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The causes of rising wage inequality: the race between institutions and technology

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Abstract

Many inequality scholars view skill-biased technological change—the computerization of workplaces that favours high-skilled workers—as the main cause of rising wage inequality in America, while institutional factors are generally relegated to a secondary role. The evidence presented in this article, however, does not support this widely held view. Using direct measures for computers and pay-setting institutions at the industry level, this article provides the first rigorous analysis of the independent effect of technological and institutional factors on rising wage inequality. Analysing data on 43 US industries between 1968 and 2012, we find that declining unions and the fall in the real value of the minimum wage explain about half of rising inequality, while computerization explains about one-quarter. This suggests that much of rising inequality in the USA is driven by worker disempowerment rather than by market forces—a finding that can resolve the puzzle on the diverging inequality trends in USA and Europe.

Key words: income distribution, industrial relations, inequality, labor market institutions, technological change, trade unions

JEL classification: J5 labor-management relations, trade unions, and collective bargaining, J3 wages, compensation, and labor costs, D3 distribution

1. Introduction

The sharp rise in wage inequality in the USA and other countries is usually attributed to two sets of factors. The first, advanced by most economists, consists of technological change (Acemoglu and Autor, 2011). The rise of computer technology in the workplace since the late 1970s, so goes the argument, has increased the productivity of, and demands for, high-skilled workers that tend to use computers, thereby raising their wages relative to less-skilled workers who do not use computers. Moreover, at the time of rising demand for skilled workers, there was a slowdown in the growth of college graduates, thereby raising the wages of highly educated Americans even more (Goldin and Katz, 2008). This explanation, known as skill-biased technological change (SBTC), implies that the invisible hand of the market is the main mechanism through which computerization increases wage inequality.

Most sociologists and political scientists as well as some economists tend to emphasize institutional factors as driving inequality and question the assumption that the invisible hand of the market is the main explanation for rising inequality (Blau and Khan, 1996; DiPrete and McManus, 1996; Rueda and Pontusson, 2000; Alderson and Nielsen, 2002; Brady, 2003; Lucifora *et al.*, 2005; Beckfield, 2006; Iversen and Soskice, 2006; DiPrete *et al.*, 2010; Kalleberg, 2011; Western and Rosenfeld, 2011; Kristal, 2013; Lin and Tomaskovic-Devey, 2013; Liu and Grusky, 2013; Kristal and Cohen, 2015). They identify mainly pay-setting institutional changes that have occurred in the US labour market and economy since the 1970s—primarily declining unionization and the fall in the real value of the minimum wage, but also the spread of non-standard employment practices as well as the ascent of financialization and globalization—as being responsible for much of the rise in income inequality during that period.

To be sure, the two types of explanation are not mutually exclusive, and most scholars agree that both technology and institutional factors are responsible for rising wage inequality. There is less agreement, however, on the relative importance of each set of factors. The SBTC literature has often tended to empirically ignore wage-setting institutions, emphasizing 'the central role of both the supply and demand for skills in shaping inequality' (Autor, 2014, pp. 843). By using the correlation between investments in computers and inequality across industries (and/or the correlation between the supply of college graduates and college to high-school wage premium) as evidence for SBTC, this literature has been conveying the impression that computerization, together with the deceleration in the supply of college graduates, has been the central driving force behind the overall increase in wage inequality, at least among the 'other 99%' (Acemoglu and Autor, 2011; Autor, 2014). Institutional accounts of rising inequality, on the other hand, analyse individual-level and country-level data that do not allow the incorporation of a direct measure for computer technologies. Instead of using a direct measure for computerization, previous institutional studies have often used its expected outcome by including standard measures of workforce skills, based on educational attainment, in the statistical analyses. As a result, there is no statistical analysis to date that directly tests the effect of computerization vis-à-vis institutional factors on rising wage inequality.[1] To be sure, estimating the relative importance of the various causes of rising inequality is not only the first step towards initiating effective government policies, but essential as well for gaining a better understanding of how labour markets operate.

This article's contribution, then, is to provide an empirical answer to this debate over the 'causes of inequality'. Specifically, based on industry-level data, we provide the first empirical test of the main established explanations for rising wage inequality in the USA since the early 1970s. The remainder of this article is structured as follows. In Section 2, we present the institutional arguments and the SBTC thesis on rising wage inequality. In Section 3, we describe the longitudinal industry data, measures and method of analysis. In Section 4, we analyse the

1 Studies that incorporated direct measures for both computers and unions at the industry level (Kristal, 2013; Lin and Tomaskovic-Devey, 2013) did not include other measures of pay-setting institutions, nor have they estimated the relative effect of each set of factors on wage inequality.

long- and short-run effects of direct measures for computer technologies, unionization, minimum wage, demographic changes of the labour force, non-standard employment relations, financialization and import penetration on changes in wage inequality in 43 non-agricultural private industries between 1969 and 2012. This will enable us to provide an estimate of the relative importance of computerization versus institutional factors as causes of rising inequality. In Section 5, we summarize and discuss the implications of the main findings for the dominant explanations for rising wage inequality in the past four decades.

2. Why has wage inequality increased?

2.1 Fading pay-setting institutions

In the past four decades, the US labour market has changed dramatically. Some of these changes, in particular the erosion of pay-setting institutions, are partly responsible for the rise in wage inequality. These include the decline of organized labour, the fall in the real value of the minimum wage, the spread of non-standard employment relations, the growth of finance capitalism and the fall of US trade barriers that led to the importation of goods from less-developed countries. Taken together, these changes, which reflect in part a deeper transformation in the political landscape, are responsible for a substantial, yet unknown, portion of the rise in wage inequality since the late 1970s. Below is a brief account of the changes and their effects on inequality as reported by past research.

Union density has been in decline in the USA since reaching its peak in the mid-1950s. In the private sector, union density has dropped from one-in-four union members of all wage and salary workers in the early 1970s to below one-in-thirteen today (Western and Rosenfeld, 2011). Past research provided a variety of explanations to account for the decline in union membership in the private sector. Unions declined as jobs shifted from unionized core industries to less unionized service industries (Farber and Western, 2001). Capital flow and overseas competition affected unions in several industries, in particular in steel and auto manufacturing (Brady and Wallace, 2000; Slaughter, 2007). Unions also found themselves under relentless attack by employers using legal and illegal anti-union tactics (Bronfenbrenner, 2009), by the anti-union Reagan administration (Tope and Jacobs, 2009) as well as by labour legislation that had powerfully negative implications for the labour movement (Wallace *et al.*, 1988; Jacobs and Dixon, 2006). While recent challenges to the labour movement have provoked militancy among some service unions (Fantasia and Voss, 2004), private-sector union density has continued to drop, to 6.6% in 2014 (Hirsch and Macpherson, 2015).

There is an emerging consensus that the decline of organized labour has led to rising wage inequality due to the equalizing effect of unions on the distribution of wages in both the union and non-union sectors. Among unionized workers, unions decrease within-group wage inequality by reducing the spread of wages among union members with similar characteristics; and between-group wage inequality by reducing educational and occupational inequality (Freeman, 2005). Unions also equalize the overall wage distribution by causing non-union employers to raise wages to union level to avert the threat of unionization (Leicht, 1989), buttressing labour market norms of fair pay by setting the pattern for industry-wide wage increases (Wallerstein, 1999; Kristal and Cohen, 2007; Western and Rosenfeld, 2011), and promoting social legislation in favour of low-wage workers (Korpi, 1983). Although less notable, unions equalizing effect on wages operate at the upper tail of the wage distribution as well, serving as an important check on the pay of managers, including upper management. CEOs compensation was found to be lower in countries and firms with higher unionization rates and to increase following a loss of union membership due to decertification elections (DiNardo *et al*., 1997; Shin, 2014). In addition, union decline generally increases managers to workers pay inequality (Rosenfeld, 2006) and the number of managerial positions (Goldstein, 2012).

Empirical studies have found that union decline explains the variation in rising income inequality across countries (Bradley *et al*., 2003; Brady, 2003) and in the USA (Card, 2001; Wolff, 2006; Moller *et al*., 2009; Lin and Tomaskovic-Devey, 2013). Declining unionization explains about one-third of the rise in men's wage inequality (Card *et al*., 2004; Western and Rosenfeld, 2011), and about 20% among women (Western and Rosenfeld, 2011).

Most empirical studies have tested the effect of de-unionization on rising wage inequality at the individual level using mainly counterfactual interpretation (i.e. calculating the level of inequality assuming unionization had remained at its 1973 level), and at the country level using cross-section time-series variation. Because a direct measure for computer technology is not readily available at the individual or country levels, previous studies (with the exception of Lin and Tomaskovic-Devey, 2013) have analysed the effects of union decline on rising wage inequality while controlling for education and other relevant individual factors, but without a direct measure for the level of computerization in the workplace. Rather, increasing wage gaps between educational groups are interpreted as a by-product of SBTC, assuming that computerization raises the wages of highly educated workers. However, without a direct measure for computer technology, these studies have only been able to conclude how much of the growth in inequality is explained by the decline of organized labour compared with the growing stratification of wages by education, but not to estimate the role of unionization vis-à-vis computerization in rising wage inequality.[2]

In addition to de-unionization, three additional factors have disempowered low- to medium-wage workers due to the elimination of pay-setting institutions and in turn led to rising wage inequality. First, there is strong evidence that the decline in the real value of the minimum wage in the USA during the 1980s played a major role in the increase in inequality in the lower tail of the wage distribution (the 50/10 wage ratio) during this period (DiNardo *et al*., 1996; Lee, 1999) and that a national statutory minimum wage is associated with lower levels of wage inequality across countries (Garnero *et al*., 2014). A fall in the real minimum wage should increase wage inequality because it lowers the wages only at the bottom of the income distribution. Likewise, raising the minimum wage depresses inequality by raising the wages at the bottom without reducing employment (Card and Krueger, 2000).

Second, shifts in organizational work practices, including the externalization of employment relations (DiPrete *et al*., 2002; Kalleberg, 2011), which is indicative of the state of decline of internal labour markets, appear to have considerable explanatory power with respect to rising wage inequality. In particular, changes in the organization of work to feature new flexible work systems have caused growth in inequality by increasingly restricting less-skilled workers to precarious low-wage jobs (Kalleberg *et al*., 2000). High-performance

2 Using data at the aggregate national level, Wolff (2006) found that in the USA computerization had a larger effect than unionization on rising inequality (respectively, explaining about 48% versus 36% of the increase in inequality since 1968). However, the aggregate data mask important variations between industries in both unionization and computerization, which probably results in an underestimation for the effects of these institutional variables on inequality.

work practices, which are often supported by non-traditional compensation systems (such as performance bonuses, productivity gain sharing, and profit sharing), have also contributed to rising wage inequality by limiting the added compensation only to highly skilled workers (Handel and Gittleman, 2004; Lemieux *et al.*, 2009; Hanley, 2011).

Lastly, when countries open up the economy to international trade, new fields for capital accumulation in domains hitherto regarded as off-limits to the calculus of profitability become more accessible, thereby affecting the relative power positions of employers and specific groups of employees. The importation of goods from less-developed countries (i.e. import penetration), in particular, places American workers in direct competition with lower-paid workers in developing countries. This competition curbs the bargaining power of workers, brings down the wages of the least skilled American workers (Wood, 1994) and increases earnings inequality among workers (Brady and Wallace, 2000; Alderson and Nielsen, 2002).

The growing weight of finance in the economy, commonly known as financialization (Krippner, 2005), is an additional political cause for recent inequality trends (Lin and Tomaskovic-Devey, 2013; Jacobs and Myers, 2014; Lin, 2015). To be sure, the more established relations between finance capitalism and inequality relate to those individuals and institutions that derive substantial part of their incomes from financial assets and transactions (Lin and Tomaskovic-Devey, 2013; Alvarez, 2015). Financialization, however, has increased inequality not only through the high salaries in Wall Street (financed by about 6 trillion dollars that were shifted to finance, insurance and real estate from other industries) that widen gaps between Wall Street and Main Street (Tomaskovic-Devey and Lin, 2011; Lin, 2015), but has also increased within-industries wage inequality by 10.2% during 1970–1997, as non-financial firms have increased their involvement in financial activity during this period (Lin and Tomaskovic-Devey, 2013). The mechanisms by which growing profits from financial income in the non-financial sector is expected to affect inequality are political: corporate restructuring due to financialization affected working conditions and employment relations, leading to flourishing of non-standard employment relations (Fligstein and Shin, 2004), and finance-related workers have a greater bargaining power and therefore higher wages compared with other workers (Lin and Tomaskovic-Devey, 2013).

2.2 Computerization, skills and productivity

The ‘canonical’ (Acemoglu and Autor, 2011) or ‘consensual’ (Lemieux, 2008) economic explanation of rising inequality asserts a negative relation between the use of new computer technologies in the workplace and wage equality. By new computer technologies, studies generally refer to developments since the late 1960s in semiconductor technology that have found their broadest applications in computing and communications equipment. Such equipment makes extensive use of microelectronics and programmed instructions or software that is implemented at all stages of the production process. As we elaborate below, this well-known SBTC hypothesis holds that computers have increased the productivity of highly skilled workers, which in turn increases their wages.

A series of studies published over the 1990s pointed to technological change—especially the development of microcomputers—as the leading explanation for the rise in wage inequality (Katz and Murphy, 1992; Levy and Murnane, 1992; Juhn *et al.*, 1993). Computer technology, so goes the SBTC argument, is complementary with human capital, meaning that at the same level of human capital, productivity is much higher when computer technology is used. That being the case, the diffusion of Information and Communication Technologies

(ICT) led to an increase in the relative demand for all dimensions of skill (education, experience, unobserved ability, etc.), causing relative wage rises for educated workers and an increase in inequality within educational groups. The wage increase for high-skilled workers was accentuated during the 1980s and the 1990s by the sluggish growth of college graduates that lasted during that period, until the cohorts born in the mid-1970s entered the labour market (Goldin and Katz, 2008). Because highly skilled workers earn higher wages, an increase in the wage differential between the highly and less highly skilled led to a rise in wage inequality.

In support of the SBTC hypothesis is the fact that although the relative supply of skills (i.e. the proportion of college graduates in the labour force) has increased, the demand for skilled workers has increased even more, and therefore there has been no tendency for the returns to skills (i.e. college premium) to fall in the face of this large increase in supply. On the contrary, there has been an increase in the college premium both in the 1980s and 1990s (Autor, 2014) when there was a slowdown in the supply of college graduates, and since 2004, when the supply growth increased. In fact, the SBTC literature often focuses on explaining the college premium, assuming that the high correlation between the increase in the education wage premium and the rise in the dispersion of wages indicates the central role of skills and education in rising inequality.

While the earlier SBTC literature often tended to simply attribute changes in the wage structure unexplained by other factors to technological change, more recent studies use precise measures of technological change that can then be tested empirically. The first piece of evidence that points to computer technology and human capital as complementary factors is the fact that highly skilled workers—especially those with more schooling—are more likely to use computers on the job and there is a wage premium associated with computer use on the job, net of standard human capital variables (Krueger, 1993). The assumption is that workers who are more likely to use computers have skills that are more complementary with computers and experience bigger gains in productivity with the continuing innovations in computer technology. Following Krueger's widely cited study, an abundance of quantitative and case-study evidence documents a strong correlation between the adoption of computer-based technologies and the increased use of college-educated labour and their higher relative wages within detailed industries and firms (Doms *et al.*, 1997; Autor *et al.*, 1998).

Yet, as critics point out, the SBTC interpretation of the positive correlation between computer technologies and rising wage inequality merely labels this correlation without explaining its cause. A more recent version of the SBTC hypothesis, developed by Autor *et al.* (2003), provides a possible answer to the question regarding what it is that workers do with computers that causes educated workers to be relatively more productive and therefore earn higher wages. Accordingly, the argument is that computers (i) substitute for workers in performing routine tasks (i.e. well-defined cognitive and manual tasks that can be accomplished by the following explicit rules); and (ii) complement workers in performing non-routine tasks (i.e. problem-solving and complex communications activities). Together, these effects of computerization increased relative demand for highly educated workers, who hold a comparative advantage in non-routine versus routine tasks, hence increasing their relative earnings.

3. Data, variables and method

3.1 Data

We test the effect of pay-setting institutions and computerization on rising wage inequality using longitudinal data on US industries. We use a pooled cross-sectional time-series design (i.e. yearly observations for each industry) to test the study's arguments. The combined industry-year data sets include 43 comparable (two-digit) industries that cover the entire non-agricultural private sector. Due to the major change in the industry classification structure in 1997, we have one data set for the years 1969–1997 (based on the Standard Industrial Classification) and another data set for the years 1988–2012 (based on the North American Industry Classification System).

The analyses are based on data drawn from several governmental and census publications on US industries. We combine data on earnings from the Current Population Survey (CPS) samples with data on the magnitude of each industry's investments in computers from the Bureau of Economic Analysis (BEA) Industry Economic Accounts data, with data on unionization from the Bureau of Labor Statistics (for the years 1968–1969)[3] as well as from the March (1971 survey) and May/ORG CPS surveys (for the years 1973–2012), with data on education, part-time employment and demographic composition of the workforce from the March CPS samples, with data on employment in large firms from the Census Bureau County Business Patterns, with data on financialization from the Internal Revenue Service (IRS) and with data on import penetration in manufacturing from Schott (2010). Annual data on the federal minimum hourly wage, which varies only between years and is constant between industries, are from the US Department of Labor.[4]

To measure the changes in the US wage structure over the last four decades, we use the March CPS files from 1969 to 2013 (covering earnings from 1968 to 2012) to compile a sample of annual earnings for wage and salary workers aged 18–65 who participate in the labour force on a full-time, full-year (FTFY) basis, defined as working 35-plus hours per week and 50-plus weeks per year. Starting in 1976 (earnings year 1975), the March survey began collecting information on hours worked in the previous year. This allows us to create a second sample of hourly wage data for all wage and salary workers for the earnings years 1975 to 2012. For both the annual wage sample and the hourly wage sample, we follow standard practice and replace top-coded wages with 1.5 times the top-coded value (Card and DiNardo, 2002), which means that the study excludes the top 1 percentile of wage and salary workers.[5] The samples of annual wage exclude all observations whose estimated annual earnings are below \$2000 in 1979 dollars, and the samples of hourly wage exclude all observations whose estimated hourly wage is less than \$1 or greater than \$100 per hour in 1979 dollars. In constructing statistics for FTFY workers, we use the CPS sample weights. In constructing statistics for all workers, we use the CPS sample weights, multiplied by the number of hours worked in the previous year (divided by 2000). Weighting by hours worked allows the inclusion of part-time workers.

3 This data are available only to 28 industries. We therefore imputed the aggregate information to the more detailed industries, assuming that the disaggregate industries were relatively similar in terms of union density. We also imputed data for the years 1971, 1972 and 1982 because the question on union membership was not asked in the CPS in these years.

4 See more details at: http://www.dol.gov/whd/minwage/chart.htm.

5 By multiplying the top-coding of annual earnings in the March CPS by 1.5, the top wage we analyse is at about the 99.0 percentile of annual earnings according to Thomas Piketty and Emmanuel Saez (http://elsa.berkeley.edu/~saez/TabFig2010.xls). For example, the March CPS total annual earnings were top-coded at \$200,000 from 2003 onwards, which means that in our data the highest annual earnings for the years 2003–2007 are \$300,000. In 2003, according to Piketty and Saez, the average annual salary for those located at the 99.0 and the 99.0–99.5 percentiles were \$281,740 and \$328,197, respectively.

3.2 Variables

We follow previous studies and measure overall *wage inequality* by the standard deviation of log wages and the log of the ratio of the 90th percentile of wages to the 10th percentile (i.e. the 90/10 log wage differential). The two measures are usually very close, with differences mainly reflecting top-coding and the treatment of very low-wage observations. Descriptive statistics for all variables are presented in Table 1.

Following studies that make use of BEA data on the magnitude and composition of each industry's capital investments to explain rising wage inequality (Autor *et al.*, 1998; Wolff, 2006; Fligstein and Shin, 2007; Kristal, 2013), we employ a simple measure of *computer technology* by measuring real investments in computers as a share of total non-residential fixed assets investments. Under 'computers', we include investments in mainframe computers, personal computers, direct access storage devices, computer terminals, computer storage devices, integrated systems and software.[6] While the BEA data do not directly measure the kind of technology implemented in the production process and it is affected by both the quantity and prices of computer technology, we assume that when firms invest in computing equipment they are most likely to use this new equipment at different stages of the production process. Following Autor (2014), we use college share of hours work as a proxy for *college supply* in each year and added its annual growth rate to the models. Assuming that labour supply is not industry-specific, we allow it to vary between years but not between industries.

Union density is measured by dividing the number of union members in each industry by the number of wage and salary workers. Union membership figures have been compiled for all employed civilian wage and salary workers, aged 16 and over. We have two measures for organizational change that serves as proxies for non-standard employment relations: part-time employment, and employment in large firms, where the likelihood for the persistence of internal labour market is greater than that in smaller firms. *Part-time* employment is measured by dividing the number of part-time workers employed in each industry by the number of employed workers. We measure *large firms* by the percentage of the workforce that is employed in firms employing more than 500 workers, which is computed using the County Business Patterns provided by the Census Bureau. To measure *financialization* we followed Lin and Tomaskovic-Devey (2013), and use the ratio between financial income (income from interest, dividends and capital gains) to business income.[7] We imputed the average annual value of financialization in the non-financial sector to FIRE industries. This measure is not available to the second period between 1988 and 2012 due to a major change in the industrial classification that took place in the IRS in 1998. Nevertheless, we also analyse models only for the years 1998–2012 (data not shown) and find no affect for financialization on wage inequality, much

6 A broader measure for computer technology that was used by Autor *et al.* (1998) and Wolff (2006) also includes investments in office and accounting equipment (i.e. electric and non-electric office machines). The correlation between this measure and the one we use is 0.982, and the estimations results are appreciably the same. Another common measure for computerization relies on net stocks instead of investments in computer technology. Because net stocks are subject to tax manipulations more than investments, we prefer to use the latter. At any rate, computer stocks at the industry level between 1969 and 1997 highly correlate with computer investments (0.902) and its relations with union density and wage inequality are very similar to computer investments.

7 Data for the years 1970–2008 was kindly made available to us by Ken-Hou Lin and Donald Tomaskovic-Devey.

Table 1 Descriptive statistics of relevant variables

Sector	Private sector		Manufacturing
Industries	43 Industries	43 Industries	18 Industries
Years	1969–1997	1988–2012	1973–1997
Dependent variable			
Annual earnings inequality—90/10 (FTFY)			
Mean (standard deviation)	1.28 (0.22)	1.44 (0.25)	1.24 (0.15)
Source	March CPS	March CPS	March CPS
Hourly wage inequality 90/10 (from 1976)			
Mean (standard deviation)	1.31 (0.21)	1.40 (0.22)	1.23 (0.12)
Source	March CPS	March CPS	March CPS
Independent variables			
Computer investment (%)			
Mean (standard deviation)	6.2 (8.2)	18.1 (15.9)	7.4 (7.5)
Source	BEA	BEA	BEA
College share of hours worked (%)			
Mean (standard deviation)	33.3 (6.3)	44.2 (4.2)	35.0 (5.0)
Source	March CPS	March CPS	March CPS
Unionization (%)			
Mean (standard deviation)	24.2 (18.0)	14.8 (14.3)	27.5 (14.4)
Source	BLS, CPS	CPS	CPS
Part-time (%)			
Mean (standard deviation)	9.5 (8.9)	9.7 (9.0)	4.3 (3.2)
Source	March CPS	March CPS	March CPS
500+ Firm size (%)			
Mean (standard deviation)	25.5 (19.7)	20.1(16.6)	35.8 (19.3)
Source	CBP	CBP	CBP
Minimum wage (2014 dollars)			
Mean (standard deviation)	8.1 (1.2)	6.9 (0.5)	7.9 (1.1)
Source	DOL	DOL	DOL
Financialization[a]			
Mean (standard deviation)	2.2 (1.4)	–	2.5 (1.5)
Source	IRS		IRS
Non-Hispanic white men (%)[b]			
Mean (standard deviation)	55.5 (16.7)	49.5 (14.8)	56.0 (14.0)
Source	March CPS	March CPS	March CPS
Import penetration (%)			
Mean (standard deviation)	–	–	4.7 (11.8)
Source			Schott, BEA
N	1,247	1,075	450

CPS, Current Population Survey; BEA, Bureau of Economic Analysis Industry Economic Accounts data; BLS, Bureau of Labor Statistics; CBP, Census Bureau County Business Patterns; DOL, Department of Labor; IRS, Internal Revenue Service.

[a]Aggregate data on transportation and communication were imputed to their detailed industries. For FIRE industries, we imputed the annual average.

[b]Because the question on Hispanic ethnicity was not asked in 1968, 1969 and 1970, we impute industry-specific predictions using the data points from 1971 to 1979.

similar to the results of Lin and Tomaskovic-Devey (2013). To account for the changing demographic composition of the workforce, we control for the proportion of the workforce that was *non-Hispanic white men*, a demographic change that should affect not only wage inequality but also union density. We use import data by industry and country from Schott (2010) to construct a measure of the imports in manufacturing industries originating in low-wage countries' industrial product. *Import penetration* is thereby measured by imports from low-wage countries as a share of industry's value added.[8] While we do not have measures for foreign outsourcing, offshoring and foreign investments, which are important elements of globalization, our measure of import penetration is highly correlated with other indicators of globalization (Alderson and Nielsen, 2002; Feenstra, and Hanson, 1996).

3.3 Method

The method of analysis is straightforward—we analyse the effects of indicators for computer technology and pay-setting institutions on different measures of overall wage inequality. We analyse the determinants of wage inequality in time-series cross-sectional dynamic specification (a lagged dependent variable is included among the predictors) by fixed effects estimators. Fixed effects estimators, which exploit within-industry variation as a means of purging unit heterogeneity, make it possible to obtain unbiased and consistent estimates of parameters when industry effects are arbitrarily correlated with measured explanatory variables (Halaby, 2004). By applying fixed effects estimators, the models focus on the within-industry variation over time, and the coefficients represent a cross-industry average of the longitudinal effect. Given that the rise in wage inequality occurred mostly within rather than between industries, as we demonstrate in the next section, our research strategy is suited to analysing the causes of overall rising inequality.

One potential difficulty in analysing cross-section time-series data over a relatively short period of time is that the empirical data are likely to trend over time, i.e. to be non-stationary. Consequently, OLS regression can produce 'spurious relations' as a result of the variables trending together over time. In early econometrics work dealing with non-stationary data, the common 'solution' to the 'problem of non-stationarity' has been to transform the variables so that they appear to be stationary. In practice, this typically means analysing OLS with first differenced variables that explain the growth or decline of the dependent variable. While first-differencing is a convenient technical solution to some of the problems inherent in time-series analysis, it is notorious for downsizing effects that researchers believe in theoretically and find ample evidence for in tests using level-based data (Beck and Katz, 2011). Mainly because it throws out any long-run information about the variables and restricts the type of relationship that can be uncovered to those in which the effect of an explanatory variable is constrained to a single point in time.

That the data series are non-stationary does not rule out a long-run equilibrium relationship. It may be the case that the data series are cointegrated; namely, the dependent and independent variables maintain a long-run error correction relationship (Engle and Granger,

8 We classify a country as low-wage in year *t* if its per capita GDP is less than 20% of US per capita GDP (data on countries' per capita GDP are from Penn World Table). We choose a 20% cutoff to classify countries as low wage because it represents the world's most labour-abundant cohort of countries and therefore the set of countries most likely to have an effect on US manufacturing plants. We also constructed a measure of overall imports, and it showed similar but slightly weaker results. Results are available upon request.

1987). To test whether the data series are cointegrated, we performed the standard two-step cointegration test by regressing Y on X (in levels) and then testing whether the residual is stationary. We find that we can reject the null hypothesis of no cointegration at the 5% confidence level or better for all independent variables, concluding that there is equilibrium between wage inequality and the independent variables.

To estimate the long- and short-run effects of indicators for computer technology and pay-setting institutions on wage inequality, we analyse single-equation error correction models (ECMs) that can accommodate stationary and non-stationary variables, given that the errors are stationary (De Boef and Keele, 2008; Beck and Katz, 2011),[9] and fit cointegrated data. The ECMs are particularly appropriate in the context of this study because their parameterization has the advantage of explicitly modelling both short- and long-run effects on wage inequality, providing easily interpretable estimates of these parameters. For example, they make it possible to estimate two likely effects of unionization and computerization on wage inequality: one that occurs immediately with a decline in union density or with the implementation of computer technology in the production process, and another impact of the erosion of labour unions or computerization that is dispersed across future time periods. We therefore specify the cross-section time-series variant of the single-equation ECM for the dynamic relationships:

$$\Delta \text{wage\_inequality}_{i,t} = \alpha_0 + \beta_1 \Delta X_{i,t} - \beta_2(\text{wage\_inequality}_{i,t-1} - \beta_3 X_{i,t-1}) + \varepsilon_{i,t}.$$

In this model, current changes in wage inequality (measured in first difference, i.e. $Y_t - Y_{t-1}$) are a function of both the short-term changes (i.e. first differences) in the independent variables and their long-term levels. Specifically, β_1 captures any short-term effects on wage inequality, while the long-term effects are captured by β_3. The long-term effect occurs at a rate dictated by the value of β_2 that captures the rate of return to equilibrium. In all models, the estimates are weighted by industry size to make sure that the results are not biased by small industries representing only a small fraction of the workforce.[10]

We acknowledge that the explanatory variables are potentially endogenous, meaning that over time they may influence each other; endogeneity that may result in inconsistent estimates of the effects of the explanatory variables. Yet we test the robustness of the results by estimating models without controlling for certain variables, employing different lag structures, and exploiting diverse time periods, and the main findings are robust for these specifications. The common statistical solution to the problem of endogeneity, i.e. finding convincing instrument variable for computerization for example, is notoriously hard with the industrial data. In the model specifications, we therefore assume that the explanatory variables are exogenous; positing that analysis of the effects of direct measures for computerization and pay-setting institutions on wage inequality within industries over time can provide important answer to the debate on the causes of inequality.

9 Based on the results from stationary tests for the error terms in all models.

10 The five smallest industries in the dataset, each of which accounts for 0.4% of the workforce in 1969–1997, are motion pictures, telephone, transportation services, petroleum coal and water transportation. The five largest industries include retail trade (21.8% of the workforce), business services (8.7%), wholesale trade (8.3%), construction (6.9%) and electric and electronic equipment (4.1%). Weighting ensures that large industries such as retail trade and small industries such as motion pictures do not carry the same weight in the estimations.

4. The effects of computers and institutions on rising wage inequality

We first analyse how much of the well-known trend of rising inequality since the mid-1970s is due to within-industry inequality, and how much due to between-industry inequality. Figure 1 divides the total variance in log wages into shifts that occur within and between industries. We obtained these components from a regression of log wages with 2-digit industry categories as predictors. Between-industry inequality, measured by the variance of predicted wages, describes the dispersion of average wages across the industries. Within-industry inequality, measured by the residual variance, describes the spread of wages among workers in each of these industries. Figure 1 clearly shows that rising inequality is mostly due to the increase in within-industries inequality (about 85–90%, depending on the year), the trend on which we focus in this article.

Table 2 presents the growth in wage inequality for seven industrial sectors, and Figure 2 plots the raw data for the independent variables by industrial sector. A visual inspection of the time-series data by industrial sector is useful, enabling us to observe the major changes in the independent variables over the last four decades in sectors that experienced the sharpest rise in wage inequality. Altogether, the figures by industrial sector indicate that the erosion of pay-setting institutions was probably the main explanation for rising inequality during the 1980s, and together with computerization accounted for the continuing rise in inequality in the 1990s.

Table 2 reveals that the largest growth in inequality occurred in transportation and manufacturing industries (that accounted for nearly half of the labour force in 1970, decreasing to one fifth in 2012). As shown in Figure 2, the salient time trends for the small transportation industry where inequality increased most sharply are mainly institutional: the rapid decline in union density and the decrease in the share of large employers. Changes in other independent variables in transportation, including computerization, are relatively minor. In manufacturing, too, union density and the share of large employers declined sharply over the entire period, but at the same time investment in computers increased substantially. In manufacturing, there was also the most profound growth in the weight of finance income, which significantly slowdown in the 2000s.

In the non-union industries of finance, insurance and real estate (FIRE), the expanding services and trade (with combined private-sector employment of over 70% in 2012), inequality has also increased substantially, although not as much as in transportation and manufacturing. In these industries, there was a significant rise in computer investments, while the main institutional factor, union density, remained very low (in FIRE) or declined slightly (in services and trade). However, services and trade industries are characterized by a large and growing (mainly in the 1980s) proportion of low-wage workers—measured as those earning hourly wages below the 1975 minimum wage ($9.3 in 2014 prices). Therefore, the fall in real minimum wage in the 1980s should have increased inequality mainly in these industries. Finally, the rise in wage inequality came earlier in construction than in other industrial sectors and was steepest in the 1970s (data not shown), in parallel with the dramatic decline in union density, while staying relatively constant in the 1980s and 1990s, only to accelerate again since the early 2000s.[11]

11 Part-time employment increased mainly in the 1970s in trade and construction industries, stayed relatively constant in the 1980s and even slightly declined in the 1990s, probably with the expansion of other forms of non-standard employment relations such as temporary-agency employment and employment through contract companies.

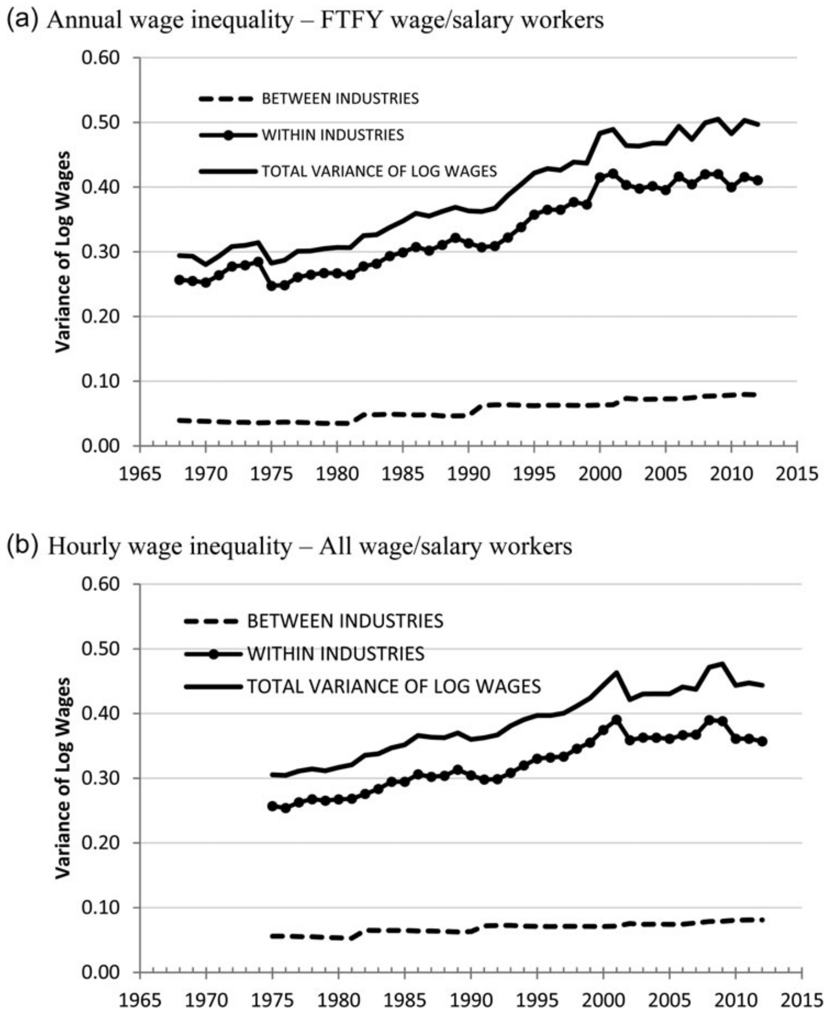


Figure 1 Overall wage inequality, between-industries inequality and within-industries inequality.

In Table 3, we estimate the institutional and technological effects on annual change in wage inequality measured by the 90–10 gap in log wages. Results for measuring inequality by the standard deviation are appreciably the same (data not shown). Using the methods described in the preceding section, we model the change in wage inequality within industries as a function of short-term changes (i.e. first differences) and long-term levels (i.e. lagged values) of industry-level measures. We expect to find a positive effect (i.e. increasing inequality) for an increase in computer investments, part-time employment, financialization and import penetration on changes in wage inequality and a negative effect (i.e. decreasing inequality) for an increase in college supply, unionization, employment in large firms and real minimum wage. Results for annual wage inequality among FTFY workers are shown for 43 non-agricultural private-sector industries (Models 1–2), and only for 18 manufacturing industries

Table 2 Wage inequality and employment in non-agricultural private-sector industries[a] by industrial sector[b], 1970–2012

	Annual wage inequality—FTFY workers			Annual wage inequality—FTFY workers			Share in total employment—FTE workers			
	1970	1997	Growth	1988	2012	Growth	1970	1997	1988	2012
Mining	0.923	1.386	50.2%	1.413	1.526	8.0%	1.3%	0.7%	0.9%	0.9%
Transportation[c]	1.044	1.386	32.8%	1.232	1.481	20.2%	8.8%	7.7%	5.5%	5.6%
Manufacturing	1.214	1.482	22.1%	1.452	1.607	10.6%	38.6%	23.3%	23.0%	13.8%
FIRE[d]	1.342	1.582	18.0%	1.470	1.671	13.7%	7.1%	8.6%	8.8%	8.8%
Services[e]	1.517	1.750	15.4%	1.664	1.881	13.1%	10.1%	20.9%	32.3%	42.7%
Trade	1.415	1.534	8.4%	1.492	1.638	9.8%	27.0%	31.6%	22.3%	21.6%
Construction	1.235	1.335	8.1%	1.364	1.447	6.1%	7.1%	7.2%	7.3%	6.5%
Total private	1.288	1.609	25%	1.525	1.671	9.6%	100%	100%	100%	100%

Source: March CPS and BEA Industry Economic Accounts.

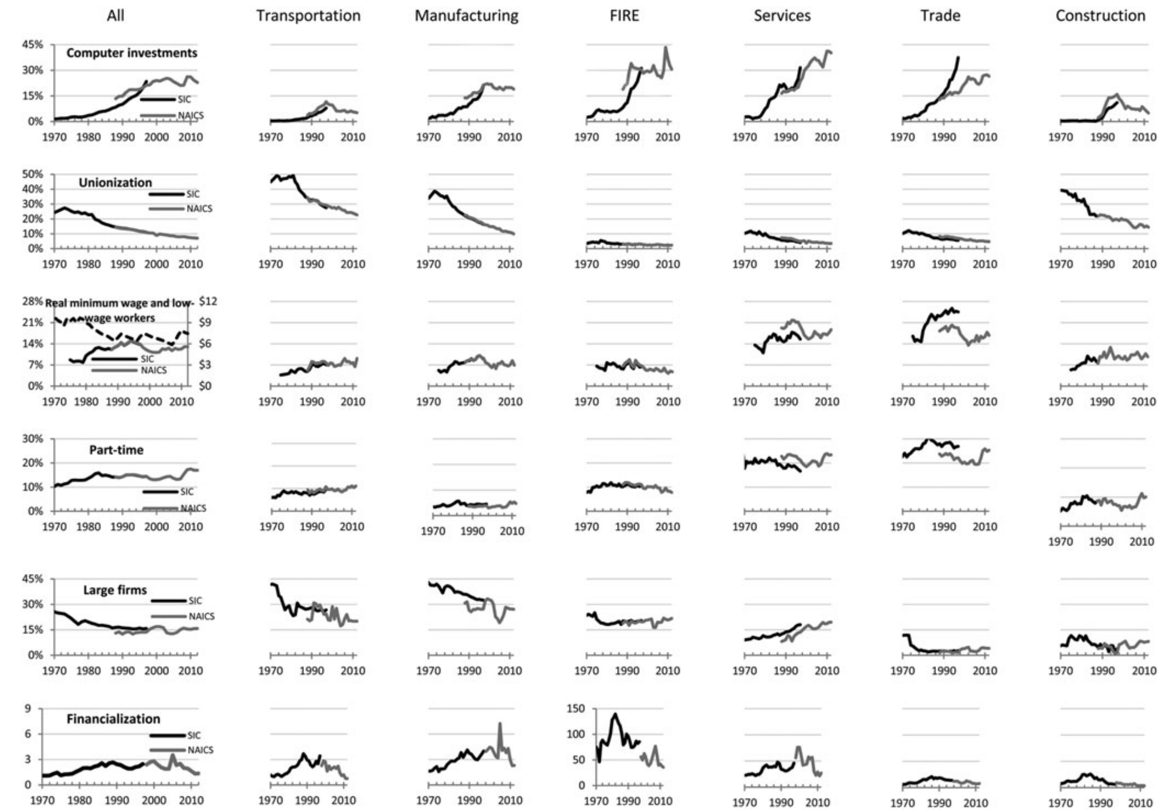
[a]Excluding agriculture, government, service-sector aggregates with substantial government employment (e.g. healthcare and educational services), and private households.

[b]It is not possible to provide comparable time-series trends by industrial sectors for the entire 1970–2012 period. Starting in 1997, the Census Bureau shifted to a new industry classification structure, the North American Industry Classification System (NAICS), which replaced the 1987 Standard Industrial Classification (SIC) system. The NAICS caused disruptions in time series far more profound than any previous revision of the SIC system, due to the addition of industries not previously recognized separately under the SIC, and because several activities were not only reclassified, but moved to other industrial sectors.

[c]Including transportation, communication and utilities industries in the SIC and transportation and utilities industries in the NAICS.

[d]FIRE is the industry group comprised by finance, insurance and real estate.

[e]Services include industries such as personal services, business services, hotels and restaurants, repair services, amusement and recreation services and motion pictures.



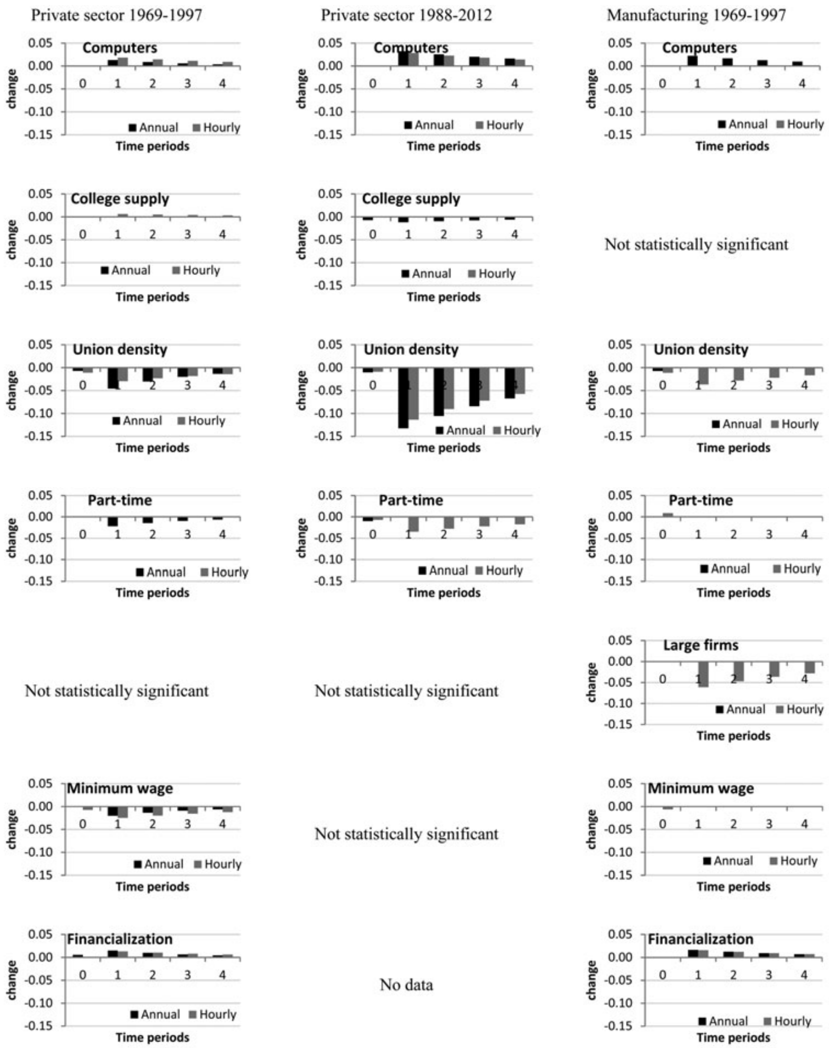
Note: It is not possible to provide comparable time-series trends by industrial sectors for the entire period. We therefore present one line for 1970-1997 (Standard Industrial Classification in the black line) and another line for 1987-2012 (North American Industry Classification System in the grey line). [a] Low-wage workers are those with hourly wages below the 1975 minimum-wage ($9.3 in 2014 prices).

Figure 2 Trends in computerization and pay-setting institutions by industrial sector, 1970–2012[a].

Table 3 Computers, college supply, pay-setting institutions and earnings inequality (1969–2012) in non-agricultural private-sector industries, dependent variable is annual change in the annual or hourly wage inequality

Dep. variable	Δ Annual wage inequality 90/10			Δ Hourly wage inequality 90/10		
Sector	Private sector		Manufacturing	Private sector		Manufacturing
Number of industries	43	43	18	43	43	18
Year	1969–1997	1988–1912	1973–1997	1976–1997	1988–2007	1976–1997
Model	I	II	III	IV	V	VI
Δ Computer investments	−0.001 (0.002)	0.002 (0.002)	−0.001 (0.002)	−0.001 (0.002)	0.001 (0.001)	−0.004 (0.002)
Computer investments$_{(t-1)}$	0.002** (0.001)	0.002** (0.001)	0.003** (0.001)	0.002** (0.000)	0.002** (0.001)	0.001 (0.001)
Δ College supply growth	0.001 (0.001)	−0.004** (0.002)	−0.001 (0.002)	0.002 (0.002)	−0.003 (0.002)	0.001 (0.002)
College supply growth$_{(t-1)}$	0.001 (0.001)	−0.008** (0.003)	−0.000 (0.002)	0.003* (0.002)	−0.002 (0.002)	0.002 (0.003)
Δ Union density	−0.003** (0.001)	−0.006** (0.002)	−0.003* (0.001)	−0.005** (0.001)	−0.005** (0.002)	−0.005** (0.001)
Union density$_{(t-1)}$	−0.003** (0.001)	−0.009** (0.002)	−0.002 (0.002)	−0.002* (0.001)	−0.008** (0.002)	−0.003* (0.001)
Δ Part-time	−0.003 (0.002)	−0.004* (0.002)	0.001 (0.003)	0.002 (0.002)	−0.003* (0.002)	0.006* (0.003)
Part-time$_{(t-1)}$	−0.002* (0.001)	−0.003 (0.002)	0.001 (0.005)	0.001 (0.002)	−0.004* (0.002)	0.005 (0.004)
Δ Large firms	−0.001 (0.001)	0.001 (0.001)	0.001 (0.003)	−0.001 (0.001)	0.001 (0.001)	−0.003 (0.003)
Large firms$_{(t-1)}$	−0.001 (0.001)	0.001 (0.001)	−0.002 (0.001)	−0.001 (0.001)	0.000 (0.001)	−0.003** (0.001)
Δ Minimum wage	−0.003 (0.006)	0.002 (0.009)	−0.006 (0.011)	−0.019** (0.007)	−0.004 (0.007)	−0.016* (0.009)
Minimum wage$_{(t-1)}$	−0.016** (0.005)	0.005 (0.007)	−0.015 (0.009)	−0.023** (0.006)	−0.001 (0.005)	−0.011 (0.010)
Δ Financialization	0.010** (0.005)	–	0.003 (0.005)	0.004 (0.005)	–	−0.001 (0.006)
Financialization$_{(t-1)}$	0.011** (0.003)	–	0.011** (0.004)	0.009* (0.005)	–	0.010* (0.005)
Δ Non-Hispanic White Men	−0.001 (0.001)	−0.002 (0.001)	−0.002 (0.002)	0.002 (0.001)	−0.000 (0.001)	−0.002 (0.001)
Non-Hispanic White Men$_{(t-1)}$	0.001 (0.001)	−0.002 (0.001)	−0.003 (0.002)	0.003** (0.001)	−0.001 (0.001)	−0.001 (0.001)
Δ Import penetration	–	–	0.001 (0.006)	–	–	−0.001 (0.004)
Import penetration$_{(t-1)}$	–	–	0.000 (0.000)	–	–	0.002** (0.001)
Dependent variable$_{(t-1)}$	−0.664** (0.035)	−0.798** (0.089)	−0.755** (0.083)	−0.785** (0.056)	−0.796** (0.098)	−0.771** (0.055)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.341	0.398	0.386	0.401	0.401	0.407
Modified DW	1.88	1.99	1.98	1.92	2.01	1.99
Panel stationary test, P value	0.000	0.000	0.000	0.000	0.000	0.000
N	1247	1075	450	946	1075	396

Each column represents a pooled regression of changes in wage inequality. Table entries are OLS estimates. Estimates are weighted by the mean industry share of total employed workers over the years. The robust standard errors in parentheses are heteroskedasticity and autocorrelation consistent. All models include constant term and control for recession years. The null hypothesis in the panel stationary test is that the error terms are non-stationary. $^*P < 0.10$, $^{**}P < 0.05$, two-tailed test. Δ indicates the annual change in the variable.



Note: not statistically significant refers to p>0.1, two-tailed test. [a] Unstandardized regression coefficient multiplied by the sample standard deviation of the independent variable. This represents the change in Y over time after an increase of one standard deviation in X, in original units of Y.

Figure 3 Estimated lag distributions for change in wage inequality within-industries, 1969–2012[a].

(Model 3). Results for hourly wage inequality among all workers are shown for private industries (Models 4 and 5) and in manufacturing industries (Model 6). To illustrate the dynamic pattern of relations and the size effect for each independent variable, Figure 3 plots their lag distributions for the private-sector industries and manufacturing industries. The lag distribution, presented by the comparable semi-standardized coefficients, is the amount by which wage inequality changes each year, expressed in percentage points, in response to an increase of one standard deviation in the independent variable.

Overall, we find strong empirical support for the argument that the erosion of pay-setting institutions led to rising wage inequality. The results reveal that the decline in unionization and the fall in minimum wage led to a significant rise in wage inequality between 1969 and 2012. Union density in particular has robust long- and short-term negative effects on changes in annual and hourly wage inequality in both periods, and in both the entire private non-agricultural sector and only manufacturing industries. The rise in part-time employment, the decline of employment by large firms and the importation of goods from less-developed countries mostly increased hourly wage inequality among manufacturing workers in the first period (1969–1997). Hence, the decline in the share of employees in large firms in manufacturing industries from 43% in 1973 to 35% in 1997 increased wage inequality among all workers, but had no effect on inequality among FTFY workers who are more likely to be employed in standard employment relations. That part-time employment had a negative effect on changes in wage inequality in the 1990s is probably due to the change of trend as part-time employment slightly decreased (see Figure 2).

We also find strong empirical support for the argument that computerization has led to rising wage inequality. Computer investments have a long-term positive effect on wage inequality in private-sector industries and in manufacturing industries, among all workers and among only FTFY workers (but short-term change effects are not statistically significant). In line with the SBTC thesis, we find that the slowdown in the growth of the supply of college-educated workers explain part of rising inequality, but only among FTFY workers and in the second period (1988–2012).

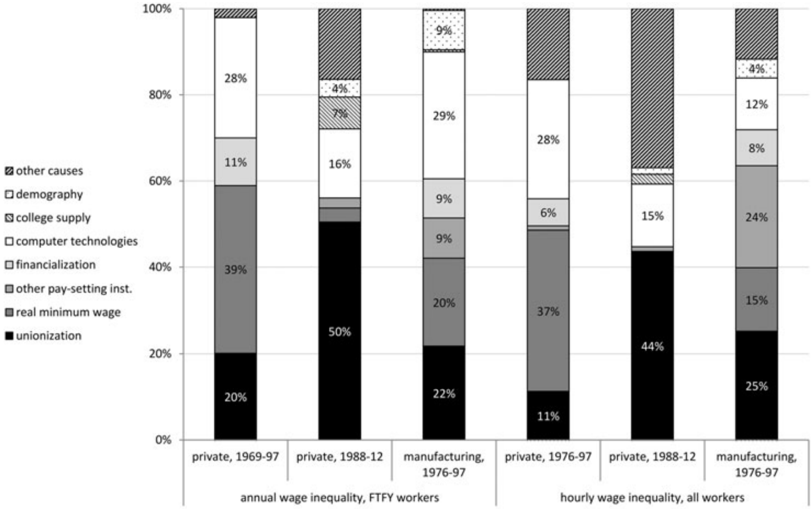
While semi-standardized coefficients allow us to compare independent variables according to the relative strength of their effects on wage inequality, one would also like to have an idea of the maximum impact of a given variable on inequality, given the range of values of that variable in the data set. To measure how much a given independent variable may have affected wage inequality within the history of a single industry, we calculated a coefficient of maximum longitudinal impact (Alderson and Nielsen, 2002). This is the long-run multiplier (LRM) coefficient (measured by dividing the coefficient of the lagged independent variable by the coefficient of the lagged wage inequality) multiplied by the average within-industry range of the independent variable. The coefficient reflects how much change in inequality could have taken place over time in a single industry given the typical range of variation in the independent variable within an industry (Table 4). In Figure 4, we calculate how much of overall rising inequality between 1969 and 2012 these (positive) maximum longitudinal impacts account for. To this end, we compute the variables' maximum longitudinal impact in each period as a percentage of rising inequality during these years. While admittedly crude and partly affected by model specifications, this common method for estimating the relative explanatory power provides a rough estimation for the important question of the relative importance of market forces versus institutional factors as causes of rising inequality.

We find that for the entire period 1969–2012 the decline of organized labour is the main factor that led to rising inequality in the private sector. As shown in Figure 4, de-unionization and the fall in minimum wage together explain almost half of overall rising inequality in the private sector. Computerization also explains a significant part of the change in wage inequality, albeit smaller than that attributable to the two main institutional factors. The diffusion of computer technologies explains 28% of rising wage inequality among FTFY workers and 28% of rising wage inequality among all workers between 1969 and 1997. In the second period (1988–2012), the explanatory power of computerization is lower, accounting for 16% of rising wage inequality among FTFY workers and 15% of rising wage inequality among all workers. Our measures for non-standard employment relations—part-time

Table 4 Long-run multipliers[a] for wage inequality and maximum longitudinal impact[b]

Sector	Private-sector industries							Manufacturing industries	
Indicator	Long-run multipliers		Maximum longitudinal impact					LRM	MLI
Years	1969–1997	1988–2012	1969–1997	1988–2012	1980s	1990s	2000s	1976–1997	1976–1997
	I	II	III	IV	V	VI	VII	VIII	IX
Expected change in annual inequality due to:									
Computer investments	0.003	0.003	0.056	0.023	0.017	0.018	0.004	0.004	0.075
College supply growth	0.002	−0.010	−0.013	0.011	−0.007	−0.004	−0.007	−0.001	0.001
Union density	−0.004	−0.011	0.040	0.074	0.032	0.033	0.036	−0.003	0.056
Part-time	−0.004	−0.005	−0.006	0.000	0.001	0.007	−0.009	0.002	0.001
Large firms	−0.001	0.001	0.004	0.003	0.001	0.003	0.000	−0.002	0.019
Minimum wage	−0.023	0.006	0.077	0.005	0.073	0.006	0.001	−0.020	0.052
Financialization	0.016		0.022		0.017			0.014	0.023
Non-Hispanic White Men	0.000	−0.002	−0.004	0.006	−0.001	0.004	0.002	−0.003	0.023
Import penetration								0.000	0.005
Expected change in hourly inequality due to:									
Computer investments	0.003	0.002	0.056	0.020	0.019	0.015	0.004	0.002	0.030
College supply growth	0.004	−0.003	−0.007	0.003	−0.012	−0.001	−0.002	0.002	−0.004
Union density	−0.002	−0.010	0.023	0.061	0.017	0.027	0.030	−0.003	0.063
Part-time	0.002	−0.005	0.000	0.000	−0.001	0.008	−0.011	0.007	0.002
Large firms	−0.001	0.000	0.002	0.001	0.002	0.001	0.000	−0.004	0.030
Minimum wage	−0.029	−0.001	0.075	−0.001	0.090	−0.001	0.000	−0.014	0.037
Financialization	0.012		0.013		0.012			0.013	0.021
Non-Hispanic White Men	0.004	−0.001	−0.035	0.002	−0.017	0.001	0.001	−0.002	0.011
Import penetration								0.002	0.026
Observed change in annual wage inequality			0.199	0.146	0.116	0.088	0.063		0.255
Observed change in hourly wage inequality			0.202	0.139	0.118	0.081	0.067		0.251

[a]This is a result of dividing the coefficient of the lagged independent variable by the coefficient of the lagged wage inequality. This calculation yields the long-term multiplier that represents the total long- and short-term effect on wage inequality for a one-point increase in the independent variable.
[b]This is the long-run multiplier multiplied by the average within-industry range of the independent variable. The coefficient reflects how much change in inequality could have taken place over time in a single industry given the typical range of variation in the independent variable within an industry.



Source: Table 4.
Note: Other pay-setting institutions includes large-firms' employment, part-time employment, and import penetration.

Figure 4 Causes of rising wage inequality, 1969–2012.

employment and employment in large firms—explain only a minor share of rising inequality. Only for hourly wage inequality in manufacturing industries does the decline in large-firm employment explain a noteworthy share of the rise, 12%. We also find that financialization is an important factor in rising wage inequality, explaining 11% of rising wage inequality among FTFY workers and 6% of rising wage inequality among all workers between 1969 and 1997.

That de-unionization and the fall in the minimum wage are the main explanations for rising inequality is also apparent when we break down the analyses by decades (Table 4). In the 1980s, union density and minimum wage had the largest longitudinal impact on annual and hourly wage inequality, and in the 1990s and 2000s union density had the largest impact. Minimum wage, which increased slightly in the 1990s and since 2008, does not explain rising inequality in these decades. All of the above is based on inequality within industries, in which almost all (about 85–90%) of the rise in inequality occurred. Our estimations are likely to be an underestimate of the role of pay-setting institutions, given the pivotal role of de-unionization and the spread of non-standard employment relations in between-industry inequality (Kim and Sakamoto, 2008; Morgan and Tang, 2007).

5. Discussion and conclusion

In 1997, Alan Krueger, a leading labour economist and contributor to the inequality literature, asked a non-random group of prominent economists what they think are the main causes of rising inequality. In a recent policy speech, Krueger (2012), then the Chairman of the Council of Economic Advisors to the President, reiterated the consensus among his respondents: 'The most important factor. . . was skill-biased technical change. . . . A distant second in this poll was other and unknown factors' ('other' did not include institutional factors). Even Thomas Piketty, whose chapter on labour income inequality (2014, pp. 304–

335), sympathizes with institutional explanations, especially the fall in real minimum wage is silent about the effect of union decline on rising wage inequality.

Contrary to that view, we find that the decline of pay-setting institutions is almost twice as important as technology-driven demand for skilled labour in explaining rising inequality within US industries. In fact, the decline of unionization and the real minimum wage explains about 50–60% of rising wage inequality in US private industries between 1969 and 2012, while the spread of computer technology explains 28–29% between 1969 and 1997 and 15–16% between 1988 and 2012, and the slowdown in the supply of educated workers explains 7% between 1988 and 2012. For reasons we explained earlier, the available US results (Wolff, 2006) are different, but similar results showing a larger effect of de-unionization (versus computerization) on inequality were found in Germany (King, 2013), as well as in a study on 22 developed countries (OECD, 2011).

Our findings also put in question the common notion that the erosion of pay-setting institutions accounts only for lower-tail (50/10) inequality (which rose sharply in the 1980s and has been constant or even contracted thereafter), while upper-tail (90/50) inequality (which led to the overall rise in wage inequality in the 1990s and 2000s) was mostly driven by market mechanisms, especially SBTC (Lemieux, 2008). Breaking down the analysis by decades, we find that, as expected, during the 1980s wage inequality grew mainly due to the decline of organized labour and the fall in the minimum wage. Yet the decline of unions is the main explanations for rising inequality in the 1990s and 2000s as well. These findings imply that the erosion of labour unions explains not only lower-tail inequality in the 1970s and 1980s, as is commonly acknowledged, but also upper-tail inequality in more recent decades, possibly since unions served as an important check on the pay of upper management (DiNardo *et al*., 1997).

One question in the inequality literature is why the US has experienced a sharper increase in wage inequality than European countries (Kenworthy, 2007), although computer technology, presumably the main cause of rising inequality, diffused about equally across all countries. Our finding that the erosion of pay-setting institutions, in particular labour unions, is the dominant factor which explains rising wage inequality in the USA may help solve this puzzle by pointing to the system of industrial relations as the key factor. In the USA and other English-speaking countries where inequality increased sharply, unions declined (both in density and power) more than in most European countries (Wallerstein and Western, 2000). Our conclusion that institutional processes rather than technology are the main cause of inequality is thus in line with comparative studies showing that institutional forces such as unions, centralized wage bargaining and leftist political parties affect the extent of inequality across rich countries (Bradley *et al*., 2003; Brady, 2003; Iversen and Soskice, 2006).

We should also bear in mind that finding a positive effect for computers on rising inequality does not reveal what caused this effect. Recently, a few studies have questioned the assumption that SBTC is the only mechanism through which computerization increases inequality (DiMaggio and Bonikowski, 2008). While SBTC surely has a role in explaining the effect of computerization on rising inequality, it is rather restrictive to assume that computers, having profound impact on various structural aspects of the production process, have impacted the labour market and wage inequality solely via skills and productivity. In her study of the decline in labour's share of national income, Kristal (2013) demonstrated that computerization reduced the labour's share (and increased corporate profits) also indirectly by exacerbating union decline. In a study of wage inequality (Kristal and Cohen, 2015), the indirect effects of computerization on inequality—channelled mainly through weakening unions and to a lesser extent by enhancing the rise of non-standard employment relations—were even greater than the direct effects. Additionally, the SBTC thesis does not take into account the possibility that class-based inequality can affect the supply of skills. In other words, the distribution of education depends on the educational system that is shaped by public policy and class power to resist or support more public investment in education (Busemeyer and Iversen, 2014).

Evidently, the diffusion of ICT across establishments and industries and the erosion of pay-setting institutions are embedded in a larger institutional context that led to an increase in various dimensions of social and economic inequality. In the early post-war accord years, market outcomes were greatly moderated by labour unions, an industrial system of collective bargaining, high minimum wage and progressive taxes. In the past four decades, the social contract between capital, labour and the state has been broken (Mizruchi, 2013), raising the question whether the sharp increase in earnings inequality has been due to the invisible hand of the market or to what some call the 'grabbing hand' of the elite (Krugman, 2002; Piketty, 2009). Evidence from the current study mainly supports the second possibility, namely that the erosion of pay-setting institutions has enabled business and top earners to grab a disproportionate share of income, leaving most rank and file workers far behind.

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