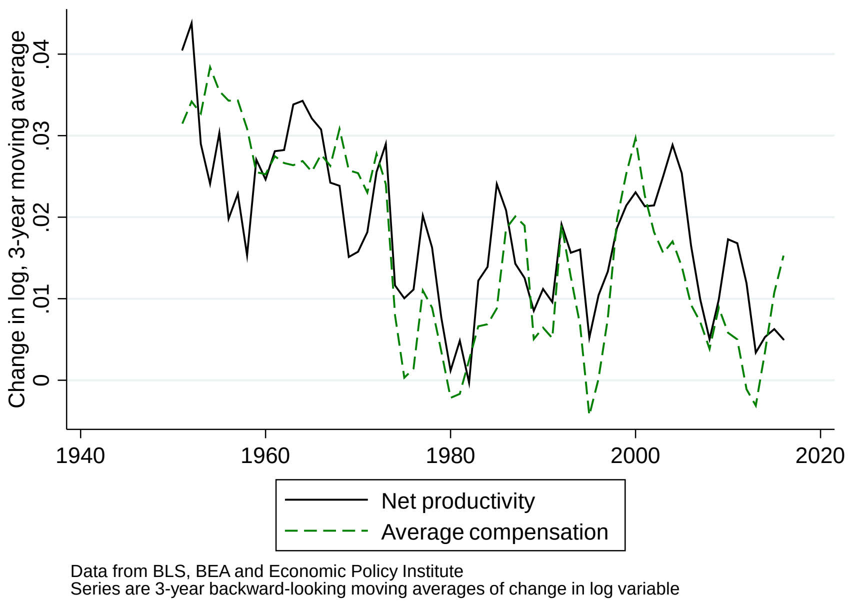


Table 1 displays our baseline regression results. The dependent variable is the growth in average compensation in columns a-d, median compensation in column e and production and non-supervisory compensation in columns f-h. For average and for production/nonsupervisory compensation we show coefficients for the whole postwar period as well as on either side of 1973[11]. 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 productivity[12]; breakpoint tests also identify a structural break at 1973 for both average and production/nonsupervisory compensation[13]. Since our median compensation data only goes back to 1973, splitting the sample then 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 the growth rate of productivity 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

[11] Note that 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 of data for 1974, 1975 and 1976.

[12] 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 US productivity and compensation.

[13] 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.

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 the growth rate of productivity 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 positive linkage between productivity and production/nonsupervisory compensation, but does not support the "strong linkage" hypothesis of a one-for-one relationship.

Average compensation: Table 1 shows that there has been a strongly positive and significant association between changes in log productivity and average compensation. Over 1950-2015 and 1975-2015 a one percentage point increase in the growth rate of productivity was associated with a 0.74 and 0.77 percentage point increase in the 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 Appendix 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.

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

We do this using average compensation and production/nonsupervisory compensation since 1948 and median compensation since 1973. Table 2 shows a summary of these results for the coefficient on the change in log productivity. We show the full regressions in Appendix Tables A1-A7[14].

In general we find our results relatively robust across different specifications.

The coefficient estimates for **median compensation** are in the range of 0.65 to 1, 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.

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.

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

[14] 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 the Appendix. These results are available on request.

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.

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

Cumulative dynamic multiplier, Δ log productivity		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 Appendix Tables A1-A7. Unless otherwise stated, regressions use 3-year moving averages.

The fact that the coefficients are significantly lower for production/nonsupervisory compensation than for median compensation bears further investigation. Average compensation growth trends for production/nonsupervisory workers do not appear to reflect productivity growth to the same extent as compensation for the median worker, in spite of the fact that in terms of levels, the two series are relatively similar throughout the postwar period[15].

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 regression (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

[15] 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.

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. The labor productivity series is constructed by deflating nominal Net Domestic Product by the NDP price index, and dividing by total hours worked. The NDP price index is constructed as an aggregate of sector- or product-specific producer and consumer price indexes from the BLS and BEA. The average real compensation series is constructed by deflating nominal aggregate compensation by the CPI, and dividing by total hours worked. We have no reason to believe that there is substantial mismeasurement in the nominal series: output and compensation. 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, as long as the *relative* degree of mismeasurement in the price deflators for output and consumption has not changed, mismeasurement should not affect our conclusions[16].

The rest of the income distribution

Our 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?

We test 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*, constructed from CPS-ORG microdata. This data estimates hourly *wages* at each decile of the distribution rather than total hourly compensation, so is likely to understate compensation growth as benefits have grown faster than wages for much of the postwar period (as discussed in e.g. Bosworth and Perry 1994, Feldstein 2008, Bivens and Mishel 2015, Lawrence 2016).

We repeat our baseline three-year moving average regressions of wage growth on productivity growth for each decile of the wage distribution below in tables 3 and 4. The results show substantial differences in the co-movement of productivity and wages by decile. The wages of the workers at the 20th and 40th to 90th percentiles co-move significantly with productivity, with coefficients between 0.3 and 0.7.

[16] This argument is stronger if we deflate the compensation series by the implicit price deflator for output. In that case, both the compensation and productivity series are deflated by the same price index and so the underlying relationship between the two should remain in spite of any mismeasurement. We have redone 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: 10^{th} to 50^{th} 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, 3-year moving average	**0.34**	**0.69****	**0.18**	**0.37****	**0.60*****
	(0.39)	**(0.26)**	**(0.28)**	**(0.16)**	**(0.16)**
Unemployment (25-54), 3-year moving average	-1.05*	-0.63*	-0.53	-0.42	-0.43*
	(0.54)	(0.37)	(0.36)	(0.34)	(0.22)
Lag unemployment, 3-year moving average	0.29	0.04	-0.04	0.03	0.14
	(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.

Table 4: Wage and productivity regressions: 50^{th} to 90^{th} 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, 3-year moving average	**0.48****	**0.33****	**0.35****	**0.38****	**0.30**
	(0.19)	**(0.13)**	**(0.13)**	**(0.17)**	**(0.23)**
Unemployment (25-54), 3-year moving average	-0.28	-0.16	-0.18	-0.25	-0.44
	(0.27)	(0.27)	(0.24)	(0.23)	(0.27)
Lag unemployment, 3-year moving average	-0.03	-0.09	-0.04	0.05	0.25
	(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.

A significant caveat in interpreting these regressions is that these data are for wages not for total compensation. Since non-wage compensation grew more quickly than wages for much of the period we investigate, our wage data underestimates total real compensation growth. It is probable that the growth in non-wage benefits is positively correlated with both the growth rate in wages and the growth rate of aggregate productivity. 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 (demonstrated in Appendix 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 with any confidence 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 40^{th} and 60^{th} percentiles (Pierce 2010, Monaco and Pierce 2015). We therefore extrapolate the rough magnitude of the bias at the 50^{th} percentile to suggest that the coefficient estimates from the wage-productivity regressions at the 40^{th} and 60^{th} percentiles may be similar underestimates of the compensation-productivity relationship.

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[17].

Though the cross-country relationship between productivity and compensation is strong, as in the US median compensation has diverged from productivity in most OECD countries over the last two decades, with common trends of rising mean-median income inequality and a falling labor share[18](Schwellnus, Kappeler and Pionnier 2017, Sharpe and Uggucioni 2017, Nolan, Roser and Thewissen 2016, International Labor Organization 2015). This suggests the possibility that in some of these countries there may have been a delinkage of productivity from compensation.

Studying this delinkage question in detail for other countries as we have done for the US would be a valuable direction for future research. As an initial exploration we repeat our regressions for average compensation for the G7 economies, shown in table 5 below. We do not repeat our regressions for median compensation, since most countries lack comparable median hourly compensation data over a sufficiently long time series to do this.

[17] 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 Appendix Figure A2.

[18] 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.

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, the 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, and we believe further exploration would be valuable.

Technological change and the productivity-compensation divergence

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

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. We first outline some of the major theories behind these divergences, then suggest that the pure technological change based theories have a testable implication: periods of faster productivity growth (and by implication faster technological progress) should be associated with faster growth in each of these divergences.

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:

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

A number of theories of this recent labor share decline (productivity/mean compensation divergence) focus on technological progress. Karabarbounis and Neiman (2014) argue that the labor share has fallen in the US and around the world as a result of a fall in the price of investment goods. This, combined with an elasticity of substitution between labor and capital greater than one, would cause capital deepening and a fall in the labor share[19]. Acemoglu and Restrepo (2016) and Brynolfsson and McAfee (2014) have argued that capital-augmenting technological change – enabling the mechanization and automation of production – may be responsible for the decline in the labor share; assumptions about economic structure and the endogeneity of technological progress then determine whether this fall in the labor share is temporary or permanent. 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.

Lawrence (2015) has a contrasting technology-based explanation: that the falling labor share is a result of rapid labor-augmenting technological change which has led to a fall in the effective capital-labor ratio. This, combined with an elasticity of substitution between labor and capital less than one, would cause a fall in the labor share.

Grossman, Helpman, Oberfield and Sampson (2017) argue that the labor share is increasing in the rate of technological progress through its effects on human capital accumulation, and therefore attribute the recent decline in the labor share to the productivity slowdown.

Many authors on the other hand 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 the effect of offshoring of labor-intensive production tasks (Elsby, Hobijn and Sahin 2013), capital accumulation (Piketty 2014, Piketty and Zucman 2014), reductions of

[19] This possibility was raised by Jones (2003), who argued that differences between the short- and long-run elasticities of substitution between capital and labor could explain trends in the labor share and relative price of investment goods.

worker bargaining power as a result of changing labor market institutions (e.g. 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) and increased markups (Barkai 2017), and dynamics in the housing market (Rognlie 2015).

Rising top-half labor income inequality (mean/median compensation divergence): The growing "wedge" between mean compensation and median compensation is a manifestation of rising top-half labor income inequality. This rise in top-half labor income inequality has had various different dimensions. At a broad-brush level, 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[20].

A number of pure technology-based explanations of rising labor income inequality have been put forward, which focus on changes in the pace or nature of technological change. Examples of these are capital-skill complementarity (Griliches 1969, Krusell et al 2000), computerization increasing the pace of skill upgrading (e.g. Autor, Katz 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).

Goldin and Katz (2007) argue that rising labor income inequality in the late twentieth century was not caused by technology alone: rather, against a roughly constant pace of skill-

[20] 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.

biased technological change, the rate of increase in educational attainment slowed, leading to rising education premia and rising income inequality as a result.

Non-technological explanations of rising top-half labor income inequality include declining unionization (e.g. Freeman et al 2016, Rosenfeld et al 2016[21]), lower top marginal tax rates (Piketty et al 2014), globalization, including rising trade with China and other low-cost manufacturing hubs (e.g. Autor et al 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

In general, 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[22]. 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[23].

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[21] 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.

[22] 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.

[23] 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 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.

It could still however be the case that these medium-term correlations 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 run the following regressions[24]:

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

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

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 of productivity in the labor share regressions and a positive and significant coefficient the change in log of productivity in the mean/median compensation regressions.

In addition, particular technology-based theories lend themselves to particular testable implications. Karabarbounis and Neiman (2014) argue that the labor share has fallen because as the relative price of investment goods has fallen, firms have substituted capital for labor (under the assumption of an elasticity of substitution between labor and capital greater than one). Under the same logic as above, this should imply that in periods where the relative price of investment goods falls more quickly, the labor share should fall faster. We run the following regression to test this:

$$\frac{1}{3}\sum_0^2 \Delta \log labor\ share_{t-i} = \alpha + \beta \frac{1}{3}\sum_0^2 \Delta \log rel.pr.inv.goods_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \quad (5)$$

We use the Penn World Tables measure of the labor share, which covers labor

[24] 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.

compensation for the total US economy as a share of GDP. As raised by Johnson (1954), Kravis (1959) and others, the imputation of the income of self-employed proprietors 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[25]. 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 consistent with much of the literature on the labor share[26]. However others including the BLS use alternative approaches[27], and so for robustness, we repeated our regressions with the BLS measures of the labor share for the total economy and the nonfarm business sector. These do not show substantially different results from our baseline results, and are available on request[28].

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

[25] Gollin (2002) discussed three different reasonable methods to impute mixed income when calculating the labor share, of which this is one. Kravis (1959) introduced a similar set of approaches.

[26] This approach is followed by Elsby et al (2013), who argue strongly against a wage-based approach and instead favor a labor share imputation or the Kravis "asset basis" approach. Some other recent examples using this approach include Koh et al (2016), Valentinyi and Herrendorf (2008), Caselli and Feyrer (2007), Gomme and Rupert (2004). Rognlie (2015) and Piketty and Zucman (2014) follow a very similar method, assuming that the noncorporate sector (excluding housing) 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 et al (1989) and Geerolf (2013) among others.

[27] 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) and Karabarbounis and Neiman (2014) only investigate the corporate labor share, which avoids the need to impute the income of self-employed proprietors to either labor or capital.

[28] In addition 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. Calculating the labor share using Net Domestic Product rather than Gross Domestic Product does not significantly alter the outcomes of our regressions.

productivity growth and changes in the labor share, as would be predicted by technology-based theories of the labor share decline[29]. 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 at 2002, significant at the 1% level. Taking the estimated coefficients for the post-2000 period at face value, their magnitude could be economically significant. They imply that a one percentage point increase in the rate of productivity growth over 2000-2014 was associated with between 0.07 and 0.43 percent faster declines 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%.

Note however that the magnitude of the coefficient for the post-2000 period falls substantially as the moving average bandwidth increases: since one would mechanically expect a negative relationship between contemporaneous productivity growth and compensation growth after unanticipated productivity shocks, the longer bandwidths may be more reliable estimates of the underlying relationship. 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

[29] Note also that one would mechanically expect some negative relationship between contemporaneous productivity growth and compensation growth, 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 periods when compensation is re-set –resulting in a temporary fall in the labor share in years where productivity growth is unexpectedly high.

pre- and post-2000 period substantially declines and is not significant (results in Appendix 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 since these estimates are rather sensitive to the time horizon and methodology used, they do not provide robust support.

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** **(0.11)**	**-0.03** **(0.24)**	**-0.11** **(0.18)**	**-0.43***** **(0.11)**
Unemployment (25-54), 3-year moving average	-0.51*** (0.14)	-0.49* (0.26)	-0.47*** (0.16)	-0.20 (0.16)
Lag unemployment, 3-year moving average	0.27** (0.13)	0.04 (0.25)	0.28** (0.12)	0.10 (0.18)
Constant	0.01*** (0.00)	0.02*** (0.00)	0.01* (0.01)	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 Appendix Tables **X and X**.

Falling relative price of investment goods and the labor share: results

As discussed above, one of the dominant technological theories of the decline in the labor share relates to the falling relative price of investment goods (Karabarbounis and Neiman 2014). If the falling relative price of investment goods is driving the decline in the labor share as firms substitute capital for labor, one should expect to see periods of faster decline in the relative price of investment goods coinciding with periods of faster decline in the labor share. As shown in Table 9, there is no significant relationship between the change in log labor share and the change in log relative price of investment goods over the whole postwar period or since 1973. Since 2000 there is a significant relationship but the coefficient estimate is negative, implying that a fall in the relative price of investment goods has actually been associated with a rise in the labor share[30].

[30] There is also no significant relationship between changes in log of the labor share and changes in log of the relative price of investment goods when using the BLS measures of the labor share.

Table 9: Relative price of investment goods and labor share regressions

Dependent variable: 3-year moving average of Δ log labor share	(9a) 1950-2013	(9b) 1950-1973	(9c) 1975-2013	(9d) 2000-2013
Δ log relative price investment goods, 3-year moving average	**-0.07**	**0.12**	**-0.21**	**-0.55****
	(0.09)	**(0.11)**	**(0.13)**	**(0.18)**
Unemployment (25-54), 3-year moving average	-0.46***	-0.48	-0.45***	-0.55**
	(0.12)	(0.33)	(0.12)	(0.19)
Lag unemployment, 3-year moving average	0.24*	0.07	0.28**	0.52**
	(0.13)	(0.33)	(0.13)	(0.17)
Constant	0.01**	0.02***	0.00	-0.02***
	(0.00)	(0.01)	(0.01)	(0.00)
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.

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 10 shows, there is no significant relationship between productivity growth and changes in the mean/median ratio. This casts doubt on pure technology-based theories of the rising mean/median compensation ratio.

Table 10: 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**	**0.00**
	(0.10)	**(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***	0.01
	(0.00)	(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 compensation per hour for the average worker rose by 48% between 1973 and 2016, or at an annual rate of only 0.9% per year. Real median compensation per hour rose only 12% in total between 1973 and 2016 (and real average 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 compensation per hour for the average worker rose by 106% or at a 2.9% annual rate. Real average compensation per hour for production and nonsupervisory workers – whose pay is likely to have been similar to that of the median worker over the period (Bivens and Mishel 2015) – rose at a 2.6% annual rate. Hourly labor productivity rose at a 2.7% annual rate.

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.

In the introduction, we introduced a spectrum of possible interpretations of these divergences between productivity and typical and average pay: at one end of the spectrum, the “strong delinkage” view where factors are impeding the productivity-pay transmission mechanism such that productivity growth no longer systematically translates 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 pay growth but a variety of other factors have been putting downward pressure on workers' compensation.

Our regressions of compensation growth on productivity growth are supportive of substantial linkage between productivity and compensation for both typical and average compensation. Almost all specifications strongly reject the “strong delinkage” hypothesis, and the “strong linkage” hypothesis of a one-for-one relationship between productivity growth and compensation growth cannot be rejected for either median or average compensation (while it is rejected for production/nonsupervisory compensation).

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 the median worker and for average compensation over 1973-2016, and of 0.4 to 0.7 percentage points for the average production/nonsupervisory worker. Evidence on different deciles of the wage distribution also shows large and significant positive co-movement between productivity and wages at middle percentiles of the distribution.

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 orthogonal factors are likely to be responsible for creating the wedge between productivity and pay in the US economy, suppressing typical workers’ incomes even as productivity growth acts to increase them.

The increasing wedge between productivity and median compensation has two key components: rapidly rising labor income inequality has caused mean and median compensation to diverge, and a falling labor share has caused productivity and mean compensation to diverge.

Many different explanations have been proposed to explain these two divergences. Several explanations focus on the role of technological change – both to explain the divergence in mean and median compensation, and to explain the falling labor share. These pure technology-based theories would imply that in periods where productivity growth is faster, productivity and median pay should diverge more rapidly. We test this 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. Taken together the results tend not provide strong support for purely technology-based theories of the labor share decline. We find no significant relationship between the mean-median ratio and productivity growth over the last four decades, and very small coefficient estimates, providing little support for purely technology-based theories of the rising mean/median compensation ratio.

It is interesting to compare the relative magnitude of changes in compensation inequality, the labor share and productivity growth using some simple counterfactuals. If the ratio of the mean to median worker's hourly compensation in 2016 had been the same as it was in 1973, and mean compensation remained at its 2016 level, the median worker's pay would have been around 33% higher. 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), the average and median worker would both have had 4-8% more hourly compensation all else constant[31]. Assuming the relationship between

[31] The estimate depends on which measure of the labor share decline is used.

compensation and productivity estimated in Table 1 holds, if productivity growth had been as fast over 1973-2016 as it was over 1949-1973, (i.e. if net total economy productivity had grown at an average of 2.7% per year, rather than 1.3% per year), median and mean compensation would have been around 41% higher in 2015, holding other factors 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.

Overall, our central conclusion is as follows: 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. This suggests that 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.

Our results suggest that productivity growth still matters substantially for middle income Americans. Nonetheless the evidence of the past four decades, with stagnating compensation for the median worker and production/nonsupervisory workers, demonstrates that in the face of rising inequality productivity growth alone is not necessarily 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.

Aeppel, Timothy (2015). "Silicon Valley Doesn't Believe U.S. Productivity Is Down." Wall Street Journal, July 17, sec. US. http://www.wsj.com/articles/silicon-valley-doesnt-believe-u-s-productivity-is-down-1437100700

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.

Baker, Dean (2007). "The Productivity to Paycheck Gap: What the Data Show," mimeo Center for Economic and Policy Research

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.

Bernanke, Ben S., and Refet S. Gürkaynak (2001). "Is growth exogenous? taking Mankiw, Romer, and Weil seriously." *NBER macroeconomics annual* 16 : 11-57.

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.

Brynjolfsson, Erik (2014). “The Great Decoupling", Interview in McKinsey Quarterly September 2014.

Bunker, Nick (2015). “The pace of productivity growth and misallocation in the United States". Equitablog at the Washington Center for Equitable Growth, September 10 2015.

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.

DiCecio (2009). "Sticky wages and sectoral labor comovement," Journal of Economic Dynamics and Control, 33(3): 538-53

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.

Hatzius, Jan (2015). "Productivity Paradox 2.0". Goldman Sachs Global Macro Research, Top of Mind, Issue 39, October 5 2015.

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 (2003). "Growth, Capital Shares, and a New Perspective on Production Functions."

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 Kar-Fai Gee (2012). "Why aren't workers benefiting from labour productivity growth in the United States?." *International Productivity Monitor* 23: 31.

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. "Recent trends in compensation inequality." *Labor in the new economy*. University of Chicago Press, 2010. 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

Piketty, Thomas, Emmanuel Saez, and Stefanie Stantcheva (2014). "Optimal taxation of top labor incomes: A tale of three elasticities." *American economic journal: economic policy* 6.1 : 230-271

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.

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

Stock, James H., and Mark W. Watson (2007). *Introduction to Econometrics*. Addison Wesley.

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.

Appendix: Data Sources

Labor productivity (USA)

Net labor productivity per hour, total economy: BEA Net Domestic Product, deflated by BEA Net Domestic Product Price Index, divided by BLS Total Hours, Total Economy.

Compensation and wages (USA)

Average compensation per hour, total economy: BLS Average Hourly Compensation, Total Economy, deflated by the CPI-U-RS since 1978 and the CPI-U before 1978.

Median compensation per hour, total economy: Data obtained from EPI who calculated it as follows: Nominal median hourly wages, estimated using microdata from the CPS-ORG, multiplied by ratio of real compensation to wages. Real compensation/wage ratio was calculated by obtaining nominal compensation/wage ratio from BEA NIPA data and deflating the insurance component by the PCE medical care index and the rest of the series by the PCE. Further details in Bivens and Mishel (2015).

Average compensation per hour, production and non-supervisory workers: Data obtained from EPI who calculated it as follows: Average hourly earnings for production/nonsupervisory workers from BLS CES since 1964, estimated pre-1964 using average hourly earnings for production workers, multiplied by real compensation/wage ratio. Further details in Bivens and Mishel (2015).

Wages by decile of the wage distribution: Data obtained from EPI State of Working America Data Library, which calculates nominal hourly wages by percentile from the CPS-ORG survey and deflates by the CPI-U-RS.

Other data (USA)

Unemployment rate: Unemployment rate ages 25-54, Bureau of Labor Statistics.

Labor share: our baseline measure is the share of labour compensation in GDP from the Penn World Tables, obtained from the FRED database. We also use the Bureau of Labor Statistics measures of the labor share for the total economy and for the nonfarm business sector.

Relative price of investment goods: we use Di Cecio's measure from DiCecio (2009). "Sticky wages and sectoral labor comovement," Journal of Economic Dynamics and Control, 33(3): 538-53, available from the FRED database. This is calculated as the investment deflator divided by the consumption deflator. We cross-check against Karabarbounis and Neiman's (2014) measure: the two are very similar.

Labor productivity (Other G7 countries)

Gross labor productivity per hour – Canada, France, Italy, Japan, United Kingdom: OECD GDP per hour worked.

Gross labor productivity per hour – Germany: labor productivity per hour, German Federal Statistical Office. Available in the DeStatis publication "Volkswirtschaftliche Gesamtrechnungen: Inlandsproduktberechnung Lange Reihen ab 1970".

<u>Compensation (Other G7 countries)</u>

Compensation per hour – Canada, France, Italy, Japan, United Kingdom: OECD average compensation per hour worked.

Compensation per hour – Germany: average labor compensation per hour, German Federal Statistical Office. Available in the DeStatis publication "Volkswirtschaftliche Gesamtrechnungen: Inlandsproduktberechnung Lange Reihen ab 1970".

<u>Other data (Other G7 countries)</u>

Unemployment – Canada, Italy, Japan, United Kingdom: OECD harmonized unemployment rate, all persons.

Unemployment – France: OECD unemployment rate, ages 15-74.

Unemployment – Germany: unemployment rate as proportion of labor force, German Federal Statistical Office. Available in the DeStatis publication "Volkswirtschaftliche Gesamtrechnungen: Inlandsproduktberechnung Lange Reihen ab 1970".

Appendix: Graphs

Figure A1: Benefits share of compensation by wage percentile, 2014

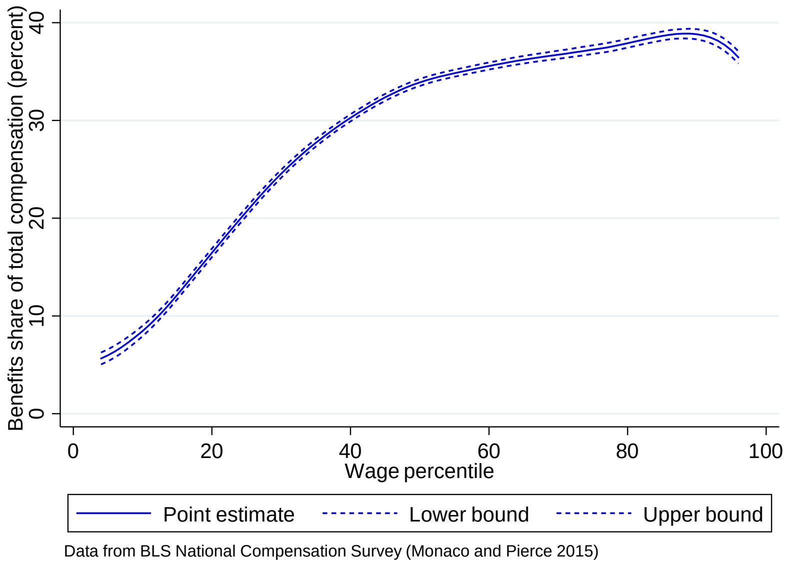
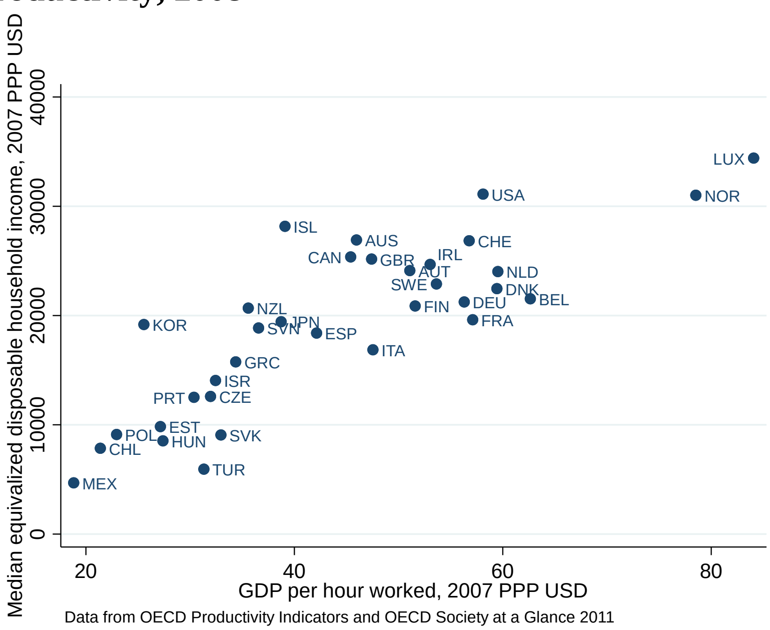


Figure A2: Median equivalized household disposable income and labor productivity, 2008



Appendix: Regressions

This section shows robustness checks using alternate specifications for the baseline regressions.

- Tables A1-A4 show the baseline moving average regressions with different bandwidths: 1, 2, 4 and 5 years.

- Tables A5-A7 show the baseline moving average regressions with different controls: A4 removes the unemployment control, A5 adds a time trend and A6 adds decade dummies.

- Tables A8-A10 show the productivity-labor share moving average regressions with different bandwidths: 2, 4 and 5 years.

- Tables A11 and A12 show the pre- and post-2000 restricted and unrestricted regressions for the baseline productivity-compensation specification and for the productivity-labor share specification.

Table A1: Baseline regression: contemporaneous

Dependent variable is Δ log compensation	Total economy Average comp 1949-2016	Total economy Average comp 1949-1973	Total economy Average comp 1975-2016	Total economy Average comp 2000-2016	Total economy Median comp 1975-20156	Total economy Production/ nonsupervisory comp 1949-2016	Total economy Production/ nonsupervisory comp 1949-1973	Total economy Production/ nonsupervisory comp 1975-2016
Δ log productivity	**0.63*** **	**0.39**	**0.56*** **	**0.48*** **	**0.33** **	**0.61*** **	**0.24**	**0.41*** **
	(0.09)	**(0.23)**	**(0.16)**	**(0.14)**	**(0.16)**	**(0.08)**	**(0.16)**	**(0.12)**
Unemployment (25-54)	-0.03	-0.05	0.02	-0.11	0.22	-0.06	-0.29	0.19
	(0.12)	(0.18)	(0.16)	(0.19)	(0.18)	(0.26)	(0.27)	(0.32)
Lag unemployment	-0.36***	-0.32	-0.27*	-0.18	-0.52***	-0.30	0.17	-0.31
	(0.13)	(0.32)	(0.13)	(0.14)	(0.17)	(0.22)	(0.35)	(0.30)
Constant	0.02***	0.03***	0.02***	0.02**	0.01	0.02**	0.02*	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	67	24	42	17	42	67	24	42
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	15.4***	6.93**	7.90***	14.0***	18.0***	22.1***	23.2***	24.1***
Prob>F	0.00	0.02	0.00	0.00	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: year listed is second year in moving average.

Table A2: Moving average regression, two-year bandwidth

Dependent variables are the 2-year moving average of the Δ log compensation	Total economy Average comp 1949-2016	Total economy Average comp 1949-1973	Total economy Average comp 1975-2016	Total economy Average comp 2000-2016	Total economy Median comp 1975-20156	Total economy Production/ nonsupervisory comp 1949-2016	Total economy Production/ nonsupervisory comp 1949-1973	Total economy Production/ nonsupervisory comp 1975-2016
Δ log productivity, 2-year moving average	**0.73*** **	**0.30**	**0.70*** **	**0.45** **	**0.72*** **	**0.82*** **	**0.43* **	**0.55*** **
	(0.11)	**(0.19)**	**(0.15)**	**(0.16)**	**(0.17)**	**(0.12)**	**(0.24)**	**(0.18)**
Unemployment (25-54), 2-year moving average	-0.15	0.01	-0.16	-0.24	0.01	0.02	0.17	0.08
	(0.13)	(0.23)	(0.16)	(0.14)	(0.20)	(0.25)	(0.46)	(0.33)
Lag unemployment, 2-year moving average	-0.23	-0.31	-0.07	-0.07	-0.28	-0.35	-0.35	-0.19
	(0.15)	(0.31)	(0.14)	(0.08)	(0.17)	(0.25)	(0.49)	(0.32)
Constant	0.02***	0.03***	0.01**	0.02**	0.01	0.01*	0.02*	0.00
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	67	24	42	17	42	67	24	42
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	6.39**	13.2***	3.90*	12.5***	2.85*	2.38	5.88**	6.47**
Prob>F	0.01	0.00	0.06	0.00	0.10	0.13	0.02	0.02

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

Table A3: Moving average regression, four-year bandwidth

Dependent variables are the 4-year moving average of the Δ log compensation	Total economy Average comp 1951-2015	Total economy Average comp 1951-1973	Total economy Average comp 1976-2015	Total economy Average comp 2001-2015	Total economy Median comp 1976-2015	Total economy Production/ nonsupervisory comp 1951-2015	Total economy Production/ nonsupervisory comp 1951-1973	Total economy Production/ nonsupervisory comp 1976-2015
Δ log productivity, 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)**
Unemployment (25-54), 4-year moving average	-0.25 (0.16)	0.55** (0.21)	-0.30** (0.12)	-0.24* (0.12)	-0.20 (0.16)	0.15 (0.25)	1.21*** (0.40)	0.12 (0.30)
Lag unemployment, 4-year moving average	-0.09 (0.20)	-0.93*** (0.25)	0.10 (0.11)	-0.01 (0.07)	-0.04 (0.14)	-0.48* (0.28)	-1.60*** (0.42)	-0.26 (0.27)
Constant	0.02*** (0.00)	0.02*** (0.00)	0.01*** (0.00)	0.02** (0.01)	0.01 (0.01)	0.01* (0.01)	0.01 (0.01)	0.00 (0.00)
Observations	65	23	40	15	40	65	23	40
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	3.23*	2.45	4.95**	17.3***	2.79	1.03	0.07	8.18***
Prob>F	0.08	0.13	0.03	0.00	0.10	0.31	0.80	0.01

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

Table A4: Moving average regression, five-year bandwidth

Dependent variables are the 5-year moving average of the Δ log compensation	Total economy Average comp 1951-2014	Total economy Average comp 1951-1973	Total economy Average comp 1976-2014	Total economy Average comp 2001-2014	Total economy Median comp 1976-2014	Total economy Production/ nonsupervisory comp 1951-2014	Total economy Production/ nonsupervisory comp 1951-1973	Total economy Production/ nonsupervisory comp 1976-2014
Δ log productivity, 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)**
Unemployment (25-54), 5-year moving average	-0.30 (0.18)	0.18 (0.30)	-0.38*** (0.09)	-0.33*** (0.10)	-0.22 (0.14)	0.21 (0.22)	0.73** (0.33)	0.16 (0.28)
Lag unemployment, 5-year moving average	-0.03 (0.23)	-0.60** (0.25)	0.21** (0.10)	0.11* (0.05)	-0.02 (0.14)	-0.55* (0.29)	-1.19*** (0.31)	-0.32 (0.24)
Constant	0.02*** (0.00)	0.02*** (0.01)	0.01** (0.00)	0.01** (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)
Observations	64	23	39	14	39	64	23	39
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	1.84	0.76	4.22**	10.8***	4.63**	0.54	0.00	18.9***
Prob>F	0.18	0.39	0.05	0.00	0.04	0.47	0.97	0.00

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

Table A5: Moving average regression, no unemployment control

Dependent variables are the 3-year moving average of the Δ log compensation	Total economy Average comp 1950-2015	Total economy Average comp 1950-1973	Total economy Average comp 1975-2015	Total economy Average comp 2000-2015	Total economy Median comp 1975-2014	Total economy Production/ nonsupervisory comp 1950-2015	Total economy Production/ nonsupervisory comp 1950-1973	Total economy Production/ nonsupervisory comp 1975-2015
Δ log productivity, 3-year moving average	**0.96*****	**0.29**	**0.79*****	**0.55*****	**0.80*****	**1.00*****	**0.35***	**0.58*****
	(0.08)	**(0.20)**	**(0.17)**	**(0.14)**	**(0.20)**	**(0.11)**	**(0.18)**	**(0.17)**
Constant	-0.00	0.02***	-0.00	0.00	-0.01***	-0.01***	0.02**	-0.00*
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Observations	66	24	41	16	41	66	24	41
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	0.22	12.3***	1.51	10.8***	0.95	0.00	12.9***	6.03**
Prob>F	0.64	0.00	0.23	0.00	0.34	0.98	0.00	0.02

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

Table A6: Moving average regression, with time trend

Dependent variables are the 3-year moving average of the Δ log compensation	Total economy Average comp 1950-2015	Total economy Average comp 1950-1973	Total economy Average comp 1975-2015	Total economy Average comp 2000-2015	Total economy Median comp 1975-2014	Total economy Production/ nonsupervisory comp 1950-2015	Total economy Production/ nonsupervisory comp 1950-1973	Total economy Production/ nonsupervisory comp 1975-2015
Δ log productivity, 3-year moving average	**0.68*****	**0.26**	**0.73*****	**0.79*****	**0.73*****	**0.73*****	**0.38**	**0.51*****
	(0.16)	**(0.28)**	**(0.14)**	**(0.21)**	**(0.17)**	**(0.17)**	**(0.32)**	**(0.15)**
Unemployment (25-54) 3-year moving average	-0.19	0.14	-0.24*	-0.27***	-0.15	0.07	0.47	0.13
	(0.15)	(0.23)	(0.14)	(0.08)	(0.18)	(0.29)	(0.47)	(0.25)
Lag unemployment, 3-year moving average	-0.12	-0.48	0.01	-0.19***	-0.10	-0.34	-0.74	-0.26
	(0.16)	(0.31)	(0.11)	(0.05)	(0.15)	(0.28)	(0.44)	(0.24)
Time trend	-0.11	-0.56***	0.05	1.17*	-0.02	-0.12	-0.55*	0.26*
	(0.09)	(0.12)	(0.09)	(0.60)	(0.10)	(0.12)	(0.27)	(0.13)
Constant	0.02***	0.04***	0.01*	-0.05	0.01	0.01*	0.03**	-0.01
	(0.01)	(0.01)	(0.00)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	66	24	41	16	41	66	24	41
F-test: is coefficient on productivity significantly different from 1?								
Test statistic	4.29**	7.31**	3.69*	1.00	2.44	2.60	3.84*	11.2***
Prob>F	0.04	0.01	0.06	0.34	0.13	0.11	0.06	0.00

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

Table A7: Moving average regression, with decade dummies

Dependent variables are the 3-year moving average of the Δ log compensation	Total economy Average comp	Total economy Average comp	Total economy Average comp	Total economy Average comp	Total economy Median comp	Total economy Production/nonsupervisory comp	Total economy Production/nonsupervisory comp	Total economy Production/nonsupervisory comp
	1950-2015	1950-1973	1975-2015	2000-2015	1975-2014	1950-2015	1950-1973	1975-2015
Δ log productivity, 3-year moving average	**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)**
Δ unemployment (25-54) 3-year moving average	-0.18 (0.13)	0.32 (0.29)	-0.31** (0.13)	-0.32*** (0.09)	-0.24 (0.16)	0.09 (0.19)	0.40 (0.40)	0.07 (0.22)
	-0.29** (0.14)	-0.69* (0.40)	-0.16 (0.12)	-0.27*** (0.07)	-0.38** (0.17)	-0.36* (0.22)	-0.52 (0.45)	-0.33 (0.27)
1950s dummy	0.00 (0.01)	0.01*** (0.00)				0.00 (0.01)	0.01** (0.00)	
1960s dummy	-0.00 (0.01)	0.01*** (0.00)				-0.00 (0.01)	-0.00 (0.00)	
1970s dummy	-0.01** (0.00)		-0.01** (0.00)		-0.01 (0.00)	-0.00 (0.00)		-0.00 (0.00)
1980s dummy	-0.00 (0.00)		-0.00 (0.00)		-0.00 (0.00)	-0.01*** (0.00)		-0.01*** (0.00)
1990s dummy	-0.01** (0.00)		-0.01* (0.00)		-0.01*** (0.00)	-0.01*** (0.00)		-0.01*** (0.00)
2000s dummy	-0.01** (0.00)		-0.01* (0.01)	-0.01** (0.00)	-0.02*** (0.01)	-0.01** (0.00)		-0.01* (0.01)
Constant	0.03*** (0.01)	0.03*** (0.00)	0.03*** (0.01)	0.04*** (0.01)	0.03** (0.01)	0.02*** (0.01)	0.02*** (0.00)	0.02 (0.01)
Observations	66	24	41	16	41	66	24	41
Test statistic	3.37*	6.22**	0.28	30.8***	0.00	6.87**	4.91**	10.8***
Prob>F	0.07	0.02	0.60	0.00	0.98	0.01	0.04	0.00

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

Table A8: Productivity and the labor share, 2-year moving average regression

Dependent variable: 2-year moving average of Δ log labor share	1950-2014	1950-2014	1975-2014	2000-2014
Δ log productivity, 2-year moving average	**-0.17***	**-0.31**	**-0.14**	**-0.43*****
	(0.09)	**(0.25)**	**(0.17)**	**(0.11)**
Unemployment (25-54), 2-year moving average	-0.54***	-0.79***	-0.46***	-0.31
	(0.14)	(0.26)	(0.16)	(0.19)
Lag unemployment, 2-year moving average	0.27**	0.38***	0.27*	0.16
	(0.12)	(0.12)	(0.13)	(0.13)
Constant	0.01***	0.02***	0.01*	0.01
	(0.00)	(0.00)	(0.01)	(0.01)
Observations	64	23	40	15

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

Table A9: Productivity and the labor share, 4-year moving average regression

Dependent variable: 4-year moving average of Δ log labor share	1951-2014	1951-1973	1976-2014	2000-2014
Δ log productivity, 4-year moving average	**-0.09**	**0.19**	**-0.12**	**-0.34*****
	(0.12)	**(0.25)**	**(0.14)**	**(0.09)**
Unemployment (25-54), 4-year moving average	-0.52***	-0.10	-0.51***	-0.11
	(0.14)	(0.30)	(0.15)	(0.16)
Lag unemployment, 4-year moving average	0.30**	-0.41	0.33***	0.08
	(0.12)	(0.33)	(0.10)	(0.19)
Constant	0.01**	0.01**	0.01*	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
Observations	63	23	38	13

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

Table A10: Productivity and the labor share, 5-year moving average regression

Dependent variable: 5-year moving average of Δ log labor share	1951-2013	1951-1973	1976-2013	2001-2013
Δ log productivity, 5-year moving average	**-0.11**	**0.08**	**-0.06**	**-0.07**
	(0.11)	**(0.16)**	**(0.12)**	**(0.15)**
Unemployment (25-54), 5-year moving average	-0.57***	-0.25	-0.59***	-0.03
	(0.15)	(0.22)	(0.14)	(0.16)
Lag unemployment, 5-year moving average	0.35**	-0.25	0.44***	0.10
	(0.13)	(0.19)	(0.09)	(0.17)
Constant	0.01**	0.02***	0.01	-0.01***
	(0.01)	(0.00)	(0.01)	(0.00)
Observations	62	23	37	12

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

Table A11: Average compensation and productivity regressions – pre and post 2000

	(2a)	(2b)	(2c)	(2d)
	Restricted		*Unrestricted*	
Dependent variables are the X-year moving average of the Δ log compensation	Average comp 1950-1999	Average comp 2000-2015	Average comp 1950-1999	Average comp 2000-2015
Δ log productivity, contemporaneous only	0.65***	0.47***	0.68***	0.48***
	(0.09)	(0.14)	(0.11)	(0.14)
Δ log productivity, 2-year moving average	0.75***	0.55***	0.82***	0.45**
	(0.11)	(0.16)	(0.13)	(0.16)
Δ log productivity, 3-year moving average	0.80***	0.56***	0.89***	0.40**
	(0.11)	(0.15)	(0.11)	(0.14)
Δ log productivity, 4-year moving average	0.86***	0.60***	0.95***	0.42**
	(0.11)	(0.14)	(0.10)	(0.15)
Δ log productivity, 5-year moving average	0.90***	0.65***	0.98***	0.46**
	(0.11)	(0.14)	(0.10)	(0.18)

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Pairs of cells shaded grey are statistically significantly different from each other at the 5% level.

Table A12: Labor share and productivity regressions – pre and post 2000

Dependent variables are the X-year moving average of the Δ log labor share	(2a)	(2b)	(2c)	(2d)
	Restricted		*Unrestricted*	
	Labor share 1950-1999	Labor share 2000-2013	Labor share 1950-1999	Labor share 2000-2013
Δ log productivity, contemporaneous only	-0.33** (0.12)	-0.47*** (0.14)	-0.31** (0.15)	-0.52*** (0.08)
Δ log productivity, 2-year moving average	-0.16 (0.10)	-0.28* (0.15)	-0.14 (0.11)	-0.43*** (0.11)
Δ log productivity, 3-year moving average	-0.08 (0.12)	-0.25 (0.15)	-0.08 (0.12)	-0.43*** (0.11)
Δ log productivity, 4-year moving average	-0.06 (0.13)	-0.26* (0.15)	-0.10 (0.12)	-0.34** (0.11)
Δ log productivity, 5-year moving average	-0.08 (0.12)	-0.28* (0.14)	-0.15 (0.10)	-0.07 (0.16)

Newey-West standard errors (HAC) in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Pairs of cells shaded grey are statistically significantly different from each other at the 5% level.