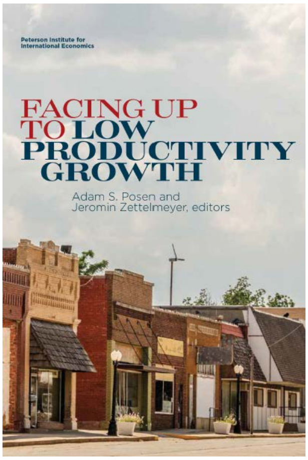
Productivity and Pay: Is the Link Broken?



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After growing in tandem for nearly 30 years after World War II, average labor productivity and the compensation of the typical American worker diverged beginning in 1973. Between 1973 and 2016, median compensation grew by only 11 percent in real terms, and compensation of production/nonsupervisory workers rose by only 12 percent; over the same period, labor productivity rose by 75 percent. Since 2000 average compensation has also diverged from labor productivity (figure 8.1).

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 8.1.

At 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 ("strong delinkage"). On the other hand, just as two time series growing in tandem does not mean that one causes the other,

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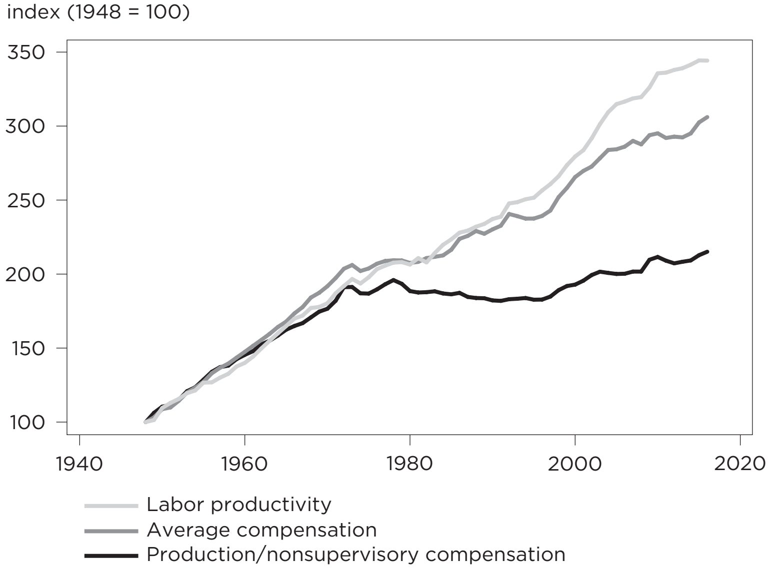
Figure 8.1 Labor productivity, average compensation, and compensation of production/nonsupervisory workers, 1948–2016



Note: Labor productivity = total real output per hour. Average compensation = total real compensation per hour, calculated using the consumer price index research series using current methods (CPI-U-RS) deflator. Production/nonsupervisory compensation = real hourly compensation of production and nonsupervisory workers, calculated using the CPI-U-RS deflator.

Source: Authors' calculations using data from Bureau of Labor Statistics, Bureau of Economic Analysis, and Economic Policy Institute.

two series diverging may not mean that the causal link between the two has broken down. Productivity growth may have been acting to raise pay while at the same time other orthogonal factors acted to reduce it, creating a divergence between productivity and pay despite the two series being causally linked ("strong linkage"). Between these two ends of the spectrum lies a range of possibilities in which some degree of linkage between productivity and typical compensation exists.

Several observers have questioned the degree of linkage between productivity and compensation in the United States. Harold Meyerson 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 divergence between productivity and compensation has also led to questions about 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, 2) note that "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-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.

This chapter estimates the extent of linkage or delinkage by investigating the comovement of productivity growth and typical compensation growth, using the natural quasi-experiment provided by the fact that productivity growth fluctuates over 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.[1] Between these views is a transmission of productivity growth to compensation growth that is positive but less than one.

Most of the debate on the productivity-pay divergence has focused on the divergence between *typical* workers' pay (median or production/nonsupervisory workers) and productivity. It is also possible to examine the gap between *average* compensation and labor productivity. This gap has grown since about 2000, as labor's share of income started to fall. The chapter investigates the evidence on the linkage/delinkage question for both typical and average compensation.

Periods of faster productivity growth over the last seven decades have in general coincided with faster real compensation growth for the typical American worker.[2] The regression results show that since 1973, a 1 percentage point increase in productivity growth has been associated with 0.65 to 1 percentage point higher real compensation growth for the median worker, with almost none of the coefficient estimates significantly different from 1 and all significantly different from 0. For average production/nonsuper-

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

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

visory compensation, a 1 percentage point increase in productivity growth has been associated with 0.4 to 0.6 percentage point higher real compensation growth.

For average compensation, since both 1948 and 1973 a 1 percentage point increase in productivity growth has been associated with 0.7 to 1 percentage point higher real compensation growth, with the coefficients in most specifications significantly different from 0. The coefficient estimates are slightly lower since 2000 (0.4 to 0.8, depending on the specification).

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 diverged in levels. For production/nonsupervisory compensation, the evidence suggests that there is substantial linkage between productivity growth and compensation growth but that this linkage is likely less than one for one. As median and production/nonsupervisory compensation grew by the same amount over the period, 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; whether the degree of linkage has fallen somewhat since 2000 is not clear.

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

What are these factors that are causing productivity and typical pay to diverge? A large body of research has sought to understand 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, unions, and market power. Technology-focused theories have a testable implication: If technological change is the primary driver of the divergence and more rapid technological change causes faster productivity growth, periods of faster productivity growth should coincide with more rapid divergence between productivity and pay.

The analysis in this chapter examines the comovement of labor productivity with the labor share and with the mean-median compensation ratio, finding little support for a pure technology-based cause of the productivity-pay divergence. It finds little evidence of a significant relationship between productivity growth and changes in the labor share for any period except since 2000, and no evidence of a relationship between productivity growth and changes in the mean-median ratio.

The chapter is organized as follows. The next section reviews the literature on the relationship between compensation and productivity. Section three describes the model and the data and presents the baseline results. It also discusses robustness (testing alternate specifications and considering the effect of productivity mismeasurement) and presents regressions for different deciles of the wage distribution in the United States and other G-7 countries. Section four examines the comovement of productivity growth with the pay-productivity divergence and its implications for technology-based theories of the divergence. The last section summarizes the chapter's main findings.

Literature on the Relationship between Compensation and Productivity

The divergence between median compensation and productivity can be decomposed into various components (figure 8.2). Doing so reveals the following trends:[3]

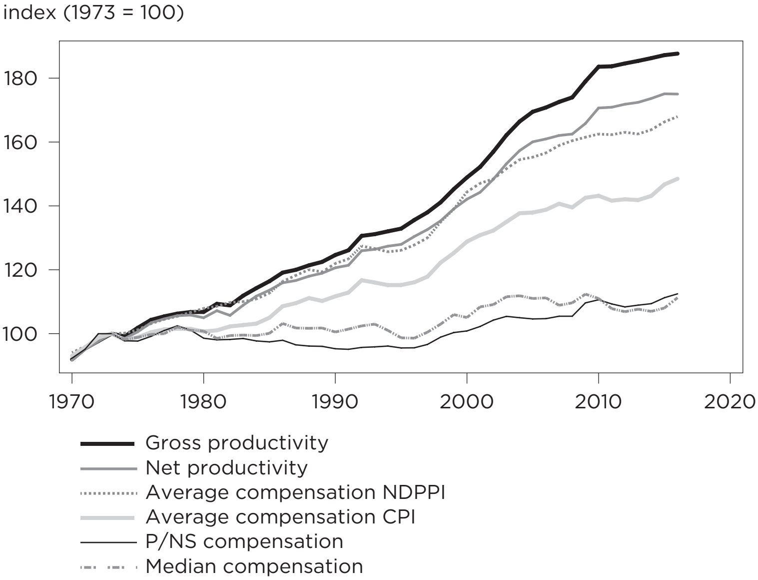
- Gross labor productivity grew more rapidly than net labor productivity, because of rising depreciation.[4]
- Net labor productivity grew more rapidly than average compensation deflated by a producer price index (PPI), as the labor share fell.
- Average compensation deflated by a PPI grew more rapidly than average compensation deflated by a consumer price index (CPI), as the consumer and producer price indexes diverged.[5]
- Average compensation grew more rapidly than median compensation, as income inequality in the top half of the distribution rose.
- Median compensation grew more rapidly than median wages, as nonwage benefits increased their share of total compensation (not shown in figure 8.2).

3. Bivens and Mishel (2015) and Lawrence (2016) present similar figures. Baker (2007); Fleck, Glaser, and Sprague (2011); and Pessoa and Van Reenen (2013) demonstrate similar divergences.

4. Baker (2007), Sherk (2013), Bivens and Mishel (2015), and Lawrence (2016) discuss the importance of this trend in the productivity-compensation divergence.

5. See Lawrence and Slaughter (1993), Bosworth and Perry (1994), Feldstein (2008), Sherk (2013), and Lawrence (2016). According to the Bureau of Labor Statistics (BLS), this divergence exists partly because the consumer price index 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). Extensive work has been done on the divergence between different deflators; see Triplett (1981); Fixler and Jaditz (2002); McCully, Moyer, and Stewart (2007); and Bosworth (2010).

Figure 8.2 Decomposition of divergence between productivity and compensation in the United States, 1970–2016



Note: Average compensation NDPPI = average compensation deflated by the net domestic product (NDP) price index. Average compensation CPI = average compensation deflated by the consumer price index research series using current methods (CPI-U-RS) deflator. P/NS compensation = average production/nonsupervisory worker compensation. Median and P/NS compensation are deflated by the CPI-U-RS. All compensation measures refer to compensation inclusive of nonwage benefits.

Source: Authors' calculations using data from Bureau of Labor Statistics, Bureau of Economic Analysis, and Economic Policy Institute.

Many researchers have investigated different aspects of the productivity-pay divergence. Bivens and Mishel (2015) document the divergence between productivity and the typical worker's compensation, comparing net labor productivity in the total economy with two measures of typical worker compensation: median compensation and average production/nonsupervisory compensation, deflated by consumer price deflators. They argue that production/nonsupervisory compensation is both a good measure of typical compensation (representing about 80 percent of the private sector workforce) and a good proxy for trends in median compensation before 1973 (a period for which median compensation data are not available). They use a consumer price deflator to reflect consumers' experienced change in living standards. Dew-Becker and Gordon (2005), Baker (2007), and Pessoa and Van Reenen (2013) carry out similar analyses, using median household income, production/nonsupervisory compensation, and median compensation, respectively.

Another line of inquiry is the divergence between productivity and average compensation, which is conceptually equivalent to the decline in the labor share.[6] Feldstein (2008) compares labor productivity and average compensation in the nonfarm business sector, as deflated by a producer price deflator, over 1948–2006. He uses a producer price deflator to reflect the real cost to firms of employing workers. Lawrence and Slaughter (1993) and Bosworth and Perry (1994) carried out similar analyses in the 1990s.

Lawrence (2016) compares average compensation to net productivity, a more accurate reflection of the increase in income available for distribution to factors of production. Because depreciation accelerated in recent decades, using gross productivity reveals 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 (labor's share of income started to fall). Many other studies also find a decline in the U.S. labor share of income since about 2000, though the timing and magnitude are disputed (see, for example, Elsby, Hobijn, and Şahin 2013; Pessoa and Van Reenen 2013; Karabarbounis and Neiman 2014; Lawrence 2015; Rognlie 2015; and Grossman et al. 2017).

Model and Results

The analysis in this chapter examines the divergence of productivity from both typical and average compensation. It tries to establish the extent to which labor productivity growth feeds through into worker compensation.

The measure of productivity used is net output per hour for the total economy, in order to capture trends affecting all workers. Net (rather than gross) output is used to reflect only the extra output that is available for distribution to factors of production.[7]

Typical compensation is measured using median compensation. Results are also reported for average production/nonsupervisory compensation, both as an interesting measure in itself and because it enables analy-

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

7. Productivity is difficult to measure accurately for the entire economy, because it includes government and nonprofit institutions, whose output is difficult to measure (as it is not usually traded on markets). Productivity of the nonfarm business sector is likely to be easier to measure than productivity of the economy as a whole, but it captures only 75 percent of GDP and only a gross measure of productivity is available. Repeating the baseline regressions with nonfarm business sector productivity yielded little change in the results (results available on request).

sis of the pre-1973 period, for which median data are not available (as in Bivens and Mishel 2015).

Median compensation is the measure that is most clearly interpretable as revealing trends for middle-income workers. It captures trends for the middle of the income distribution, in contrast to average production and nonsupervisory compensation, which captures compensation for roughly 80 percent of the private sector workforce. Median compensation is consistently lower than average production/nonsupervisory compensation (in 2015, for example, median hourly compensation was $22.04 and average production/nonsupervisory compensation $26.61). As the average production/nonsupervisory compensation figure is a mean, it can be skewed by large changes at the top or bottom of its distribution. In addition, there is some evidence that the average production/nonsupervisory compensation measure does not cover all of the workers it is intended to cover and that this group may be growing (Barkume 2007).[8]

Although the two series cover different workers, they move in a similar fashion over most of 1973–2016, except during the 1980s, when real production/nonsupervisory compensation fell significantly more than median compensation. The divergence during the 1980s may have been driven partly by the substantial fall in incomes at 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 and the increase in middle-income white-collar jobs (the former covered in the production/nonsupervisory measure, the latter possibly missed).

For average compensation, we look at mean compensation in the total economy. We deflate all compensation series using consumer price deflators to reflect the changes in standards of living experienced by workers.[9]

Feldstein (2008) investigates the linkage between productivity and average compensation by regressing the change in log average compensation on the current and lagged change in log productivity, finding a close to one-for-one relationship. We use a similar approach to investigate the linkage between typical compensation and productivity and to update

8. Abraham, Spletzer, and Stewart (1998) and Champagne, Kurmann, and Stewart (2017) suggest that many service sector establishments surveyed for the Bureau of Labor Statistics' Current Employment Statistics (from which production/nonsupervisory wages are calculated) interpret the "production and nonsupervisory" category to include workers paid by the hour and/or nonexempt workers (under the Fair Labor Practices Act) but to exclude other types of salaried or exempt workers even if they are nonsupervisory.

9. We deflate using the CPI-U-RS. Repeating the baseline regressions with compensation deflated by the personal consumption expenditures (PCE) and net domestic product (NDP) price indexes had little effect on the results (results available on request).

Feldstein's estimates of the linkage between average compensation and productivity.

Empirical Estimation

At the simplest level, a linear model can relate productivity and typical or average compensation growth, as shown in equation (8.1).[10] Under the strongest "linkage" view, $\beta = 1$. Under the strongest "delinkage" view, $\beta = 0$. A value of β between 0 and 1 suggests a point on the linkage-delinkage spectrum. Many other factors affect compensation growth besides productivity. As long as they are orthogonal to productivity growth, however, they will not affect the estimation of β:

$$compensation\ growth_t = \alpha + \beta\ productivity\ growth_t \tag{8.1}$$

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

In our baseline specification (equation 8.2), we regress the three-year moving average of the change in log compensation on the three-year moving average of the change in log labor productivity and the current and lagged three-year moving average of the unemployment rate:[11]

$$\frac{1}{3}\sum_0^2 \Delta \log comp_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \tag{8.2}$$

The time horizon over which any productivity-compensation relationship would hold depends on both the wage-setting process and the degree to which productivity changes are correctly perceived and anticipated. If the average firm changes pay and benefits infrequently, or if it takes some time for firms and workers to discern the extent to which an increase in output reflects a rise in productivity rather than other factors, productivity increases will translate into compensation only with a lag. In contrast, if firms and workers correctly anticipate that there will be a productivity

10. We use the change in logged values of compensation and productivity, rather than their levels, as compensation and productivity are both nonstationary unit-root processes but their first differences appear to be stationary (as suggested by Dickey-Fuller tests).

11. To account for the autocorrelation introduced by the moving-average specification, we use Newey-West heteroskedasticity and autocorrelation robust standard errors, with a lag length of twice the length of the moving average.

increase in the near future, the rise in compensation may precede the actual rise in productivity.

To take this uncertainty into account, alongside our baseline three-year moving average regressions we present results for regressions without a moving average and with two-, four-, and five-year moving averages. We also repeat our regressions with a distributed-lag specification with up to four years of lagged productivity. The results are similar to the results in our moving-average regressions (results available on request).

We control for the level of unemployment for two reasons. First, it is likely to affect bargaining dynamics: For a given rate of productivity growth, a higher unemployment rate should enable employers to raise compensation by less, because more unemployed workers are searching for jobs.

Second, unemployment is likely to reflect broader cyclical economic fluctuations that may affect compensation in the short term. Higher unemployment may reflect a downturn, which could mean lower pay rises for a given rate of productivity growth. If unemployment is also related to changes in productivity growth—if, for example, the least productive workers are likely to be laid off first—then excluding unemployment would bias the results.

By controlling for the current and one-year lagged moving average of the unemployment rate, we allow for both the level and the change in unemployment to affect compensation growth. We use the unemployment rate of 25- to 54-year-olds, in order to avoid capturing the effects of demographic shifts, such as an aging population. Using the total unemployment rate instead had almost no effect on our results (available on request).

Data

We primarily use publicly available data from the Bureau of Labor Statistics (BLS), the Bureau of Economic Analysis (BEA), and the Economic Policy Institute's State of Working America Data Library, as well as the BLS total economy productivity dataset, which is available on request from BLS.[12]

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; it is deflated by the CPI-U-RS. The median and production/nonsupervisory compensation series are from the Economic Policy Institute's State of Working America Data Library. They

12. For a detailed list of data sources, see the working paper version of this chapter (Stansbury and Summers 2017).

are constructed from median wages from the Current Population Survey Outgoing Rotation Group (CPS-ORG) and average production/nonsupervisory wages from the BLS *Current Employment Statistics*, respectively, and deflated by the CPI-U-RS. They are then adjusted to include nonwage compensation using the average real compensation/wage ratio, which is calculated from BEA national income and product accounts data on the composition of workers' compensation. All components of compensation are deflated by personal consumption expenditures (PCE) except health and life insurance, which are deflated by the PCE healthcare index (details are available in Bivens and Mishel 2015).[13]

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

For our analysis of the other major advanced economies, for all countries except Germany we use OECD data on unemployment, labor productivity per hour, and average compensation per hour, deflated by the CPI for the country in question. For Germany before and after reunification, we use data on hourly labor productivity, hourly compensation, and unemployment from the German Federal Statistical Office (Statistiches Bundesamt Deutschland).

Baseline Results

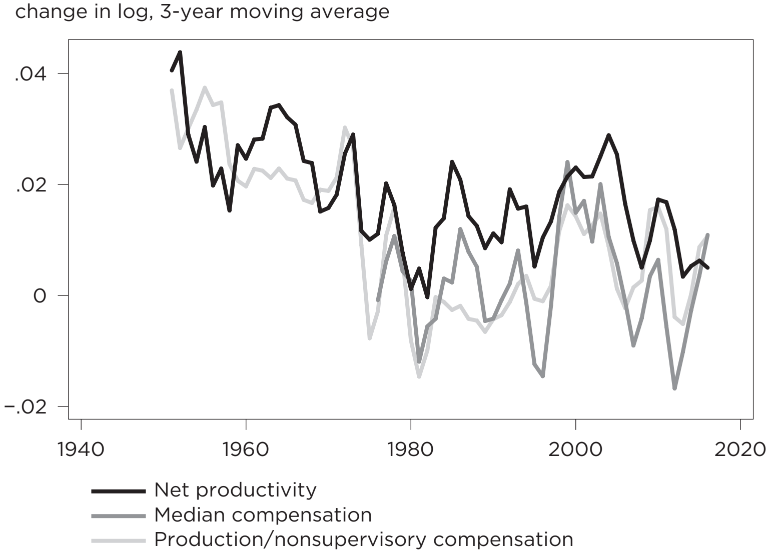
Figures 8.3 and 8.4 illustrate the relationship between compensation growth and productivity growth in the U.S. economy by plotting the three-year moving average of productivity growth and median, production/nonsupervisory, and average compensation growth (in change in log form). While median and production/nonsupervisory compensation consistently grew more slowly than productivity since the 1970s, the series move largely together. Average compensation and productivity move closely together, particularly since the 1970s.

Table 8.1 displays our baseline regression results.[14] For average and production/nonsupervisory compensation, we show coefficients for the entire

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

14. In all tables, the year is listed as the middle year of the moving average (a regression over 1950–2015 implies that the first observation is the three-year moving averages of the change in logged variable in 1949, 1950, and 1951 and the last observation is the three-year moving averages of the change in logged variable in 2014, 2015, and 2016).

Figure 8.3 Change in log labor productivity, median compensation, and average production/nonsupervisory compensation in the United States, 1951–2016



Note: Series are three-year backward-looking moving averages of change in logs.

Source: Authors' calculations using data from Bureau of Labor Statistics, Bureau of Economic Analysis, and Economic Policy Institute.

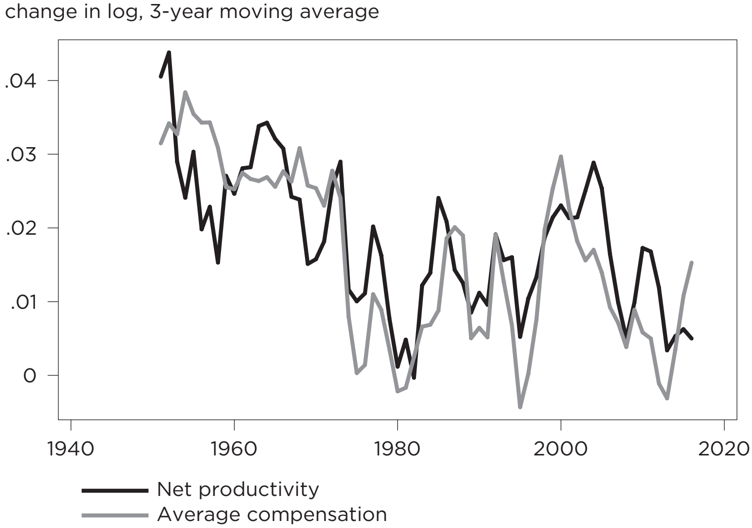
postwar period and on either side of 1973.[15] The year 1973 is often identified as the beginning of the modern productivity slowdown, as well as the year when median and production/nonsupervisory compensation began to diverge from productivity.[16] Breakpoint tests also identify a structural break at 1973 for both average and production/nonsupervisory compensation.[17] As our median compensation data go back only to 1973, showing results for average and production/nonsupervisory compensation since 1973 also

15. We break the regressions so that the last data point in the 1950–73 regressions is the three-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 three-year moving average for 1974, 1975, and 1976.

16. Bosworth and Perry (1994), Baker (2007), Bivens and Mishel (2015), and the Economic Report of the President (US Government Printing Office 2015) identify a break at 1973 when discussing trends in productivity and compensation.

17. For regressions of the change in log productivity with either average or production/nonsupervisory compensation, a Wald test is significant at the 0.1 percent level for a break at 1973.

Figure 8.4 Change in log labor productivity and average compensation in the United States, 1951–2016



Note: Series are three-year backward-looking moving averages of change in logs.

Source: Authors' calculations using data from Bureau of Labor Statistics, Bureau of Economic Analysis, and Economic Policy Institute.

makes it easier to compare the results. For average compensation, we also show a split from 2000 onward, the period over which average compensation and productivity began to diverge.

The results in table 8.1 suggest that over 1975–2015, the period during which productivity and median compensation diverged in levels, a 1 percentage point increase in productivity growth was associated with a 0.73 percentage point increase in the growth rate of median compensation. The coefficient is strongly significantly different from 0 and not significantly different from 1, suggesting substantial linkage between productivity and median compensation. The strong linkage hypothesis of a one-for-one relationship between productivity and compensation cannot be rejected.

Over 1975–2015, a 1 percentage point increase in productivity growth was associated with a 0.53 percentage point increase in the growth rate of average production/nonsupervisory compensation. The coefficient is significantly different from both 0 and 1. The result suggests substantial linkage between productivity and production/nonsupervisory compensation but does not support the strong linkage hypothesis of a one-for-one relationship.

Table 8.1 Baseline regression results on compensation and productivity

Dependent variable is 3-year moving average of the change in log compensation	Average compensation				Median compensation	Production/ nonsupervisory compensation		
	1950–2015	**1950–1973**	**1975–2015**	**2000–2015**	**1975–2015**	**1950–2015**	**1950–1973**	**1975–2015**
	(1a)	**(1b)**	**(1c)**	**(1d)**	**(1e)**	**(1f)**	**(1g)**	**(1h)**
Change in log productivity	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 among people 25–54	−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	−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)
Number of 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

Note: Newey-West standard errors (HAC) in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Notation: The year is listed as the middle year of the moving average. A regression over "1950–2015" implies the first observation is the three-year moving average of the change in logged variable in 1949, 1950, and 1951 and the last observation is the three-year moving average of the change in logged variable in 2014, 2015, and 2016.

F-test null hypothesis: Coefficient on productivity is *not* significantly different from one.

Source: Authors' calculations.

A 1 percentage point increase in productivity growth was associated with a 0.77 percentage point increase in the growth rate of average compensation in 1950–2015 and a 0.74 percentage point increase in 1975–2015. The estimates are strongly significantly different from 0 and not significantly different from 1. Over 2000–15 the coefficient estimate is smaller, at 0.40; it remains significantly different from 0 but is also significantly different from 1.

Testing for significant differences in coefficients between the pre- and post-2000 period yields mixed results. In an unrestricted regression allowing all coefficients to differ between the two periods, we find significantly different coefficients on productivity at the 5 percent level. But a regression that allows the productivity coefficients to differ but restricts unemployment coefficients and the constant to be the same across the whole 1950–2015 period gives a larger coefficient on productivity over 2000–15 (0.56 rather than 0.4), and the difference between the two periods is nonsignificant (see Stansbury and Summers 2017, table A11).

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 declined, there is some suggestion that the degree of linkage may have fallen (though strong delinkage is still rejected).

Alternate Specifications

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

- excluding the unemployment control,
- including a time trend,
- including dummy variables for each decade, and
- varying the moving average bandwidth.

Table 8.2 summarizes the results for the coefficient on the change in log productivity (the full regressions are shown in Stansbury and Summers 2017, tables A1–A7).[18] The results are generally robust across specifications and largely supportive of the hypothesis that for middle-class workers, increases in productivity growth led to substantial increases in real compensation growth.

18. We 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 net domestic product price index rather than the CPI-U-RS. The overall picture from these regressions is not substantially different from the results presented here (results available on request).

Table 8.2 Coefficients on productivity from various specifications of productivity-compensation regressions

		Average compensation				Median compensation	Production/ nonsupervisory compensation		
Regression specification		1949–2016	1949–73	1974–2016	1999–2016	1974–2016	1949–2016	1949–73	1974–2016
(2a)	Initial regression (tables 8.1 and 8.3)	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*** (0.2)	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)	Two-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)	Four-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)	Five-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)

Note: Newey-West (HAC) standard errors in parentheses. Cells that are significantly different from 1 at the 5 percent level are highlighted in grey. Underlying regressions are in table 8.1 and in Stansbury and Summers (2017, tables A1–A7). Except where otherwise indicated, regressions use three-year moving averages. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

The coefficient estimates for median compensation are in the range of 0.65 to 1 for all but the contemporaneous regression. They are significantly different from 0 at the 1 percent level and mostly not significantly different from 1, suggesting substantial linkage between productivity and median compensation. In almost all specifications, the strong linkage hypothesis cannot be rejected.

For production/nonsupervisory compensation since 1973, the coefficient estimates are in the range of 0.4 to 0.6, significantly different from 0 at the 1 percent level and also significantly different from 1, suggesting a high degree of linkage between productivity and production/nonsupervisory compensation. However, both the strong linkage and strong delinkage hypotheses are rejected. The fact that the coefficients are significantly lower than for median compensation bears further investigation. Average compensation growth for production/nonsupervisory workers does not appear to reflect productivity growth to the same extent as compensation growth for the median worker, although the levels of the two series are similar throughout the postwar period.[19]

For average compensation since 1973, the coefficient estimates are in the range of 0.70 to 0.91 for all but the contemporaneous regression. They are strongly significantly different from 0 and mostly not significantly different from 1. Over 1999–2016, the estimates are 0.40 to 0.79 and mostly strongly significantly different from both 0 and 1. These results suggest substantial linkage between productivity and average compensation, with some possibility of a reduction in the degree of linkage since about 2000.

Three additional features of these results are worth noting. First, estimating only the contemporaneous relationship between productivity growth and compensation reduces the magnitude of the estimated coefficient in almost all regressions. This specification may allow insufficient time for firms to pass productivity growth on to workers' compensation.

Second, the coefficient estimates on productivity before 1973 are not as high as one might expect for either average or production/nonsupervisory compensation, considering that the levels of productivity and both compensation measures moved largely together 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. The period 1956–65 was one of particularly low variation in both compensation and productivity growth, which may magnify the effect of noise. The coeffi-

19. The difference in coverage of the two series and the likely change in this difference over time (as discussed in Abraham, Spletzer, and Stewart 1998 and Champagne, Kurmann, and Stewart 2017) may go some way to explaining the difference in the coefficient estimates.

cient estimates rise significantly if that period is excluded when running the pre-1973 regressions (to 0.82 for average and 0.80 for production/nonsupervisory compensation in the baseline specification).

Third, the coefficient estimates for production/nonsupervisory compensation are higher for the whole postwar period than for either of the two subperiods. Looking at the periods before and after 1973 separately makes sense, as there is strong evidence of a structural break in the relationship around 1973. The strong relationship over the whole period appears to be a combination of two separate and somewhat weaker relationships over the two subperiods.

Possible Mismeasurement of Productivity

There has been substantial debate over the extent to which productivity statistics are mismeasured (see, for example, Byrne, Fernald, and Reinsdorf 2016; Feldstein 2017; Groshen et al. 2017; and Syverson 2017). Mismeasurement may occur, for example, if technological innovations are undermeasured or 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, however, because we compare real output per hour (labor productivity) with real compensation per hour. Each of these series is calculated from a nominal measure (net domestic product, total compensation) divided by a price deflator and by hours worked. We have no reason to believe that there is substantial mismeasurement in the nominal series, and as both series are divided by the same metric of hours worked, we need not be concerned that mismeasurement in hours affects our conclusions. The only major causes for concern with mismeasurement are the price deflators, but as we are investigating the relationship between changes in productivity and changes in real compensation, mismeasurement should not affect our conclusions as long as the relative degree of mismeasurement in the price deflators for output and consumption did not change.[20]

Results for the Rest of the Income Distribution

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

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20. This argument is stronger if we deflate both the productivity and compensation series by the same price deflator, as in this case the underlying relationship between the two should remain despite any mismeasurement. We repeated our baseline regressions deflating compensation by the net domestic product price index. There was no substantial effect on our results (results available on request).

To answer this question, we estimate the relationship between productivity and wages at each decile of the wage distribution, using data from the Economic Policy Institute's State of Working America Data Library. The results show substantial differences in the comovement of productivity and wages by decile (tables 8.3 and 8.4). Wages at the 20th and 40th to 90th percentiles comove significantly with productivity, with coefficients between 0.3 and 0.7.

A significant caveat in interpreting these regressions is that these data are for wages, not total compensation. As benefits grew faster than wages for much of the postwar period, our wage growth measure underestimates total real compensation growth (see, among others, Bosworth and Perry 1994, Feldstein 2008, Bivens and Mishel 2015, and Lawrence 2016). Growth in nonwage benefits is probably correlated with both wage growth and aggregate productivity growth. As a result, our estimates are likely to be biased downward.

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 with 0.73 for the regression of median compensation on productivity, suggesting that the bias is about 20 percent of the coefficient size.

Nonwage benefits make up a vastly different share of total compensation for workers at different points of the wage distribution (see Stansbury and Summers 2017, figure A1), and these shares grew at different rates for different parts of the wage distribution over recent decades (Pierce 2010, Monaco and Pierce 2015). This bias estimate cannot therefore be extrapolated to the entire wage distribution. Evidence from BLS does suggest, however, that at least over the periods 1987–97, 1997–2007, and 2007–14, the ratio of wage to nonwage compensation grew similarly for the middle of the income distribution (between about the 40th and 60th percentiles) (Pierce 2010, Monaco and Pierce 2015). This evidence suggests that we may be able to extrapolate the rough magnitude of the bias at the 50th percentile to the 40th and 60th percentiles. It implies that the regression coefficients of 0.37 and 0.48 should be considered lower bounds on the true relationship between productivity and compensation in the 40th and 60th percentiles, respectively, and that the true coefficients could be about 20 percent higher.

Other Countries

In the cross-section, countries with higher labor productivity tend to have higher typical and average compensation. Lawrence (2016) finds a close to one-for-one correlation between labor productivity and average manu-

Table 8.3 Wage and productivity regression results for 10th to 50th percentile of wages

	Wage percentile (1975–2015)				
Dependent variable is 3-year moving average of the change in log wage	**(3a) 10th**	**(3b) 20th**	**(3c) 30th**	**(3d) 40th**	**(3e) Median**
Change in log productivity	0.34 (0.39)	0.69** (0.26)	0.18 (0.28)	0.37** (0.16)	0.60*** (0.16)
Unemployment among people 25–54	–1.05* (0.54)	–0.63* (0.37)	–0.53 (0.36)	–0.42 (0.34)	–0.43* (0.22)
Lagged unemployment	0.29 (0.44)	0.04 (0.32)	–0.04 (0.30)	0.03 (0.32)	0.14 (0.19)
Constant	0.04*** (0.01)	0.02*** (0.01)	0.03*** (0.01)	0.02*** (0.01)	0.01 (0.01)
Number of 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

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

F-test null hypothesis: Coefficient on productivity is not significantly different from one.

Source: Authors' calculations.

Table 8.4 Wage and productivity regression results for 60th to 95th percentile of wages

	Wage percentile (1975–2015)				
Dependent variable is 3-year moving average of the change in log wage	**(4a) 60th**	**(4b) 70th**	**(4c) 80th**	**(4d) 90th**	**(4e) 95th**
Change in log productivity	0.48** (0.19)	0.33** (0.13)	0.35** (0.13)	0.38** (0.17)	0.30 (0.23)
Unemployment among people 25–54	–0.28 (0.27)	–0.16 (0.27)	–0.18 (0.24)	–0.25 (0.23)	–0.44 (0.27)
Lagged unemployment	–0.03 (0.29)	–0.09 (0.26)	–0.04 (0.24)	0.05 (0.24)	0.25 (0.24)
Constant	0.01 (0.01)	0.01** (0.00)	0.01** (0.01)	0.01* (0.01)	0.01 (0.01)
Number of 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

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

F-test null hypothesis: Coefficient on productivity is not significantly different from one.

Source: Authors' calculations.

facturing compensation for 32 countries. We find a correlation coefficient between labor productivity and median household equivalized disposable income of 0.8 in 34 OECD countries.[21]

Although the cross-country relationship between productivity and compensation is strong, median compensation diverged from productivity in most OECD countries over the past two decades, with rising mean and median income inequality and a falling labor share (ILO 2015; Nolan, Roser, and Thewissen 2016; Schwellnus, Kappeler, and Pionnier 2017; Sharpe and Uguccioni 2017).[22] This finding suggests that there may have been a delinkage of productivity from compensation in some of these countries.

To test whether this might be the case, we repeat our regressions for average compensation for the G-7 economies (table 8.5). We do not show results for median compensation, because most countries lack comparable median hourly compensation data over a sufficiently long period.

The regressions show a mixed picture. The relationship between average compensation and productivity in Canada, West Germany (before reunification), the United Kingdom, and the United States appears to reflect a strong degree of linkage: Coefficients on the change in log of productivity are strongly significant, close to 1, and not significantly lower than 1. France, Germany after reunification, Italy, and Japan have positive but smaller coefficients.

Taken as a whole, these results 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. The surprisingly high degree of variation across countries deserves further exploration.

Technological Change and the Divergence between Productivity and Compensation

The gap between net labor productivity and median real compensation can be thought of in terms of three separate divergences: between mean compensation and productivity (equivalent to a fall in the labor share of income), between median and mean compensation (one aspect of rising

21. 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; it reflects a country's redistributive policies as well as its underlying labor market dynamics. We use this measure because there is no good comparable measure of median hourly compensation (our preferred measure across countries). A scatter plot is shown in Stansbury and Summers (2017, figure A2).

22. For comparative international evidence on the labor share decline, see Bentolila and Saint-Paul (2003); Blanchard and Giavazzi (2003); Azmat, Manning, and Van Reenen (2011); Karabarbounis and Neiman (2014); and Cho, Hwang, and Schreyer (2017).

Table 8.5 Regression results on average compensation and productivity in G-7 countries

Dependent variable is 3-year moving average of the change in log average compensation	Canada 1972–2015 (5a)	France 1972–2015 (5b)	West Germany 1972–90 (5c)	Germany 1993–2015 (5d)	Italy 1985–2015 (5e)	Japan 1997–2014 (5f)	United Kingdom 1996–2015 (5g)	United States 1950–2015 (5h)
Change in log productivity	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 among people 25–54	−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)
Lagged unemployment	−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)
Number of 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

Note: Newey-West standard errors (HAC) in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Notation: The year is listed as the middle year of the moving average.

F-test null hypothesis: Coefficient on productivity is *not* significantly different from one.

Source: Authors' calculations.

labor income inequality), and between consumer and producer price deflators (Bivens and Mishel 2015).

Several 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. This section summarizes these theories and tests them using short-term fluctuations in productivity growth.

Falling Labor Share (Divergence between Productivity and Mean Compensation)

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

$$\begin{aligned} percent\Delta \frac{Labor\ productivity}{Mean\ compensation} &= percent\Delta \left(\frac{output}{hours\ worked} / \frac{total\ compensation}{hours\ worked} \right) \\ &= percent\Delta \frac{1}{labor\ share} \end{aligned}$$

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

Grossman et al. (2017) argue that the productivity slowdown itself may have reduced the labor share by slowing technological progress on human capital accumulation.

Other authors argue that technological change is not the primary driver of the decline in the labor share. Nontechnology-focused theories of the decline in the labor share include offshoring of labor-intensive production tasks (Elsby, Hobijn, and Şahin 2013); capital accumulation (Piketty 2014, Piketty and Zucman 2014); reductions of worker bargaining power as a result of changing labor market institutions (Levy and Temin 2007, Bental and Demougin 2010, OECD 2012, Mishel and Bivens 2015, Solow 2015); industrial structure explanations, including increased firm concentration in "winner-take-most" markets (Autor et al. 2017, see also chapter 9 in this volume); increased markups (Barkai 2016); and the dynamics of the housing market (Rognlie 2015).

Rising Labor Income Inequality in the Top Half of the Distribution (Divergence between Mean and Median Compensation)

The growing wedge between mean and median compensation reflects rising income inequality in the top half of the income distribution. The gap between the 90th percentile wage and the median has risen steadily since about 1980; over the same period, the income shares of the top 1 percent and top 0.1 percent rose rapidly (see, for example, Goldin and Katz 2008; Autor, Katz, and Kearney 2008; Lemieux 2008; and Atkinson, Piketty, and Saez 2011).

As with the fall in the labor share, a number of pure technology-based explanations of rising labor income inequality have been put forward. They include capital-skill complementarity (Griliches 1969, Krusell et al. 2000); the increased pace of skill upgrading as a result of computerization (Autor, Katz, and Krueger 1998); the effect of routine-biased technological change on task demand and the hollowing out of middle-skill jobs (Autor 2010); and automation and the use of robots (Acemoglu and Restrepo 2017).

Nontechnological explanations of rising income inequality in the top half of the distribution include slower growth in educational attainment in the face of skill-biased technical change (Goldin and Katz 2008); declining unionization (Freeman et al. 2016; Rosenfeld, Denice, and Laird 2016)[23] lower top marginal tax rates (Piketty, Saez, and Stantcheva 2014); globalization, including rising trade with China and other low-cost manufacturing hubs (Autor, Dorn, and Hanson 2013); increased low-skill immigration (Borjas 2003); and the "superstar" effect, as globalization or technological change increase market size and returns to being the best (Rosen 1981, Gabaix et al. 2016, Jones and Kim forthcoming).

Implications of Technology-Based Theories of Rising Inequality

Pure technology-based theories of the falling labor share or rising wage inequality in the top half of the income distribution have a testable implication. If technological change caused the fall in the labor share and the mechanism operates over the short to medium term, one would expect the labor share to fall more quickly in periods in which labor productivity growth is more rapid, under the natural assumption that the technological

23. Freeman (1993); DiNardo, Fortin, and Lemieux (1996); and others argue that the decline in unionization significantly increased labor income inequality during the 1980s and 1990s.

Table 8.6 Average annual productivity growth and changes in inequality in the United States (percent)

Period	Average annual productivity growth	Average annual change in labor share	Average annual change in mean-median ratio
1950–73	2.58	0.10	n.a.
1973–96	1.16	–0.26	0.71
1996–2003	2.33	0.32	0.39
2003–14	1.15	–0.34	0.92

n.a. = not available

Sources: Data from Bureau of Labor Statistics, Bureau of Economic Analysis, Penn World Tables, and Economic Policy Institute Data Library.

change in question also increases labor productivity.[24] Similarly, if technological change caused the rise in the mean-median compensation ratio, one would expect that ratio to rise more rapidly in periods of faster labor productivity growth.[25]

Over a medium-term horizon, the opposite has occurred in the United States (table 8.6). During the productivity boom of 1996–2003, the labor share rose and the mean-median compensation ratio increased more slowly than in the periods of slower productivity growth before and afterward. Indeed, the labor share fell most and the mean-median ratio rose most in recent decades, during a period of productivity slowdown.

Mishel and Bivens (2017) argue that 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 information technology and software investment—increased rapidly in the late 1990s and early 2000s, a period that saw "the best across-the-board wage growth for American workers in a generation." In periods of rapidly widening inequality (1973–95 and 2005 to the present), these indicators increased more slowly.

While the lack of medium-term correlations is suggestive, a relationship may exist over shorter horizons. Short-term fluctuations in productivity growth provide a simple natural quasi-experiment to test the implications of pure technology-based theories of rising income inequality: When

24. For theories in which the mechanism is longer term, one 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 that of Grossman et al. (2017), which operates through changed incentives for human capital accumulation.

25. The correlation between short- and medium-horizon changes in the mean-median ratio and changes in the labor share is relatively low (about 0.25 to 0.3) and not statistically significant, making it unlikely a priori that the same factor is causing both trends.

productivity growth is faster, the labor share should fall more quickly and the mean-median compensation ratio should increase more quickly.

To test this possibility, we run the following regressions:[26]

$$\frac{1}{3}\sum_0^2 \Delta \log labor\ share_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \tag{8.3}$$

$$\frac{1}{3}\sum_0^2 \Delta \log \frac{mean}{median} compensation_{t-i} = \alpha + \beta\ \frac{1}{3}\sum_0^2 \Delta \log prod_{t-i} + \gamma \frac{1}{3}\sum_0^2 unemp_{t-i} + \delta \frac{1}{3}\sum_0^2 unemp_{t-i-1} + \varepsilon_t \tag{8.4}$$

If pure technology-based theories of rising inequality are correct, one should see a negative and significant coefficient on the change in log productivity in the labor share regressions and a positive and significant coefficient in the change in log productivity in the mean-median compensation regressions.[27]

We use the Penn World Tables measure of the labor share, which covers labor compensation for the total US economy as a share of GDP. As Johnson (1954), Kravis (1959), and others note, the imputation of self-employed proprietors' income to labor or capital can matter significantly for labor share calculations. The Penn World Tables measure imputes mixed income of the self-employed to labor based on the average labor share in the rest of the U.S. economy. This measure appears to be the most plausible for the United States, based on the occupational demographics of the self-employed (Elsby, Hobijn, and Şahin 2013; Feenstra, Inklaar, and Timmer 2015), and it is consistent with much of the literature on the labor share.[28] For robustness, we repeated our regressions with the BLS measures of the labor share for the total economy and the nonfarm business sector,

26. We also ran distributed-lag versions of these regressions and versions with different measures of productivity growth. They did not show substantially different results (available on request).

27. In addition, specific technology-based theories may have specific testable implications. In Stansbury and Summers (2017), we tested the hypothesis that the labor share fell because a decline in the relative price of investment goods led to an increase in the capital-labor ratio (Karabarbounis and Neiman 2014). We were unable to find evidence to support it.

28. Gollin (2002) discusses three reasonable methods for imputing mixed income when calculating the labor share, of which this labor share–based imputation is one. Studies using this approach include Gomme and Rupert (2004); Caselli and Feyrer (2007); Valentinyi and Herrendorf (2008); Elsby, Hobijn, and Şahin (2013); and Koh, Santaeulàlia-Llopis, and Zheng (2016). Piketty and Zucman (2014) and Rognlie (2015) use a similar method, assuming that the noncorporate sector has the same net capital share as the corporate sector. Krueger (1999) describes a common convention, used since Johnson (1954), of imputing two-thirds of mixed income to labor, which approximates the US economywide labor share. Christensen (1971), Abel et al. (1989), and Geerolf (2013), among others, have used this approach.

as well as a net measure of the labor share.[29] The results were not substantially different from our baseline results (results available on request).

Results on Productivity and the Labor Share

Table 8.7 shows the results from our baseline specification (three-year moving average). Table 8.8 shows the coefficient estimates on productivity in regressions with varying moving average bandwidths. Most specifications show a negative relationship between changes in productivity growth and changes in the labor share, as predicted by technology-based theories of the labor share decline. One would also expect some mechanical negative relationship over short horizons, as a positive unanticipated productivity shock would translate into higher firm income in the current year but be unlikely to feed through to worker compensation until future years.

The coefficients tend to be small and insignificant for the postwar period and for the post-1973 period but large and strongly significant for the period since 2000, when the labor share declined. A Quandt likelihood ratio test identifies a structural break in the relationship at 2002, significant at the 1 percent level. The estimated coefficients for the post-2000 period imply that a 1 percentage point increase in the rate of productivity growth was associated with a 0.07 to 0.43 percentage point faster decline in the labor share. The labor share began to decline significantly in the early 2000s, falling 4.5 percentage points (6.5 percent) over 2001–14 (an annual rate of 0.49 percent); the average annual rate of labor productivity growth over 2001–14 was 1.3 percent.

The magnitude of the coefficient for the post-2000 period falls substantially as the moving average bandwidth increases (table 8.8), in line with the hypothesis that some of the short-term negative relationship between contemporaneous productivity growth and compensation growth could be mechanical; it should disappear over longer bandwidths. Testing for a significant difference between productivity coefficients in the pre- and post-2000 period using unrestricted regressions, we find significant differences at the 5 percent level for three-year moving averages and nonsignificant differences for two-, four-, and five-year moving averages. When restricting the coefficients on unemployment and the constant to be the same over both periods, the difference in productivity coefficients between the pre- and post-2000 period declines substantially and is not significant (see

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

Table 8.7 Regression results on productivity and labor shares

Dependent variable is 3-year moving average of change in log labor share	(7a) 1950–2013	(7b) 1950–73	(7c) 1975–2013	(7d) 2000–13
Change in log productivity	−0.10 (0.11)	−0.03 (0.24)	−0.11 (0.18)	−0.43*** (0.11)
Unemployment among people 25–54	−0.51*** (0.14)	−0.49* (0.26)	−0.47*** (0.16)	−0.20 (0.16)
Lagged unemployment	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)
Number of observations	64	24	39	14

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

Source: Authors' calculations.

Table 8.8 Coefficients on productivity from productivity–labor share regressions for various moving average bandwidths

Dependent variable is X-year moving average of change in log labor share	(8a) 1950–2014	(8b) 1950–73	(8c) 1975–2014	(8d) 2000–14
Two years	−0.17* (0.09)	−0.31 (0.25)	−0.14 (0.17)	−0.43*** (0.11)
Three years	−0.10 (0.11)	−0.03 (0.24)	−0.11 (0.18)	−0.43*** (0.11)
Four years	−0.09 (0.12)	0.19 (0.25)	−0.12 (0.14)	−0.34** (0.11)
Five years	−0.11 (0.11)	0.08 (0.16)	−0.06 (0.12)	−0.07 (0.16)

Note: The independent variable is the X-year moving average of the change in the log of productivity. Regressions control for unemployment. Newey-West standard errors (HAC) are in parentheses. Underlying regressions are in table 8.7 and Stansbury and Summers (2017). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

Stansbury and Summers 2017, table A12). It is not clear a priori whether one should expect the cyclicality of the productivity–labor share relationship or the constant term to have changed since 2000. If it did not, the restricted regressions are more appropriate.

Overall, these results on productivity and labor share present a mixed picture. As 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 that 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

Table 8.9 Regressions results on productivity and mean-median compensation

Dependent variable is 3-year moving average of change in log mean-median compensation ratio	(10a) 1975–2015	(10b) 1975–2015
Change in log productivity	−0.01 (0.10)	0.00 (0.10)
Unemployment among people 25–54		−0.09 (0.12)
Lagged unemployment		0.13 (0.10)
Constant	0.01*** (0.00)	0.01 (0.00)
Number of observations	41	41

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

Source: Authors' calculations.

share relationship since 2000, but these estimates are sensitive to the time horizon and methodology used.

Results on Productivity and the Mean-Median Ratio

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 it. There is no significant relationship between productivity growth and changes in this ratio (which also holds with different moving-average bandwidths), casting doubt on pure technology-based theories of the rising mean-median compensation ratio (table 8.9).

Concluding Remarks

Over the past four decades, average compensation growth in the United States was slow and median compensation almost stagnant. Real average hourly compensation rose by 48 percent between 1973 and 2016, an annual rate of only 0.9 percent. Real hourly median compensation rose only 11 percent between 1973 and 2016 (real average hourly production/nonsupervisory compensation rose by 12 percent). During the same period, hourly labor productivity rose by 75 percent (1.3 percent a year).

In contrast, between 1948 and 1973, average pay for Americans rose much more quickly and more closely in line with productivity. Real average hourly compensation grew by 2.9 percent a year. Real hourly production/

nonsupervisory compensation—which is likely to have grown at a similar rate as median compensation (Bivens and Mishel 2015)—grew by 2.6 percent a year. Hourly labor productivity grew by 2.7 percent a year.

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

There is a spectrum of possible interpretations of this divergence between productivity and pay. At one end is the strong delinkage view, in which productivity growth did not systematically translate into growth in workers' compensation. At the other end is the strong linkage view, in which productivity growth translated one for one into compensation growth but a variety of other factors put downward pressure on workers' compensation at the same time.

Our regressions are supportive of substantial linkage between productivity and all three measures of compensation (median, production/nonsupervisory, and average). Over 1973–2016, a 1 percentage point increase in the rate of productivity growth was associated with an increase in compensation growth of 0.7 to 1.0 percentage point for median and average compensation and 0.4 to 0.6 percentage points for production/nonsupervisory compensation. Almost all specifications strongly reject the strong delinkage hypothesis. The strong linkage hypothesis of a one-for-one relationship cannot be rejected for either median or average compensation (it is rejected for production/nonsupervisory compensation). Evidence on different deciles of the wage distribution also shows large and significant positive comovement between productivity and wages for the middle deciles.

Our results suggest that productivity growth pushed up typical and average compensation significantly in recent decades. Other factors are likely to be responsible for the divergence between productivity and pay in the United States, suppressing typical workers' incomes even as productivity growth acted to increase them.

One of these factors could be technological change. Pure technology-based theories of the fall in the labor share or the rise in mean-median income inequality imply that in periods in which productivity growth is faster, productivity and median pay should diverge more rapidly. This hypothesis can be tested using the natural quasi-experiment of fluctuations in productivity growth. There is little evidence of significant comovement between productivity growth and the labor share in the United States over long periods (since 1948 and since 1973), but we find some evidence of a significantly negative relationship since 2000. We find no significant relationship between the mean-median ratio and productivity growth over the last four decades.

Taken together, these results tend not to provide strong support for purely technology-based theories of either the decline in the labor share or the rise in mean-median pay inequality. The factors suppressing median compensation over recent decades are more likely to have been factors that are orthogonal to productivity growth.

We can use the coefficient estimates from our regressions to roughly quantify the degree to which the productivity-median compensation divergence has been the result of a lack of pass-through of productivity growth to median compensation, as opposed to the suppression of median compensation by other factors orthogonal to productivity. Our baseline regression coefficient of 0.73 would suggest that if all else had been equal over 1973–2016, the productivity growth experienced in the United States would have resulted in median compensation growing by 51 percent instead of 11 percent. A lack of pass-through of productivity growth to median compensation can thus explain 38 percent of the divergence between the two series; other factors suppressing median compensation (which are orthogonal to productivity growth) can explain the other 62 percent. Using our full range of plausible coefficient estimates (from 0.65 to 1.00), 0 to 40 percent of the productivity-median compensation gap can be explained by lack of productivity pass-through; 60 to 100 percent of the gap can be explained by other factors suppressing median compensation. For production/nonsupervisory compensation, 40 to 50 percent of the gap with productivity can be explained by lack of productivity pass-through; 50 to 60 percent can be explained by other orthogonal factors suppressing production/nonsupervisory compensation.

The continued significance of productivity growth for compensation growth can be illustrated using some simple counterfactuals. If the ratio of the mean to median hourly compensation in 2016 had been the same as it was in 1973 and mean compensation had remained at its 2016 level, median compensation would have been about 33 percent higher, all else constant. If the ratio of labor productivity to mean compensation in 2016 had been the same as it was in 1973 (i.e., the labor share had not fallen), average and median compensation would have been 4 to 8 percent higher, all else constant. In contrast, assuming the relationship between compensation and productivity estimated in table 8.1 holds, if productivity growth had been as fast over 1973–2016 as it was over 1949–73 (2.7 percent rather than 1.3 percent a year), median and mean compensation would have been about 41 percent higher in 2016, all else constant.

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

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

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

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