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Abstract

Average hourly real wage series from the Labor Productivity and Costs (LPC) program and the Current Employment Statistics (CES) program have evolved very differently over the past decades. While the LPC wage has grown consistently over time and become markedly more volatile since the mid-1980s, the CES wage stagnated from the early 1970s to the mid-1990s and experienced a substantial drop in volatility since the mid-1980s. These differences are due to the divergent evolution of average weekly earnings in the two data sets. Average weekly hours, by contrast, have evolved very similarly. Using information from the Current Population Survey and other publicly available data, we identify two principal sources for the divergent evolution of weekly earnings: differences in earnings concept (employer-paid supplements and irregular earnings of high-income individuals included in the LPC data but not in the CES data); and differences in worker coverage (all non-farm business workers for the LPC data versus production and non-supervisory workers in private non-agricultural establishments for the CES data). The results have important implications for the appropriate choice of aggregate wage series in macroeconomic applications.

JEL classification: E01, E24, E30, J30
Bank classification: Business fluctuations and cycles; Labour markets

Résumé

Les mesures du salaire réel horaire moyen (aux États-Unis) provenant du programme relatif à la productivité et aux coûts du travail (Labor Productivity and Costs, ou LPC) et du programme des statistiques actuelles de l'emploi (Current Employment Statistics, ou CES) ont évolué de façon très différente au cours des dernières décennies. D'après la mesure LPC, les salaires ont connu une croissance régulière au fil du temps et une augmentation marquée de la volatilité depuis le milieu des années 1980, tandis que la mesure CES indique une stagnation entre le début des années 1970 et le milieu des années 1990 ainsi qu'une baisse substantielle de la volatilité depuis le milieu des années 1980. Ces différences découlent d'une évolution divergente du revenu hebdomadaire moyen dans les deux séries de données, car le nombre moyen d'heures travaillées par semaine a évolué de façon remarquablement similaire dans les deux programmes. À partir de données provenant de l'enquête sur la population américaine (Current Population Survey) et d'autres sources publiques de renseignements, nous montrons que l'évolution divergente du revenu hebdomadaire tient à deux grands facteurs : d'une part, des différences dans la définition du revenu (le programme LPC tient compte des suppléments payés par l'employeur et de la rémunération versée en sus du salaire régulier aux employés à salaire élevé, ce que ne fait pas le programme CES); d'autre part, des différences relatives aux catégories de travailleurs incluses dans les mesures (tous les travailleurs d'entreprises non agricoles dans le cas du programme LPC, et les travailleurs de la production et les travailleurs non cadres d'établissements privés non agricoles dans le cas du programme CES). Les résultats ont d'importantes implications pour le choix des séries statistiques sur le revenu réel horaire moyen qui sont utilisées dans des applications macroéconomiques.

Classification JEL : E01, E24, E30, J30
Classification de la Banque : Cycles et fluctuations économiques; Marchés du travail

Non-technical summary

The evolution of average hourly real wages is a key indicator for current economic analysis and the focus of much research in applied labor and macroeconomics. In the United States, two of the most popular measures of average hourly wages come from the Labor Productivity and Costs (LPC) program and from the Current Employment Statistics (CES) program, both published by the Bureau of Labor Statistics (BLS). Over the past decades, these two measures have evolved very differently: while the LPC wage has grown consistently over time and become markedly more volatile since the mid-1980s, the CES wage stagnated from the early 1970s to the mid-1990s and experienced a substantial drop in volatility since the mid-1980s. Consequently, not only do these measures differ in terms of levels, but also in terms of both trend and volatility.

Despite these remarkable differences, very little research has been devoted to understanding them and the two wage measures are often used interchangeably with little or no justification. This is problematic, since the two measures have very different implications for important policy and research questions. For instance, the extent of the decline in U.S. labor share of income, inflationary pressures coming from wage growth, or calibration of modern macroeconomic models depends very much on the wage series considered.

The objective of this paper is to reconcile the differences between the average hourly wage series from the LPC and the CES so as to provide practitioners and researchers with a basis to decide on the appropriate choice of wage measure.

We find that the divergence between the two hourly wage series is due to the divergent evolution of average earnings in the two data sets. Average hours, by contrast, evolve very similarly. We use information from the micro data of the Current Population Survey (CPS) and other publicly available data to identify and quantify the two principal sources for the divergent evolution of weekly earnings: (1) differences in earnings concept (employer-paid supplements and irregular earnings of high-income individuals included in the LPC but not in the CES), and (2) differences in worker coverage (all non-farm business workers for the LPC versus production and non-supervisory workers in private non-agricultural establishments for the CES). These two sources account for about 90% and 70%, respectively, of the divergence in trend and volatility between the LPC and the CES wage series.

1 Introduction

The average hourly real wages is a key indicator for current economic analysis and the focus of much research in applied labor and macroeconomics. In the United States, two of the most popular measures of average hourly wages come from the Labor Productivity and Costs (LPC) program and from the Current Employment Statistics (CES) program, both published by the Bureau of Labor Statistics (BLS). Over the past decades, the two measures have evolved very differently:

1. The LPC wage was about 30% higher than the CES wage in the early 1970s and has consistently grown since then. The CES wage, by contrast, stagnated from the early 1970s to the mid-1990s and, as of 2013, stood about 85% below the LPC wage.

2. The LPC wage was about half as volatile as the CES wage until the mid-1980s. Since then, the volatility of the LPC wage has almost doubled, while the volatility of the CES has dropped by about 50%, so that the LPC wage is now nearly twice as volatile as the CES wage.[1]

The objective of the current paper is to reconcile the differences between the LPC wage and the CES wage. This is important because the LPC wage and the CES wage are often used interchangeably with little or no justification, even though the two measures have potentially very different implications for a number of key policy and research questions. First, the slowdown in wage growth experienced by a large part of the U.S. workforce over the past decades has been among the most hotly debated topics in economics in recent years.[2] Yet, given the above numbers, it should be clear that the extent of this "Great Wage Slowdown" depends on the choice of wage measure.[3] Second, changes in wage growth constitute an important input for current economic analysis, especially as an indicator of inflationary pressures.[4] The LPC and the CES routinely provide different accounts in that respect, which can substantially affect the economic outlook.[5] Third, wage dynamics play a central role for many theories of the business cycle.[6] Since the LPC wage and the CES wage have similar business cycle properties when computed over the entire postwar sample, the literature

[1] These results do not depend on whether the 2008-09 recession and subsequent recovery are included.

[2] See, for example, Leonhardt (2014) and references therein.

[3] For example, based on the LPC, the labor share (computed as average hourly compensation divided by GDP per hour) fell by 11% over the past 40 years. According to the CES, by contrast, labor share dropped by 37% over the same time period.

[4] See, for example, the Federal Reserve Board's new Labor Market Conditions Index (LMCI), which includes the CES wage as a measure of labor cost (Chung et al., 2014).

[5] For example, hourly wage growth in the first quarter of 2015 relative to a year earlier was 3.3% according to the LPC, whereas it was only 2.1% according to the CES.

[6] See King and Rebelo (2000); Christiano, Eichenbaum and Evans (2005); and Shimer (2005) for three prominent examples in the context of modern dynamic stochastic general-equilibrium (DSGE) models.

has not paid much attention to the choice of wage measure. But, as highlighted above, this masks important differences in volatility for the pre-1980 and post-1980 subsamples; these differences have potentially far-reaching implications for the relative success of competing theories in accounting for the business cycle fluctuations observed in the data.

Section 2 describes the data and documents the different evolutions of the LPC wage and the CES wage. Since the average hourly wage equals the ratio of average weekly earnings to average weekly hours, Section 3 decomposes the difference between the LPC wage and the CES wage into differences coming from the earnings side and the hours side. The key result from this decomposition is that almost all of the differences between the LPC wage and the CES wage are due to differences in average weekly earnings. Average hours, by contrast, evolve very similarly in the two data sets.

Based on this finding, Section 4 attempts to account for the different behavior of average weekly earnings in the LPC and the CES. While there are several potential sources, two stand out. First, earnings in the LPC take into account all forms of compensation, including supplements such as employer contributions to pension and health plans and irregular earnings such as bonuses. In contrast, earnings in the CES only count regular wage and salary payments. Second, the LPC covers all workers in the non-farm business sector. In contrast, the historical earnings and hours series in the CES only cover production and non-supervisory workers in private non-agricultural establishments.[7]

Since the establishment records underlying the LPC neither contain information on worker occupation nor distinguish between regular and irregular earnings, it is impossible to directly quantify the importance of differences in earnings concept and worker coverage.[8] Instead, we use information from the Current Population Survey (CPS) and other publicly available data to make progress. Combining individual earnings data from the May supplements and the monthly outgoing rotation group (ORG) extracts of the CPS, we construct an average earnings series that is based on a very similar earnings concept as the one used by the CES but at the same time is representative of all workers.[9] We then add estimates for supplements from the National Income and Product Accounts (NIPAs) and for earnings of high-income individuals from the Internal Revenue Service (IRS) as tabulated by Piketty and Saez (2003), to quantify the importance of differences in earnings concept. In turn, we exploit industry and occupation information on individuals in the CPS May/ORG to assess the role played by the narrower worker coverage in the CES.

[7] Starting in 2006, the CES expanded their earnings coverage to all workers in sampled establishments. This all-workers series is examined in Section 4.

[8] Moreover, the micro data from the CES and the LPC are both confidential and currently unavailable for research purposes prior to the 1990s.

[9] Alternatively, we could have used earnings data from the CPS March supplements. As discussed below, the CPS May/ORG data have several advantages over the CPS March supplements for the purpose of our study.

Our analysis yields several important insights. First, the CPS May/ORG earnings series falls in between the LPC earnings series and the CES earnings series, both in terms of trend growth and business cycle volatility. Given that the CPS May/ORG earnings series differs from the LPC and CES earnings series in different dimensions, this implies that the difference between LPC and CES earnings must have multiple sources.

Second, supplements and earnings of high-income individuals account for almost all of the difference between LPC earnings and CPS May/ORG earnings, not only in terms of trend growth and change in volatility but also in terms of initial level and volatility differences. The result suggests that despite well-documented issues with measurement error in the cross-section (e.g. Bound and Krueger, 1991), the CPS May/ORG data provide a reliable *average* measure of the wages and salaries portion of compensation for all but the highest-paid individuals in the U.S. workforce. This is interesting in its own right because the CPS May/ORG is one of the most widely used micro data sets of individual earnings in the United States.

Third, differences in worker coverage account for almost all of the initial difference in level and volatility between CES earnings and CPS May/ORG earningss and for about two-thirds of the differential trend and business cycle dynamics of the two series thereafter. Together, the combination of differences in earnings concept and differences in worker coverage accounts for the majority of the divergent evolution of the LPC wage and the CES wage, as well as the initial level and volatility differences. The remaining difference between the two series is likely due to a combination of measurement issues that historically arose in the CES as a consequence of the unique challenges associated with administering a voluntary survey to a large panel of establishments.

Section 5 of the paper concludes by discussing the implications of our results for macroeconomic research and policy analysis. Based on our results, we argue that our CPS May/ORG construct, augmented with an estimate for supplements, provides a relevant historical measure of average labor earnings for many applications, because it abstracts from the large and volatile irregular earnings of high-income individuals but includes non-wage compensation, which accounts for a growing portion of labor costs in the United States.

Our paper contributes to a large literature describing the evolution of labor earnings in the United States. To date, only little effort has been made to compare different measures. The paper closest to ours is Abraham, Spletzer and Stewart (1998), who document the divergence in trend growth of average hourly wage measures from the NIPAs, the CPS, and the CES, and use individual earnings data from the CPS May/ORG to replicate the CES worker coverage as described above. Building on their insights, our paper makes several distinct contributions both in scope and methodology that materially affect the conclusions. First, we focus squarely on the divergence between the LPC wage and the CES wage, because the two series are the ones most commonly used for macroeconomic applications. One implication of this choice is that it highlights the growing importance of supplements, which are included in the LPC but not in any of the other earnings measures. Second, we extend the sample analyzed by Abraham, Spletzer and Stewart (1998) by 20 years and consider not only the divergence in trend growth but also the divergence in business cycle volatility as well as the initial level and volatility differences between the two wage measures.[10] Our results indicate that differences in earnings concept and differences in worker coverage can account for the majority of differences in all of these dimensions. Third, our CPS May/ORG earnings construct includes an estimate for overtime, tips and commissions that is adjusted further for earnings of high-income individuals. Both of these adjustments turn out to be important in establishing that differences in earnings concept explain almost all of the divergence between LPC and CPS May/ORG earnings. The inclusion of overtime, tips and commissions in our CPS May/ORG construct also helps to show that the narrower worker coverage in the CES accounts for much of the difference between CPS May/ORG earnings and CES earnings. These conclusions differ from the ones reached by Abraham, Spletzer and Stewart (1998), who only consider usual earnings in their CPS May/ORG measure and therefore cannot reconcile the divergence in the different wage measures as well as we do.

2 Divergent hourly wage series: data and facts

We begin by describing the principal data sources used to construct the different average wage series and then document their evolution over time. Auxiliary data used later in the analysis are described as they are introduced. The appendix contains details about the data as well as robustness checks.

2.1 Data

We consider three principal data sources. For each of them, we compute an average hourly wage series by dividing average weekly earnings with the respective average weekly hours. All weekly earnings and therefore all hourly wage series are deflated using the Personal Consumption Expenditure (PCE) index from the NIPAs.[11]

The first data source is the LPC program of the Bureau of Labor Statistics (BLS), which reports labor market data for the non-farm business sector on a quarterly basis starting in 1948. Average weekly earnings are computed from average total compensation per employee, which consists of both

[10] The divergence in business cycle volatility of the LPC wage and the CES wage has been noted previously by Champagne and Kurmann (2013) and Gali and Van Rens (2014). Neither of these papers analyzes the sources of this divergence.

[11] As Abraham and Haltiwanger (1995) document, the choice of price deflator can have important consequences for the business cycle *cyclicality* of real wages with hours or output. None of our results for the divergence in the different wage series with respect to trend growth and business cycle *volatility* are affected by the use of alternative deflators.

"wages and salaries" and "supplements." Wages and salaries are based on the Quarterly Census of Employment and Wages (QCEW), a mandatory employer-based program for all employees covered by unemployment insurance (UI) that comprises about 98% of U.S. private sector establishments and jobs and includes executive compensation, commissions, tips, bonuses and gains from exercising non-qualified stock options. Supplements are based on estimates by the Bureau of Economic Analysis (BEA) and consist of employer contributions to funds for social insurance, private pension and health and welfare plans, compensation for injuries, etc. Average weekly hours, in turn, are based on hours from the CES survey. See below for details. The resulting earnings and hours series are then augmented with estimates for self-employed workers using information from the CPS.

The second data source is the CES, a voluntary establishment survey conducted by the BLS on a monthly basis. The sample, which is benchmarked to population employment numbers from the QCEW once a year, was significantly expanded during the 1980s and currently covers about 145,000 businesses and government agencies representing 588,000 establishments. The historical average weekly earnings and hours series in the CES are available for private non-agricultural establishments from 1964 on, but only cover production and non-supervisory workers.[12] Earnings comprise regular wage and salary disbursements including overtime during the pay period reported. Tips, commissions and bonuses are included only if earned and paid regularly each pay period or month. Gains from exercising stock options and supplements are excluded. The average weekly hours series counts all hours worked including overtime during the pay period reported.

The third data source is the CPS, a monthly household survey of about 60,000 individuals sponsored jointly by the U.S. Census Bureau and the BLS. Data on earnings and hours are available from different extracts of the CPS. Following Abraham, Spletzer and Stewart (1998) and Lemieux (2006), we combine information from the annual CPS May supplements for 1973-78 with information from the monthly ORGs from 1979 onward, to construct annual series of average weekly earnings and hours for the private non-agricultural business sector (excluding self-employment as in the CES).[13] As explained in full detail in the appendix, weekly earnings are computed differently for salaried and hourly-paid workers. For salaried workers, we take reported weekly earnings at the

[12] Starting in 2006, the CES started collecting earnings data for all workers in private non-agricultural establishments. We use this information below.

[13] After removing observations with missing earnings or hours, self-employed, out of the labor force and unemployed individuals, the May supplements yield an average of 42,037 observations per year between 1973 and 1978, and the ORG files yield an average of 173,925 observations per year between 1979 and 2013. We prefer the May/ORG to the March supplement, another CPS extract that contains earnings information, for different reasons. First, the earnings concept in the May/ORG is closer to the earnings concept in the CES. Second, the March supplements only contain information on total hours worked starting in 1976. Third, the ORG portion of the May/ORG contains roughly four times as many observations as the March supplements. Fourth, as Lemieux (2006) shows, the March supplements poorly measure the wages of hourly-paid workers, which make up 60 percent of the workforce.

main job, which is defined as compensation normally received and includes overtime, tips and commissions (OTC) and bonuses if earned and paid in each period. For hourly-paid workers, we have available reported weekly earnings, reported hourly wages times hours worked and, starting in 1994, separately reported OTC. For 1994 onward, we compute weekly earnings as the higher of reported weekly earnings and the sum of the reported usual hourly wage times weekly hours worked plus OTC. For the period before 1994, we compute weekly earnings as the reported hourly wage times weekly hours worked and adjust this number with an OTC estimate based on 1996-2000 data that vary by gender and education. This provides us with earnings numbers that consistently include an estimate of OTC across both salaried and hourly-paid workers.[14] Moreover, as is usual in the literature, we adjust topcoded individual earnings by a constant factor of 1.3. In Section 4, we experiment with more sophisticated topcode adjustments. Finally, to compute average weekly earnings and average weekly hours, we convert the data from a person basis to a job basis by adjusting earnings and hours for multiple job holdings (MJH) and aggregate the resulting micro data using the CPS Census weights.[15]

Table 1 summarizes the salient features of the three data sources for average weekly earnings and average weekly hours.

[14] As the analysis in the appendix shows, simply using the higher of the reported weekly earnings and the reported hourly wage times weekly hours worked prior to 1994 leads to a discontinuity in the weekly earnings series for hourly-paid workers. This suggests that hourly-paid workers did not fully report OTC in their weekly earnings answer, which is consistent with the assessment by the BLS that led to the inclusion of the separate OTC question starting in 1994 (Polivka and Rothgeb, 1993).

[15] Following Abraham, Spletzer and Stewart (1998), weekly earnings on the second job for individuals who report MJH are set to 30% of weekly earnings on the main job, based on questions asked about multiple job holdings in select CPS May supplements. Weekly hours on the second job are set to the average hours on the second job reported in the 1994-2013 ORGs. See the appendix for details.

	LPC	CES	CPS
Source	* QCEW; covering 98% of private-sector jobs.	* Establishment survey from BLS. * About 160,000 establishments per month in early 1980s to 588,000 per month today.	* Household survey from BLS and Census. * About 60,000 households per month.
Sample	* 1948 onward; quarterly.	* 1964 onward; monthly.	* 1973 onward; annual. CPS May & ORGs. * 1979 onward; monthly. CPS ORGs.
Population coverage	* All employees in non-farm business sector, including estimate for self-employed.	* Production and non-supervisory employees in private non-agricultural sector, excluding self-employed. * From 2006 on, all employees in private non-agricultural sector.	* All individuals in private non-agricultural sector, excluding self-employed (sample is made representative using Census weights).
Earnings concept	* Wages and salaries. * Commissions, tips, bonuses, gains from exercising stock options. * Supplements (e.g. vacation pay, employer contributions to pension and health plans).	* Wages and salaries. * Overtime, commissions and bonuses only if paid regularly. * No irregular bonuses, gains from stock options or supplements. * No tips, unless reported on employee's tax form.	* Wages and salaries. * Overtime, tips, commissions and bonuses only if paid regularly. * No irregular bonuses, gains from stock options or supplements.

Table 1. Description of main data sources.

The table highlights the differences in population coverage and earnings concept – the main focus of the investigation below. While the LPC data cover all workers in the non-farm business sector and have a very comprehensive earnings concept that includes irregular bonuses and benefits, the CES data only cover production and non-supervisory workers employed in private non-agricultural establishments, and use a more restrictive earnings concept that only includes wage and salary disbursements earned and paid in the same period. In comparison, our earnings construct from the CPS May/ORGs (CPS from hereon) covers all workers in the private non-agricultural business sector, similar to the LPC data (except for some small differences that we will address below), but is based on an earnings concept that is, aside from tips, the same as the one employed by the CES.[16] We will exploit this "in-between" characteristic of the CPS data relative to the LPC data and the CES data for much of our analysis. Also note that the inclusion of OTC distinguishes our CPS earnings construct from the one by Abraham, Spletzer and Stewart (1998), who do not take into account OTC and therefore employ a more restrictive earnings concept for their CPS series than in the CES.

[16]According to Abraham, Stewart and Spletzer (1998), tips represent only a very small part of total average earnings in the economy.

2.2 Trends

Figure 1 plots the evolution of average real hourly wages (in 2009 dollars) constructed from the three different data sources.

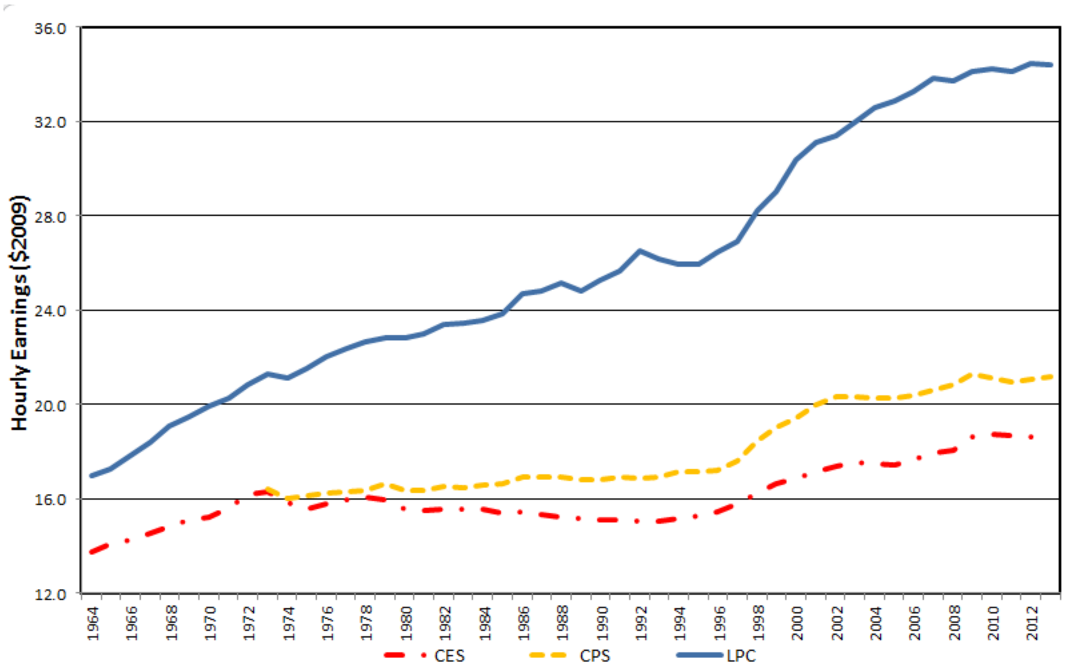


Figure 1. Real average hourly wages.

Three observations stand out. First, in the early 1970s, the LPC wage is already about 30% higher than the CES wage and the CPS wage. Second, the LPC wage grows at a substantially higher rate over the sample, ending up, in 2013, 84% and 62% higher than the CES wage and the CPS wage, respectively. Third, while the CPS wage grows consistently throughout the sample, although at a lower rate than the LPC wage, the CES wage declines slightly from the early 1970s to the early 1990s, returning to moderate growth thereafter.

2.3 Business cycle volatilities

To compute business cycle volatilities, we take logarithms of the different hourly wage series and extract the business cycle component using the Hodrick-Prescott (H-P) filter.[17] Then, we compute standard deviations of each series for the pre-1984 period and the post-1984 period. The break in 1984 is motivated by the Great Moderation literature that estimates a significant change in output

[17]The H-P filter constant is set to 1600 for quarterly data and 6.25 for annual data, as recommended by Ravn and Uhlig (2002). As shown in the appendix, results are robust to alternative filtering methods.

volatility around 1984 (e.g. McConnell and Perez-Quiros, 2000).

Table 2 shows the results. The upper panel reports standard deviations for quarterly series of the LPC wage and the CES wage for the subsamples 1964Q1-1983Q4 and 1984Q1-2013Q4, with standard errors provided in parentheses.[18] The lower panel reports the same standard deviations using annualized data for the samples 1973-1983 and 1984-2013 together with standard deviations for the CPS wage. Both tables also show the corresponding standard deviation of non-farm business real chain-weighted GDP as a benchmark and report the ratio of the standard deviation of the different wage series to the standard deviation of GDP (denoted relative standard deviation).

	Standard Deviation			Relative Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*	*Pre-84*	*Post-84*	*Post/Pre-84*
Quarterly data						
Output	2.73	1.55	0.57	1.00	1.00	1.00
	(0.31)	(0.19)				
LPC wage	0.65	1.10	1.68	0.24	0.71	2.97
	(0.08)	(0.09)		(0.03)	(0.12)	
CES wage	1.12	0.62	0.55	0.41	0.40	0.97
	(0.19)	(0.07)		(0.07)	(0.04)	
Annual data						
Output	2.90	1.40	0.48	1.00	1.00	1.00
	(0.19)	(0.20)				
LPC wage	0.59	0.94	1.60	0.20	0.67	3.31
	(0.09)	(0.14)		(0.04)	(0.17)	
CPS wage	0.66	0.76	1.15	0.23	0.54	2.38
	(0.10)	(0.09)		(0.04)	(0.10)	
CES wage	1.02	0.54	0.53	0.35	0.39	1.10
	(0.14)	(0.09)		(0.05)	(0.05)	

Notes : Total sample extends from 1964Q1 to 2013Q4 for quarterly data; from 1973 to 2013 for annual data. HP-filtered data. PCE-deflated w ages (2009 dollars). Non-farm business sector. PCE-deflated hourly w ages. P-values are reported for a test of equality of variances across the tw o subsamples. Standard errors computed using GMM and the delta method appear in parentheses below estimates.

Table 2. Business cycle volatilities.

There are clear differences in business cycle volatility across the three hourly wage series. While the LPC wage and the CPS wage both exhibit only moderate volatility in the pre-84 period, the CES wage is almost twice as volatile during the same period. The volatility of the LPC wage then increases by 60% or more from the pre-84 period to the post-84 period, and the volatility of the CPS wage increases by 15%. In contrast, the volatility of the CES wage drops by almost 50%. Since the volatility of output drops by 40% to 50% between the two periods, the *relative* volatility

[18]Standard errors are computed via the delta method from generalized method of moments (GMM)-based estimates. See the appendix for details.

of average hourly wages increases by a factor ranging from 2.4 to 3.3 according to the LPC and the CPS, but remains unchanged according to the CES.[19]

3 Earnings – hours decomposition

Since each of the hourly wage series is constructed as the ratio of average weekly earnings to average weekly hours, we start our investigation by decomposing the divergent evolution of the different hourly wage series into a part coming from earnings and a part coming from hours. We perform this exercise for both trends and business cycle volatilities.

3.1 Trends

Figures 2 and 3 plot the evolution of real average weekly earnings (in 2009 dollars) and average weekly hours used in the computation of the three hourly wage series.

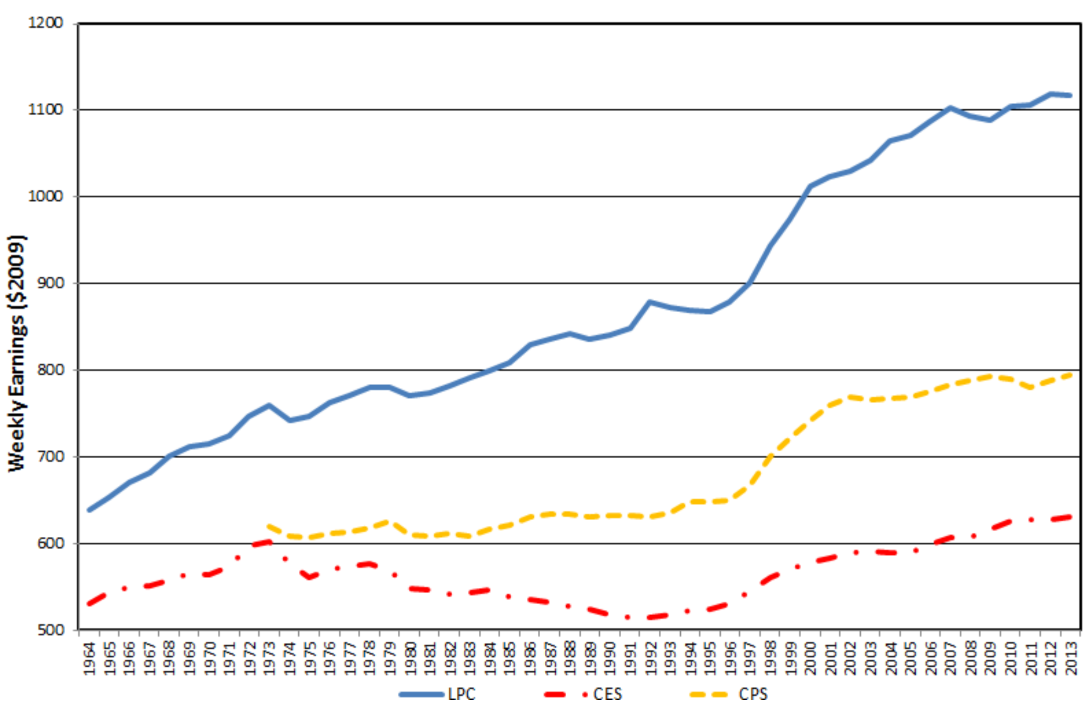


Figure 2. Real average weekly earnings.

[19] There are other big changes in labor market dynamics between the pre-1984 and the post-1984 sample. In particular, as documented by Stiroh (2009) and Gali and Gambetti (2009), both labor productivity and hourly wages experienced a substantial decline in correlation with output and hours starting in the mid-1980s. This decline in business cycle co-movement occurs for both the LPC wage and the CES wage, although it is more pronounced for the CES wage. See the results reported in the appendix.

Figure 2 shows that, similar to average hourly wages, there is already a level difference in 1973 between weekly earnings from the LPC and the two other weekly earnings measures. Thereafter, weekly earnings from both the LPC and the CPS grow consistently, although the average growth rate of LPC weekly earnings is higher. By contrast, weekly earnings from the CES fall substantially between the mid-1970s and the early 1990s before recovering to their early 1970s level by 2005.

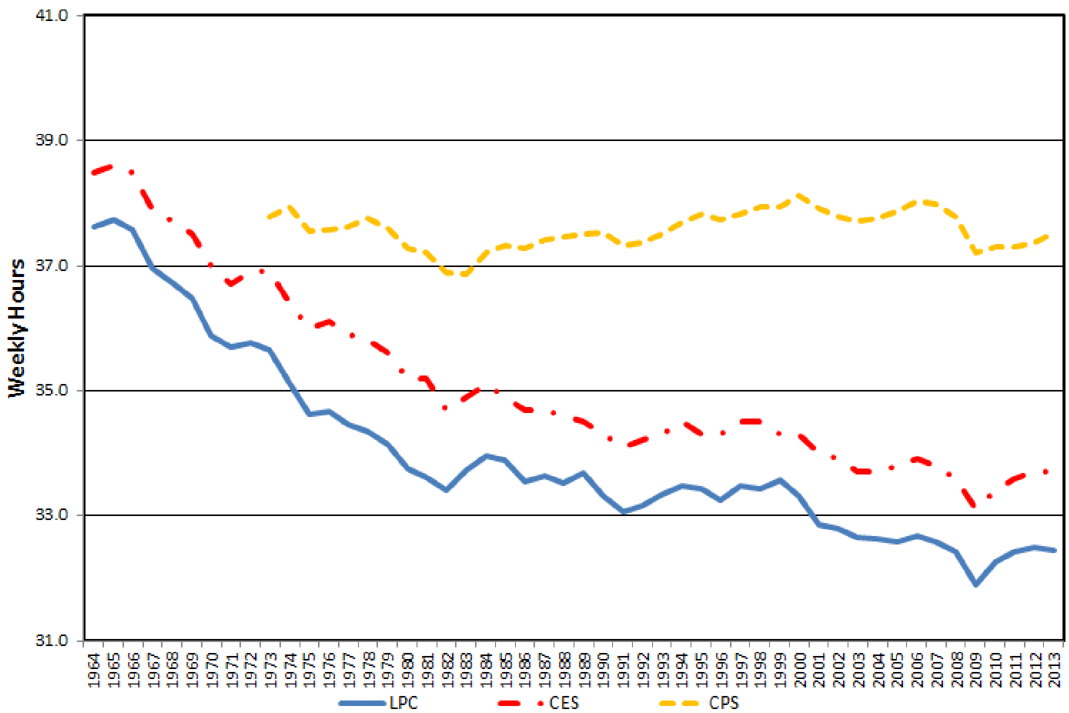


Figure 3. Average weekly hours.

Figure 3 shows that weekly hours in the CES and the LPC data decrease in very similar fashion over time. This should not come as a surprise, since LPC hours are primarily constructed from CES hours. The level difference between the two series is due to the fact that LPC hours refer to "hours worked," whereas CES hours refer to "hours paid," which includes paid leave accrued and sick leave taken.[20] In contrast, weekly hours in the CPS are higher from the beginning and evolve around a constant level. This divergence between CES (respectively, LPC) hours and CPS hours is investigated by Frazis and Stewart (2010).

To quantify the importance of these differences for the divergence in trends of the different

[20]The LPC program makes the adjustment to an "hours-worked" concept using data from the Hours at Work Survey and the National Compensation Survey. The adjustment ratio has remained around 0.93 over the years. See Eldrige, Manser and Otto (2004).

hourly wage series, we use growth accounting techniques. First, we decompose the log difference of each of the hourly wage series into the corresponding log differences of weekly earnings and weekly hours; i.e.

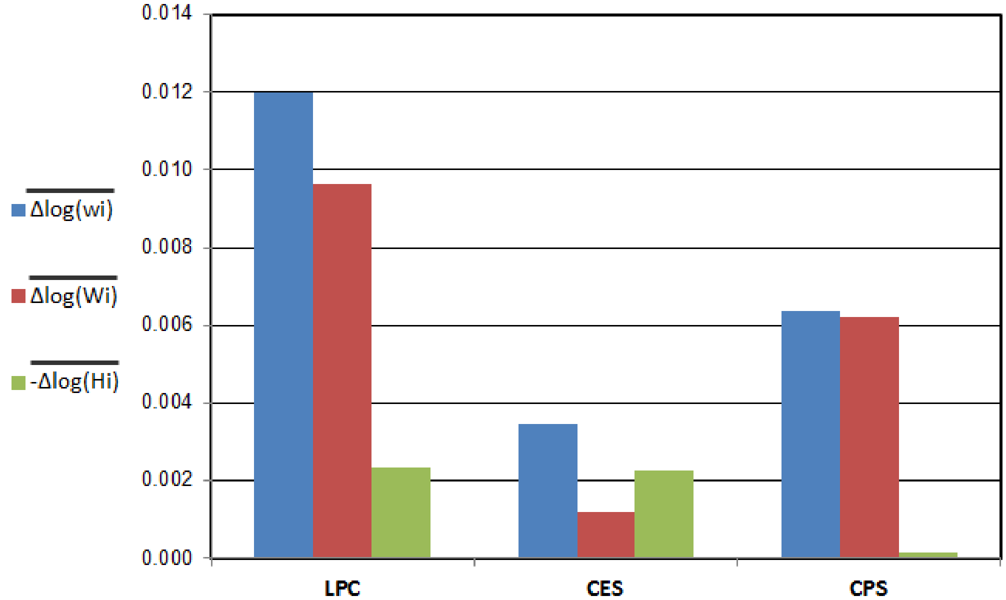
$$\Delta \log w_i = \Delta \log W_i - \Delta \log H_i, \tag{1}$$

where $\Delta \log w_i$ denotes the year-to-year log difference of the hourly wage; $\Delta \log W_i$ the year-to-year log difference of weekly earnings; and $\Delta \log H_i$ the year-to-year log difference in weekly hours from data source $i \in \{LPC, CES, CPS\}$. Second, we compute the average of the log differences over the 1973-2013 period and subtract the same average log difference decomposition for data source $j \neq i$ to obtain the percent contributions of differences in average weekly earnings growth and average weekly hours growth for the difference in average hourly wage growth; i.e.

$$\overline{\Delta \log w_i} - \overline{\Delta \log w_j} = \left(\overline{\Delta \log W_i} - \overline{\Delta \log W_j}\right) - \left(\overline{\Delta \log H_i} - \overline{\Delta \log H_j}\right), \tag{2}$$

where $\overline{\Delta \log w_i}$ denotes the 1973-2013 average log difference in hourly wages from data source i; and so forth for the other terms.

Figure 4 reports the results of this decomposition.



	LPC - CES	%	LPC - CPS	%	CPS - CES	%
$\overline{\Delta\log(w_i)} - \overline{\Delta\log(w_j)}$	0.009	100.00%	0.006	100.00%	0.003	100.00%
$\overline{\Delta\log(W_i)} - \overline{\Delta\log(W_j)}$	0.008	98.96%	0.003	60.98%	0.005	172.06%
$\overline{\Delta\log(H_i)} - \overline{\Delta\log(H_j)}$	0.000	1.04%	0.002	39.02%	-0.002	-72.06%

Note: The figure decomposes average hourly wage log first-differences (blue) between 1973 and 2013 into weekly earnings growth (red) and weekly hours growth (green), i.e. *Δlog(w) = Δlog(W) - Δlog(H)*, where w, W, and H denote the average hourly wage, average weekly earnings, and average weekly hours. The accompanying table reports the contribution of each component in accounting for the difference in hourly wage average growth between the data sources.

Figure 4. Accounting for the divergence in average hourly wage growth.

As already indicated by the above time-series plots, the divergence in average hourly wage growth between the LPC and CES is entirely accounted for by the difference in average weekly earnings growth: average weekly earnings according to the LPC grew on average by 1% per year, while weekly earnings, according to the CES, grew on average by only 0.1% per year. This confirms the findings of Abraham, Spletzer and Stewart (1998) for a substantially longer sample. In comparison, about two-thirds of the considerably smaller divergence in average hourly wage growth between the LPC and the CPS is due to smaller weekly earnings growth in the CPS (0.6% per year). The remaining third of the divergence in average hourly wage growth is due to the fact that LPC weekly hours decreased over time, whereas CPS weekly hours evolved around a constant level.

3.2 Business cycle volatilities

The decomposition of average hourly wages into weekly earnings and weekly hours can also be used to analyze the divergence in business cycle volatility. Specifically, the variance of average hourly wage growth from data source i can be expressed as

$$\sigma_{w_i}^2 = \sigma_{W_i}^2 + \sigma_{H_i}^2 - 2\rho_{W_i,H_i}\sigma_{W_i}\sigma_{H_i}, \tag{3}$$

where $\sigma_{w_i}^2 \equiv Var(\Delta \log w_i)$; $\sigma_{H_i}^2 \equiv Var(\Delta \log H_i)$; and $\rho_{W_i,H_i} \equiv Corr(\Delta \log W_i, \Delta \log H_i)$. Table 3 shows the pre-1984 and post-1984 volatilities and correlations of the three weekly earnings and weekly hours measures, together with the corresponding hourly wage volatilities from Table 2.[21]

	Standard Deviation or Correlation		
	Pre-84	*Post-84*	*Post / Pre-84**
HP-Filter			
LPC hourly wage	0.59	0.94	1.60
	(0.09)	(0.14)	
LPC weekly earnings	0.84	0.91	1.08
	(0.12)	(0.12)	
LPC weekly hours	0.41	0.45	1.09
	(0.02)	(0.05)	
ρ(LPC earnings, LPC hours)	0.76	0.17	-0.59
	(0.13)	(0.18)	
CES hourly wage	1.02	0.54	0.53
	(0.14)	(0.09)	
CES weekly earnings	1.30	0.50	0.38
	(0.18)	(0.06)	
CES weekly hours	0.41	0.37	0.90
	(0.04)	(0.06)	
ρ(CES earnings, CES hours)	0.77	0.25	-0.52
	(0.11)	(0.17)	
CPS hourly wage	0.66	0.76	1.15
	(0.10)	(0.09)	
CPS weekly earnings	0.80	0.72	0.90
	(0.15)	(0.12)	
CPS weekly hours	0.42	0.31	0.74
	(0.03)	(0.05)	
ρ(CPS earnings, CPS hours)	0.57	0.10	-0.47
	(0.18)	(0.13)	

**Notes* : Annual data 1973-2013, H-P filtered. PCE-deflated earnings (2009 dollars). Standard deviations are multiplie by 100. The first three rows in each of the above panels show standard deviations for the series defined in the left column; the fourth row of each panel shows the correlation coefficient between earnings and hours for each data source. The last column shows the ratio of post-84 to pre-84 for standard deviations, and the post-84 to pre-84 difference for correlations. Standard errors computed using GMM and the delta method appear in parentheses belo estimates.

Table 3. Average real hourly wage volatility change breakdown.

[21] The above volatility accounting formula holds exactly for first-differenced data. In Table 3, we use H-P filtered data instead, to remain comparable with the rest of the paper. This introduces an approximation error that is, however, only of minor quantitative importance.

Three observations stand out. First, the volatility of weekly earnings increases slightly in the LPC and decreases slightly in the CPS from the pre-1984 period to the post-1984 period; but, overall, the two measures remain close together.[22] In comparison, the volatility of weekly earnings in the CES is substantially higher in the pre-1984 period and then drops by more than 60% in the post-1984 period. Second, the volatility of weekly hours in the three data sets is overall quite similar and changes only little from the pre-1984 period to the post-1984 period. Third, the correlation of weekly earnings with weekly hours experiences a large drop in all three data sets.[23]

To quantify the effects of these changes in business cycle fluctuations of earnings and hours on the volatility of hourly wages, we adopt a similar accounting strategy as for trend growth. Using the above expression, we decompose the change in the variance of average hourly wage growth from the pre-1984 subsample, denoted a, to the post-1984 subsample, denoted b, as

$$\begin{aligned}\sigma^2_{w_i}(b) - \sigma^2_{w_i}(a) &= \left[\sigma^2_{W_i}(b) - \sigma^2_{W_i}(a)\right] + \left[\sigma^2_{H_i}(b) - \sigma^2_{H_i}(a)\right] \\ &\quad -2\left[\rho_{W_i,H_i}(b)\sigma_{W_i}(b)\sigma_{H_i}(b) - \rho_{W_i,H_i}(a)\sigma_{W_i}(a)\sigma_{H_i}(a)\right].\end{aligned} \tag{4}$$

By manipulating this expression further to decompose the multiplicative parts, we obtain

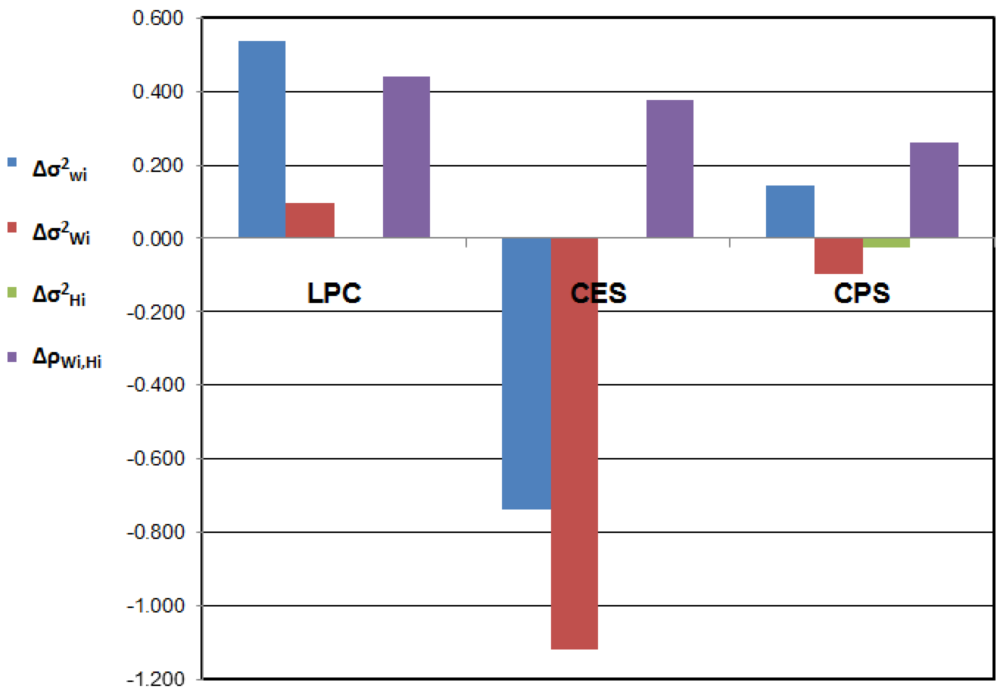
$$\begin{aligned}\sigma^2_{w_i}(b) - \sigma^2_{w_i}(a) &= \left[\sigma^2_{W_i}(b) - \sigma^2_{W_i}(a)\right] + \left[\sigma^2_{H_i}(b) - \sigma^2_{H_i}(a)\right] \\ &\quad -2\left\{\begin{array}{c}\frac{\rho_{W_i,H_i}(b)+\rho_{W_i,H_i}(a)}{2}\left[\begin{array}{c}\frac{\sigma_{H_i}(b)+\sigma_{H_i}(a)}{2}\left[\sigma_{W_i}(b) - \sigma_{W_i}(a)\right] \\ \frac{\sigma_{W_i}(b)+\sigma_{W_i}(a)}{2}\left[\sigma_{H_i}(b) - \sigma_{H_i}(a)\right]\end{array}\right] \\ +\frac{\sigma_{W_i}(b)\sigma_{H_i}(b)+\sigma_{W_i}(a)\sigma_{H_i}(a)}{2}\left[\rho_{W_i,H_i}(b) - \rho_{W_i,H_i}(a)\right]\end{array}\right\}.\end{aligned} \tag{5}$$

We then compare this "change-in-volatility" decomposition for data source i with the corresponding "change-in-volatility" decomposition for data source $j \neq i$. Figure 5 displays the results of this

[22] This is consistent with recent findings from micro data that, for most individuals, the volatility of labor earnings has remained approximately constant (e.g. Dynan et al., 2007; Jensen and Shore, 2008).

[23] Since LPC hours and CES hours are almost perfectly correlated in both subsamples (0.99 and 0.98, respectively), the slightly larger drop in correlation between earnings and hours in the LPC relative to the CES is entirely due to the different change in cyclical properties of earnings in the two data sets.

exercise based on the numbers in Table 3.



	LPC-CES	%	LPC-CPS	%	CPS-CES	%
$\Delta\sigma^2_{wi} - \Delta\sigma^2_{wj}$	1.273	100.00%	0.392	100.00%	0.882	100.00%
$\Delta\sigma^2_{Wi} - \Delta\sigma^2_{Wj}$	1.215	95.42%	0.192	48.97%	1.023	116.06%
$\Delta\sigma^2_{Hi} - \Delta\sigma^2_{Hj}$	-0.004	-0.30%	0.025	6.26%	-0.028	-3.22%
$\Delta\rho_{Wi,Hi} - \Delta\rho_{Wj,Hj}$	0.062	4.88%	0.181	46.12%	-0.118	-13.44%

Note: The figure decomposes the change in the variance of the hourly wage (blue) into changes in the variance of earnings (red), the variance of hours (green), and the correlation between earnings and hours (purple) between 1973-1983 and 1984-2013 for the LPC, CES, and CPS data series. The accompanying table reports the contribution of each component in accounting for the difference in hourly wage variance changes between data sources.

Figure 5. Accounting for the divergence in business cycle volatility of average hourly wages.

As the decomposition makes clear, the *decline* in volatility of the average hourly wage in the CES is primarily due to the drop in volatility of weekly earnings in the CES, accounting for 95% of the difference in the *increase* in volatility of the average hourly wage in the LPC. In turn, the increase in volatility of the average hourly wage in the LPC is larger than in the CPS, because the volatility of weekly earnings in the LPC increases slightly while in the CPS it decreases slightly, and because the drop in correlation between earnings and hours in the LPC receives a larger weight than in the CPS (i.e. the *average* volatility of earnings and hours over the two subsamples is larger in the LPC than in the CPS).

In sum, the earnings-hours decomposition shows that the differences in initial level, trend growth and volatility of the LPC wage relative to the CES wage are primarily due to differences in weekly earnings in the two data sets. Weekly hours only account for a relatively small part of the initial level difference between the two wage measures, but otherwise evolve very similarly.

4 Accounting for the differences in LPC and CES earnings

Following the lead of Abraham, Spletzer and Stewart (1998), we focus on two potential sources for the different evolution of weekly earnings in the LPC and the CES: (i) differences in earnings concept, and (ii) differences in worker coverage. As discussed in the introduction, the similarity of our CPS construct with the LPC in terms of worker coverage on the one hand, and with the CES in terms of earnings concept on the other, motivates our strategy of using the CPS construct as an in-between to analyze separately the importance of differences in earnings concept and differences in worker coverage. Our analysis reveals that the two sources can account for the bulk of the different evolution of weekly earnings in the LPC and the CES. We finish with a discussion of measurement issues that are particular to the CES and examine to what extent they may account for the remaining differences between LPC and CES earnings.

4.1 Differences in earnings concepts

As described in Section 2, earnings in the LPC are based on a very comprehensive concept that includes irregular earnings such as executive compensation, bonuses and gains from non-qualified stock options; as well as supplements consisting of employer contributions to funds for social insurance, private pension and health and welfare plans, compensation for injuries, etc. By contrast, CES and CPS earnings only include compensation that is earned and paid regularly each period, and completely exclude supplements.

To analyze the quantitative importance of these differences in earnings concept, we take the CPS earnings series and augment it with an estimate of supplements and an estimate of earnings of high-income individuals who, as we will show, account for a large part of irregular earnings. To make this analysis fully operational, we adjust the non-farm business universe of the LPC by taking out self-employment as well as other small components, so as to match the private non-agricultural establishment universe of the CES (and the universe of the CPS, which we defined to match the one of the CES).[24] As shown in Table 4 and Figure 6, the adjusted LPC weekly earnings series (labelled "LPC private non-agricultural") is very similar to the original LPC weekly earnings series (labelled

[24] Specifically, the universe of the LPC includes, aside from imputed data for the self-employed, agricultural services, forestry and fishing, and government enterprises. These components are not part of the universe of the CES. See the appendix for details of how we adjusted the LPC universe for these components.

"LPC").

Supplements

The LPC does not provide separate information on supplements. As we detail in the appendix, however, it is possible to construct an estimate of average weekly supplements from NIPA income data. We then simply add this estimate to our CPS weekly earnings measure. As Figure 6 shows, the resulting "CPS + supplements" earnings measure is substantially above CPS weekly earnings, and the gap between the two series widens over time, reflecting the growing importance of employer-paid benefits in total compensation. Overall, supplements account for 65% of the initial difference between LPC earnings and CES earnings in 1973, and for 57% of the difference in 2013.

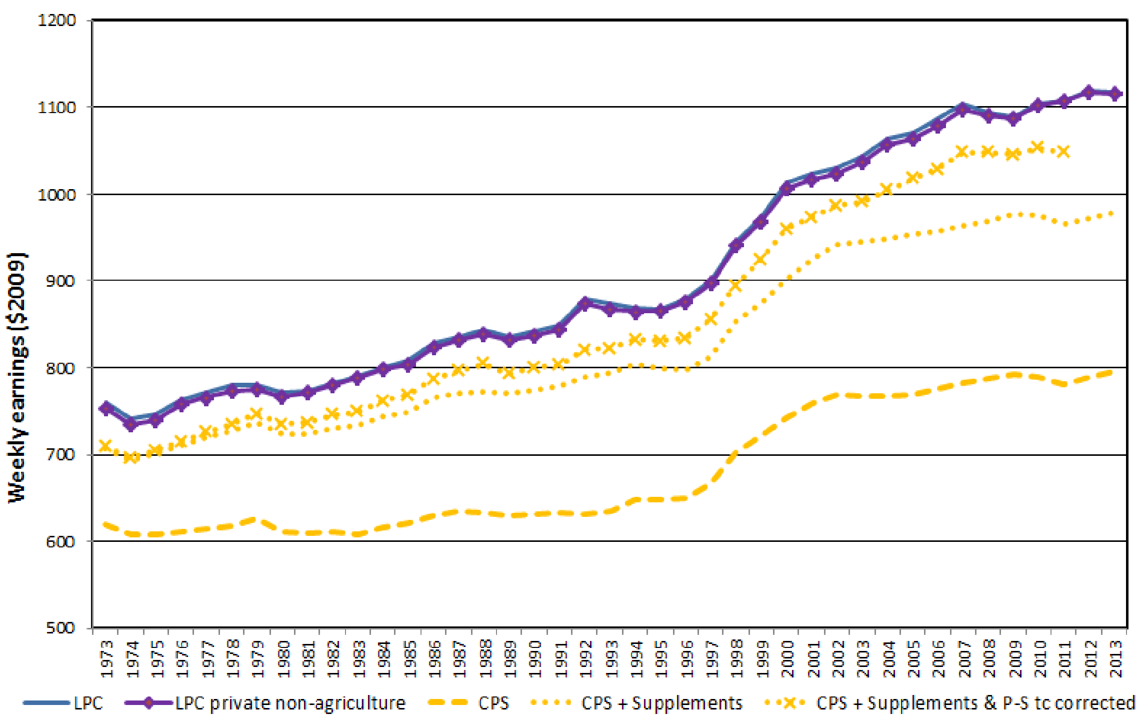


Figure 6. Real average weekly earnings.

In terms of business cycle volatility, CPS weekly earnings and "CPS + supplements" behave similarly. As Table 4 shows, both series exhibit a slight decline in volatility post-1984, but this decline is small relative to the decline in the volatility of output. The relative volatility of "CPS +

supplements" therefore increases substantially from the pre-84 to the post-84 period.

	Standard Deviation			Relative Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*	*Pre-84*	*Post-84*	*Post/Pre-84*
HP-Filter						
Output (nfb)	2.90	1.40	0.48	1.00	1.00	1.00
	(0.19)	(0.20)				
LPC total compensation	0.84	0.91	1.08	0.29	0.65	2.24
	(0.12)	(0.12)		(0.05)	(0.15)	
LPC total compensation (private non-agri)	0.82	0.87	1.07	0.28	0.62	2.21
	(0.11)	(0.12)		(0.05)	(0.15)	
CPS	0.80	0.72	0.90	0.28	0.52	1.87
	(0.15)	(0.12)		(0.05)	(0.13)	
CPS + Supplements	0.82	0.72	0.88	0.28	0.51	1.83
	(0.13)	(0.14)		(0.04)	(0.15)	
CPS + Supplements & P-S topcode values	0.80	0.79	0.98	0.28	0.56	2.03
	(0.13)	(0.10)		(0.04)	(0.13)	

Notes : Total sample extends from 1973 to 2013, except for P-S topcode adjusted series, which ends in 2011. Annual data. PCE-deflated wages 2009 dollars). HP-filtered data. Standard errors computed using GMM and the delta method appear in parentheses below estimates.

Table 4. Business cycle volatilities for various average weekly earnings series.

Earnings of high-income individuals

Our CPS weekly earnings measure provides an incomplete account of wages and salaries because it excludes irregular earnings. While many different individuals could in principle be subject to irregular earnings, we conjecture that the type of irregular earnings not reported in the CPS (e.g. year-end bonuses, exercised stock options) is quantitatively most relevant for high-income individuals whose earnings are also likely to be topcoded in the CPS. As Piketty and Saez (2003) document based on Internal Revenue Service (IRS) records, the share of total economy-wide income going to the top 1% has increased from a stable 8% between the 1950s to the mid-1990s to 23.5% by 2007, due mostly to very strong growth in labor income. As long as a substantial part of this labor income growth is driven by irregular, highly variable earnings – and much of the available evidence on high-income earners points this way – this may account for part of the higher trend growth, as well as the larger post-84 increase in volatility of weekly earnings in the LPC relative to the CPS.[25] Moreover, given the skewness of the earnings distribution at the top end documented by

[25] In particular, compensation from stock options may be highly variable because the options are likely to be exercised in upturns when their value is higher than their fair-market value at the time they were granted. See Mehran and Tracy (2001), who argue that the growth of stock options in the 1990s and their inclusion in compensation at the time of exercise has biased the evolution of compensation upward. The authors also conjecture that increased use of stock options may render compensation more variable. Also see Guvenen et al. (2015), who document that the top-income individuals experience the biggest percent decreases in labor earnings during recessions.

Piketty and Saez (2003), adjusting topcoded (regular) earnings in the CPS by a constant factor, as we and most of the literature do (see Section 2 and the appendix), fails to address the role played by irregular earnings.

To assess these conjectures, we use information on top wage incomes from Piketty and Saez and calculate a separate series of average weekly earnings for the top 5% earners and the remaining 95% in each year.[26] We then compare the two series to average weekly earnings for the corresponding top 5% earners and the remaining 95% in the CPS.[27] Since the Piketty and Saez data do not distinguish between different sectors, we can perform this exercise only on an "all economy" level. The different CPS weekly earnings series below are therefore computed for an "all economy" equivalent. Figure 7 shows the results.

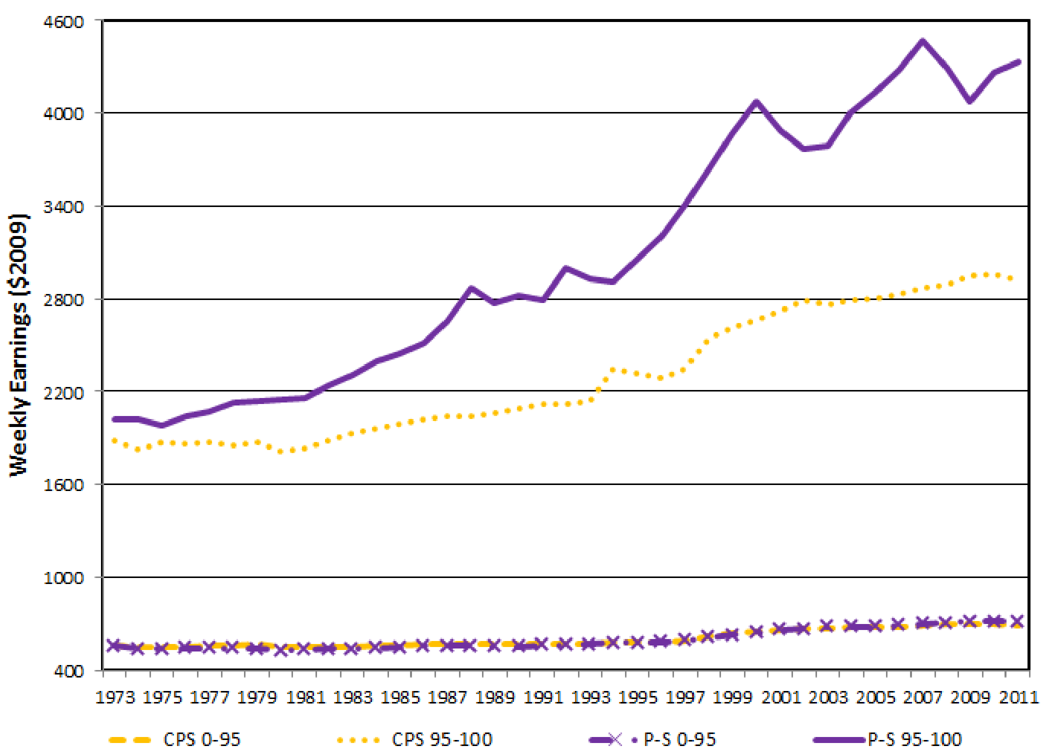


Figure 7. Real average earnings for different income groups.

Weekly earnings for 95% of workers in the CPS (labelled "CPS 0-95") and the Piketty-Saez data (labelled "P-S 0-95") lie essentially on top of each other. For the top 5%, in comparison, there is a

[26] We use the wages and salaries data from Piketty and Saez (2003) updated up to 2011 (available on Saez's website). See the appendix for details.

[27] We use a 5%-95% split because, in the CPS data, the fraction of individuals with topcoded earnings never exceeds 5%. Other, more narrow definitions of high-income earners would lead to very similar conclusions.

widening difference between the two series (labelled "CPS 95-100" and "P-S 95-100," respectively).

Table 5 reports business cycle volatilities for the different series.

	Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*
Percentiles			
P-S P0-95	0.87	0.58	0.67
	(0.11)	(0.06)	
CPS P0-95	0.86	0.61	0.71
	(0.16)	(0.11)	
P-S P95-100	1.03	2.75	2.68
	(0.13)	(0.27)	
CPS P95-100	1.15	1.51	1.31
	(0.11)	(0.37)	

Notes: CPS May-MORG data and Piketty-Saez "Top income shares" database. Real Average Weekly Earnings (2009 dollars). Annual data from 1973 to 2011. All economy. All series are H-P filtered.

Table 5. Effect of high-income earners on average earnings volatilities.

The results confirm that, for 95% of workers, the CPS and the Piketty-Saez earnings data are almost identical. For the top 5%, earnings volatility in the Piketty-Saez data increases by a factor of almost three from the pre-84 period to the post-84 period. This is in stark contrast with the earnings volatility of top 5% individuals in the CPS, which is very similar to the Piketty-Saez numbers for the pre-1984 period but then increases only modestly during the post-1984 period. These results clearly confirm our conjecture that irregular earnings are quantitatively relevant for high-income individuals, both in terms of trend growth and business cycle volatility, but do not matter for the remaining 95%.

Since the earnings concept in the IRS data used by Piketty and Saez is very similar to the one employed in the LPC, we adjust the CPS weekly earnings series for irregular earnings of high-income individuals using information from Piketty and Saez. Specifically, we take Piketty and Saez' weekly earnings information for the top-income groups (i.e. top 0.01%, 0.1%-0.01%, 0.5%-0.1%,...to 1%-5%) and extrapolate new earnings values of all topcoded CPS individuals for each year from 1973 to 2011 (the last year for which the Piketty-Saez wage data are currently available). The specifics of the procedure are described in the appendix. We then add this extrapolation to the "CPS + supplements" series discussed above. As the resulting "CPS + supplements + P-S topcode corrected" series in Figure 6 shows, the corrected CPS earnings measure covers half to two-thirds of the remaining gap between CPS and the LPC earnings, especially since the early 2000s. As the last row of Table 4 shows, the corrected CPS earnings measure also helps considerably in accounting for the increase in volatility in earnings in the LPC in the post-84 period.

We conclude from this investigation that differences in earnings concept between the LPC and the CPS explain the bulk of the divergence in weekly earnings between the two data sets, and therefore account for a large part of the divergence between the LPC wage and the CES wage. Moreover, the comparison between our CPS weekly earnings measure and administrative IRS data from Piketty and Saez (2003) shows that, for all but the top 5% of workers, our CPS weekly earnings series provides a close fit. This is a remarkable result, suggesting that despite well-documented issues with measurement error in the cross-section (e.g. Bound and Krueger, 1991), CPS earnings provide a reliable *average* measure of the wages and salaries portion of compensation for all but the highest-paid individuals in the U.S. workforce.

4.2 Differences in worker coverage

As described in Section 2, the LPC covers earnings and hours of the near totality of workers in the non-farm business sector (or, alternatively, in private non-agricultural establishments). By contrast, the CES historically asked sampled establishments only about earnings and hours of production and non-supervisory workers.[28] Since the QCEW establishment records underlying the LPC neither contain information on worker occupation nor distinguish between regular and irregular earnings, it is impossible to analyze the quantitative importance of this difference in worker coverage directly. Instead, we follow the strategy proposed by Abraham, Spletzer and Steward (1998) and exploit industry and occupation information on individuals in the CPS to create a weekly earnings series that replicates the worker coverage in the CES.

We proceed in two steps. In a first instance, we construct an average earnings series for individuals in the CPS who fit the official BLS definition of production workers in goods-producing industries and non-supervisory workers in service-providing industries (adjusting for OTC and MJH as described in Section 2). As can be seen from Figure 8, the resulting series, labelled "CES replication 1," fails to replicate the pronounced downward trend of weekly earnings in the CES throughout the mid-1990s and thereafter increases at a faster pace.[29] The result confirms, for a substantially

[28] In 2006, the CES started collecting earnings and hours information for all workers in sampled establishments. We consider these data below.

[29] The sample for this exercise stops in 2002 because occupations definitions in the CPS changed in 2003, making the construction of consistent occupation-specific series difficult.

longer sample, the findings reported in Abraham, Spletzer and Stewart (1998).

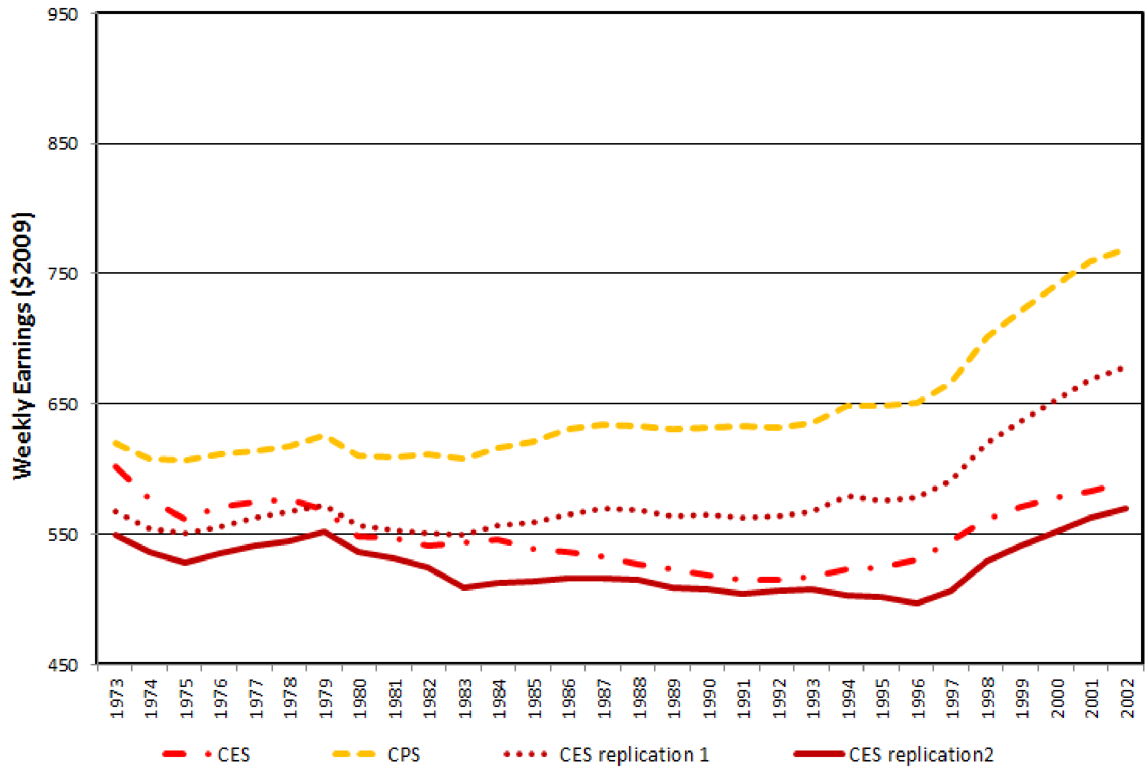


Figure 8. Real average weekly earnings for CPS, CES and the two CES replications.

While this result may appear discouraging, Plewes (1982) and Abraham, Spletzer and Stewart (1998) argue that, historically, establishments in service-providing industries often interpreted non-supervisory workers as employees paid by the hour and other employees who are non-exempt under the Fair Labor Standards Act; i.e. employees who are paid for all overtime hours worked, and generally perform operational functions such as routine clerical duties or maintenance work.[30]

Following this argument, we implement an alternative definition of production and non-supervisory workers proposed by Abraham, Spletzer and Stewart (1998) that keeps the same definition of production workers in goods-producing industries as in "CES replication 1," but categorizes all hourly-paid individuals along with clerical, sales, craft and kindred and operatives occupations in service-providing industries as non-supervisory workers. The appendix provides details of the procedure. As Figure 8 shows, the resulting series, labelled "CES replication 2," tracks the evolution of observed CES earnings more closely. In particular, the replication generates a downward trend

[30]This misreporting issue was particular to service-providing industries because the non-supervisory classification is not one that establishments would use naturally for other purposes.

from the 1970s to the mid-1990s and then a return to higher earnings from the mid-1990s onward. At the same time, CES replication 2 lies somewhat below observed CES earnings, especially in the beginning and toward the end of the sample. As we discuss at the end of this section, this may be the result of a combination of measurement changes in the CES.

Table 6 compares the business cycle volatility of the two CES replications with the volatility of the observed earnings series from the CES and the CPS.

	Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*
HP-filter			
CPS	0.80	0.73	0.92
	(0.15)	(0.16)	
CES replication 1	1.01	0.72	0.71
	(0.15)	(0.14)	
CES replication 2	1.22	0.80	0.65
	(0.09)	(0.18)	
CES	1.30	0.50	0.39
	(0.18)	(0.09)	

Notes : CPS May-MORG data. Real Average Weekly Earnings (2009 dollars). Annual data. Sample: 1973 to 2002.

Table 6. Replicating average real earnings volatility from the CES with CPS data.

As discussed in Section 2, the volatility of CES earnings is substantially above the volatility of CPS earnings for the pre-1984 sample and then drops markedly in the post-84 period, whereas the volatility of CPS earnings declines only modestly.[31] CES replication 1 accounts for part of the higher volatility of CES earnings in the pre-1984 sample and their larger drop in volatility in the post-1984 sample. CES replication 2 improves upon this picture, accounting for almost all of the difference in pre-1984 volatility between CES and CPS earnings, and for about half of the drop in volatility of observed CES weekly earnings relative to the volatility of CPS weekly earnings. This suggests that differences in worker coverage also account for a substantial part of the initially higher level and the subsequently larger drop in business cycle volatility of CES earnings.[32]

The replication exercise with CPS data suggests that the segment of workers for which estab-

[31] Notice that the CPS earnings volatility for the post-1984 period reported here is slightly different from the one in Tables 2 or 3, because the sample here stops in 2002 instead of 2013.

[32] Naturally, the same difference in worker coverage may explain the different evolution of weekly hours in the CES and the CPS. Frazis and Stewart (2010) investigate this possibility. They find that both CES replication 1 and 2 with the CPS sample decreases average hours by 1.3 to 1.7 hours, which basically closes the initial gap between CES and CPS hours. However, neither of the replications can account for the downward trend in CES hours.

lishments have traditionally reported earnings in the CES is not representative of the non-farm business sector workforce, and that this lack of representativeness accounts for a substantial part of the differences between CES earnings and CPS earnings. This conclusion receives further support from a comparison between the "production and non-supervisory" earnings series of the CES with the "all employees" earnings series that the CES implemented starting in 2006.

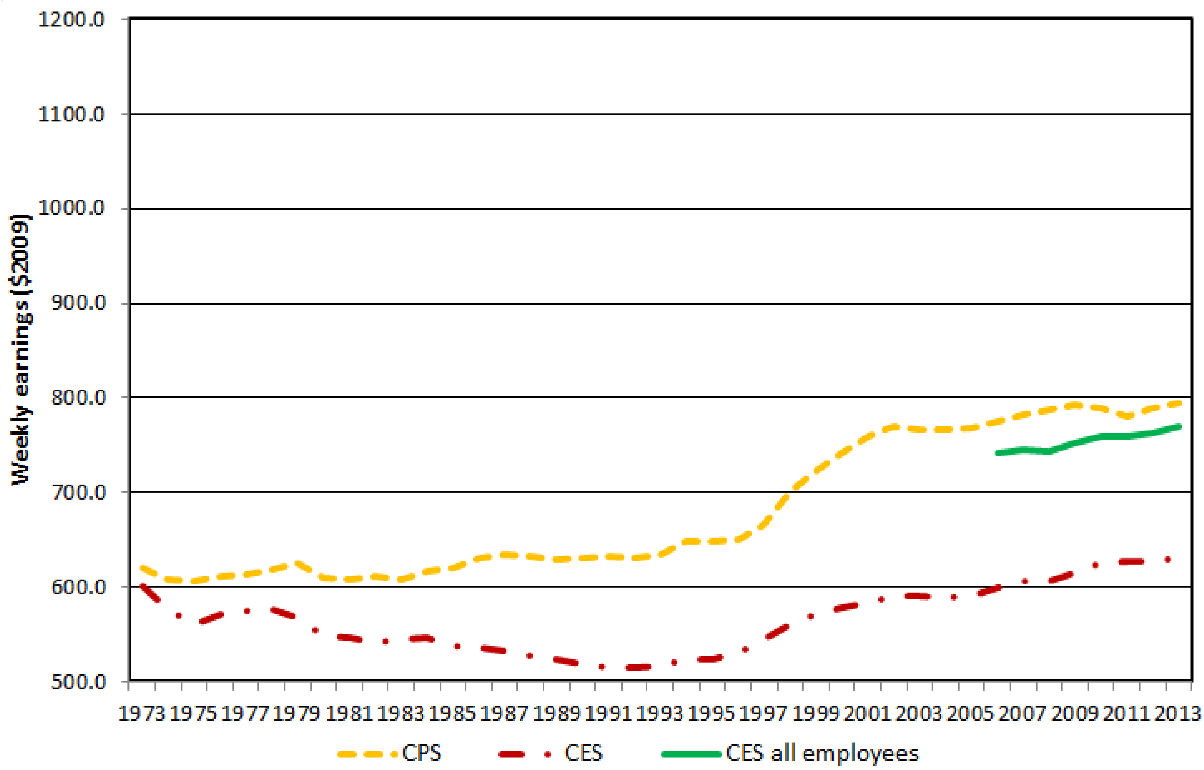


Figure 9. Real average weekly earnings for CPS, CES and CES all employees.

As Figure 9 shows, average earnings for the "all employees" series lies substantially above average weekly earnings for the "production and non-supervisory workers" series. The figure also shows that the CES "all employees" series is close to our CPS earnings construct, which confirms our finding from above that the CPS provides a reliable account of average regular earnings.[33]

[33]The small difference between the CPS earnings series and the CES "all workers" series comes from service-providing industries. For goods-producing industries, the two earnings series basically lie on top of each other. Investigating the source of this difference for service-providing industries would be interesting. We note, however, that the difference is small relative to the gap between the "all workers" and the "production and non-supervisory" averages.

4.3 Taking stock

Table 7 takes stock of the various results. The first row shows the total difference between LPC earnings and CES earnings in terms of the initial (1973) level, the change between 1973 and 2013, the 1973-1984 volatility, and the change in volatility pre-84 to post-84, respectively. Subsequent rows show how much of these differences are accounted for by differences in earnings concept and by differences in population coverage. The last row shows the residual.

	Level difference				Volatility difference			
	Initial (1973) level		Change 1973-2013		1973-1984		Change post84 - pre84	
	$	%	$	%	stdev	%	stdev	%
Total LPC-CES	**157.77**	**100.0%**	**327.53**	**100.0%**	**-0.46**	**100.0%**	**0.87**	**100.0%**
Earnings concept	**132.36**	**83.9%**	**188.09**	**57.4%**	**-0.03**	**6.9%**	**0.23**	**25.9%**
(i) Supplements	86.54	54.9%	96.56	29.5%	0.01	-3.2%	-0.02	-2.0%
(ii) Irregular earnings of high-income earners	45.82	29.0%	91.53	27.9%	-0.05	10.1%	0.24	28.0%
Population coverage	**75.97**	**48.1%**	**130.84**	**39.9%**	**-0.40**	**86.6%**	**0.37**	**42.8%**
(i) Type of worker	71.01	45.0%	128.86	39.3%	-0.42	90.5%	0.36	41.0%
(ii) Universe	4.95	3.1%	1.98	0.6%	0.02	-3.9%	0.02	1.7%
Others - residual	-50.56	-32.0%	8.60	2.6%	-0.03	6.5%	0.27	31.3%

Notes: Contributions to the difference in levels and trend growth (left) between LPC and CES, and to the difference in volatility change (right). Data sources: LPC, CES, CPS May-MORG, NIPA, and Piketty-Saez "Top income shares" database. Real average weekly earnings (2009 dollars). Private non-agriculture sector. Annual data from 1973 to 2013. All series are H-P filtered.

Table 7. Accounting for the LPC-CES average weekly earnings differences.

The table makes clear that differences in earnings concept and differences in worker coverage account for the majority of not only the divergent evolution of the two earnings measures over time, but also their initial level and volatility differences.

Since, by construction, average weekly hours evolve very similarly in the LPC and the CES, differences in earnings concept and differences in worker coverage also account for the majority of the differences in average hourly wages between the LPC and the CES.

4.4 Other sources of divergence

While differences in earnings concept and population coverage can account for the bulk of the differences in the historical weekly earnings series from the LPC and the CES, it is interesting to investigate the potential importance of other differences between the two data sets. In particular, historical CES earnings are subject to a number of potential measurement issues that arise as a consequence of the CES being a voluntary establishment survey. In comparison, LPC earnings are based on mandatory administrative data from a quasi-census of private-sector employers.

The first measurement issue concerns the fact that the CES undersamples small and young establishments.[34] Historically, this undersampling has been especially important in the service sector, to the point where "the sample in the service sector falls short of representation in the smallest size categories" (Plewes, 1982).[35] Partly in response to this representation concern, the BLS expanded the CES sample from about 190,000 establishments in 1983 to about 425,000 establishments in 1989. Other, more modest expansions occurred before and after this period. Moreover, in the early 2000s, the CES switched from a quota sample to a probability sample, which further improved the representation of small and young businesses.[36]

By itself, undersampling of small and young establishments is not an issue, since each respondent's data are weighted to represent establishments of the same size and industry in the state. Undersampling may introduce a bias in average earnings, however, if the respondents differ systematically from the population average in their size-industry-state cell. Specifically, since the CES historically tended to oversample larger establishments in each cell (see Plewes, 1982) and larger establishments tend to pay higher wages than small and young establishments, average weekly earnings may have historically been biased upward.[37] As the sample expanded and representation improved, this bias could have become smaller, leading to a spurious downward trend in average earnings.

Unfortunately, the establishment records underlying the CES and the LPC do not allow us to assess this conjecture.[38] We can, however, look at CES earnings series for goods-producing and

[34] Large establishments account for a disproportionate fraction of employment in the United States. Furthermore, large establishments typically maintain the type of payroll record system that makes it straightforward to respond to the CES survey questions. Sampling large establishments at a higher rate is therefore efficient for the CES, since it allows for coverage of a larger proportion of total employment and higher, more accurate response rates. See BLS (2014) for details.

[35] Plewes (1982) reports that establishments in service-providing industries historically had substantially lower response rates because these establishments often could not differentiate between supervisory and non-supervisory workers in their payrolls and, especially, smaller service-industry employers use outside accounting firms to prepare payrolls.

[36] Under the quota sample approach, establishments agreeing to participate could stay in the sample indefinitely, which had the effect that the average age of respondents was nine years older than that of the population. Under the probability sample approach, establishments get regularly rotated.

[37] The CES benchmarks employment numbers once a year to QCEW population counts. However, no such benchmarking source is available for earnings and hours of production and non-supervisory workers, since the QCEW does not contain information about worker occupation.

[38] While it is, in principle, possible to match survey respondents in the CES with establishment records in the QCEW (the micro data behind the LPC), the QCEW does not provide information on earnings of production and non-supervisory workers, nor does it distinguish between regular and irregular earnings. It is therefore not possible to assess whether respondents in the CES historically reported higher average earnings than the population average in their industry-size-state cell. Moreover, the CES and QCEW micro data are confidential and currently unavailable for research purposes prior to the 1990s.

service-providing industries separately, and examine how they compare with the CES replication equivalents computed from the CPS. We find that, for service-providing industries, the CES earnings series indeed starts out substantially above its replication with CPS data and then experiences a more pronounced downward trend than the replication. From the mid-1990s onward, the two series move closely together. For goods-producing industries, in contrast, there is no downward trend in the first part of the sample. See the appendix for details.

The different evolution of earnings in goods-producing and service-producing industries in the first part of the sample lends support to the idea that undersampling in service-providing industries may have led to an initial overstatement of weekly earnings in the CES and then a spurious downward trend as the sample expanded. At the same time, the bulk of the CES sample expansion occurs in the mid-1980s, about 10 years later than when the downward trend in service-providing industries' earnings takes place. Furthermore, calculations based on information in Plewes (1982) and more recent QCEW data suggests that representation problems in the 1970s and the expansion toward a more representative sample in service-providing industries during the 1980s can account for only a small fraction of the initial downward trend in observed CES earnings.[39]

A second potential measurement issue is that, up to the mid-1990s, the CES primarily collected surveys by mail shuttle form: for each month, the same form was mailed back and forth between the respondent and the BLS without respondent training. Any of the above-mentioned misreporting of non-supervisory workers in service-providing industries was therefore likely to be perpetuated. Starting in the mid-1990s, survey collection gradually shifted to automated methods with real-time editing and respondent training. This made consistent misreporting of non-supervisory workers less likely, shifting the CES sample from a worker coverage resembling the one simulated by CES replication 2 toward a coverage more in line with CES replication 1. This would explain why CES earnings exhibited stronger growth in the last part of the sample than implied by CES replication 2.

A third particularity of the CES is that published average hourly earnings and average weekly hours are computed using a "link-and-taper" estimator, defined as

$$\hat{x}_t = x_t + 0.9\left(\hat{x}_{t-1} - x_{t-1}\right), \tag{6}$$

where $\hat{x}_t$ is the published estimate of average hourly earnings, respectively average weekly hours for month t; and x_t and x_{t-1} are the actual measures of average hourly earnings, and, respectively, average weekly hours for month t and month $t-1$. Average weekly earnings are then computed as the product of the two estimates.

[39] Details of these calculations are available upon request. Abraham, Spletzer and Stewart (1998) present similar simulations for young establishments and come to the same conclusions.

This link-and-taper estimator, which is applied to each industry-size cell before aggregating up using employment weights benchmarked to the QCEW, has the effect of smoothing out the effects of establishment births and deaths. If the reporting establishments in the CES remained the same over time, then $\hat{x}_t = x_t$ for all t. But if the reporting establishments vary, then this no longer holds true. For example, if births and deaths in a given period lead to a shift down in awe_t and awe_{t-1} (the matched sample of establishments reporting for both t and $t-1$), then $\hat{x}_{t-1} - x_{t-1} > 0$, which implies $\hat{x}_t > x_t$, thereby tapering $\hat{x}_t$ toward $\hat{x}_{t-1}$.

In conjunction with the sample expansion discussed above, the link-and-taper estimator has the potential to account for at least part of the high volatility in CES earnings in the beginning of the sample and the subsequent marked drop in volatility. On the one hand, in sparsely sampled industry-size cells, as was the case before the sample expansion of the 1980s, the rotation of establishments in the CES sample may have led to spuriously high earnings volatility.[40] On the other hand, by putting a large weight on last month's published estimate, the link-and-taper formula may generate an earnings series that is too smooth. Prior to the 1980s, the two forces may have approximately canceled each other out, explaining why the CES replication 2 with CPS data can account for most of the high volatility of CES earnings in the pre-1984 period. With the sample expansion of the 1980s, the issue of sparsely sampled industry-size cells became less important. As a result, the link-and-taper estimator may have led to an artificially smooth published weekly earnings series, which would explain why the drop in volatility of the actual CES weekly earnings series exceeds the drop in volatility according to CES replication 2.

It would clearly be interesting to quantify the importance of the different measurement issues further. This would require access to historical records of CES establishment-level data, which is currently not available in electronic format usable for research. At the same time, it remains that differences in earnings concept and differences in worker coverage can account for the bulk of the divergent evolution of the CES earnings relative to LPC earnings measures over time as well as their initial level and volatility differences.

5 Implications for macroeconomics

The results of our analysis have important implications for macroeconomics. First, the slowdown in wage growth that a large part of the U.S. workforce has experienced over the past decades has

[40] In terms of the above link-and-taper formula, the term $x_t - x_{t-1}$ is spuriously variable if it reflects not only changes in average hourly earnings, and, respectively, average weekly hours, but also changes in the matched sample of establishments reporting for both month t and $t-1$.

been among the most hotly debated topics in economics in recent years.[41] Closely related, a number of recent studies have documented a secular decline in the labor share of income.[42] The choice of wage series in this literature varies widely and is usually made with little or no justification. Yet as the above results make clear, the quantitative extent of this "Great Wage Slowdown" depends very much on the wage series considered. Based on the LPC wage, for example, compensation of the average worker increased by about 70% over the past 40 years, implying a relatively moderate drop in the labor share (computed as average hourly compensation divided by average output per hour) of 11% from 0.64 to 0.56. According to the CES wage, by contrast, compensation of the average worker increased by only about 20% over the past 40 years, implying a substantially larger drop in the labor share of 37% from 0.49 to 0.31. These are big differences with important policy implications.

Second, the average hourly wage is a key variable for current economic analysis. Due to its monthly release frequency, the CES wage has been among the preferred measures of choice for policy-makers.[43] But as above, the choice of wage measure turns out to be important. For example, according to the LPC, hourly wage growth for the first quarter of 2015 relative to one year earlier was 3.3%, whereas in the CES, it was 2.1%. This is a big difference that can substantially affect the economic outlook.

Third, wage dynamics play a central role for many theories of the business cycle. Specifically, modern dynamic stochastic general-equilibrium (DSGE) models that imply volatile equilibrium wages relative to output typically fail to generate the magnitude of employment and output fluctuations observed in the data.[44] This raises the question of how volatile wages are in the data. When computed over the entire postwar sample, the LPC wage and the CES wage exhibit similarly moderate volatility, which explains why the literature typically does not pay much attention to the choice of wage measure.[45] But as we know from the preceding analysis, this similarity masks important subsample differences. While the volatility of the LPC wage was relatively low until the mid-1980s and then increased substantially, the volatility of the CES wage was relatively high until the mid-1980s and subsequently dropped by about 50%. Relative to the volatility of output,

[41] See Leonhardt (2014) or Sparshott (2015) for examples in the popular business press; and Kearney, Hershbein and Boddy (2015) or Summers and Balls (2015) for policy-oriented analysis.

[42] See Elsby, Hobijn and Sahin (2013) or Karabarbounis and Neiman (2014) for two prominent examples.

[43] For example, the Federal Reserve Board's new Labor Market Conditions Index (LMCI) includes the CES wage as its only measure of labor cost (Chung et al., 2014). Feldstein (2015), in turn, uses data from both the CES and the LPC to argue that the U.S. economy is close to full employment.

[44] See King and Rebelo (2000) for a review in the neoclassical real business cycle context; Christiano, Eichenbaum and Evans (2005) for an example in a New Keynesian context with price and wage rigidities; and Shimer (2005) for an example in a labor search context.

[45] Over the 1964-2013 sample, the standard deviation of H-P filtered quarterly average hourly wages is 0.93 according to the LPC and 0.84 according to the CES. This is roughly half the standard deviation of output.

wage volatility therefore increased by a factor of almost three according to the LPC but remained approximately constant according to the CES (since output volatility also dropped by about 50% after the mid-1980s). The choice of wage measure, then, clearly has far-reaching consequences for the quantitative success of DSGE models in accounting for business cycle fluctuations and our understanding of cyclical adjustments of U.S. labor markets more generally.[46]

The discussion raises the question of what the most appropriate choice of wage series is. While the answer depends on the exact application, our analysis reveals that the production and non-supervisory measure from the CES is a problematic historical measure of wages because it restricts coverage to a particular and hard-to-replicate group of workers, whose average earnings have grown less and have become substantially less variable than for the rest of the U.S. workforce. Moreover, CES earnings do not include supplements whose importance has grown substantially over the past decades and now constitute a large portion of total labor compensation. Concurrently, the LPC measure has its own problems because a large part of its recent trend growth and increase in volatility is driven by a small fraction of high-income individuals. As a result, the LPC wage underestimates the extent of the "Great Wage Slowdown" experienced by the U.S. labor market, on average, but overestimates the variability of wages over the business cycle.

These considerations suggest that our CPS earnings construct, augmented with an estimate for supplements, provides an interesting alternative for historical analysis. Aside from matching almost perfectly average earnings in administrative IRS data for all but the highest-paid individuals, the CPS measure has the advantage that the micro data are publicly accessible and offer rich cross-sectional information on the different respondents. Moreover, the CPS earnings series can be augmented with estimates for supplements to take into account the growing importance of non-wage payments in labor compensation. For current analysis, in turn, the "all worker" measure that the CES introduced in 2006 probably constitutes the best choice, because of its timely availability at a monthly frequency and its large survey sample size.[47]

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A Data Description

This first section outlines in detail all the data used throughout the main text. We first describe the different data sources, i.e.:

1. the Labor Productivity and Costs (LPC),
2. the Current Employment Statistics survey (CES),
3. the micro data from the May Supplements and Outgoing Rotation Groups of the Current Population Survey (CPS),
4. the National Income and Product Accounts (NIPAs) from the Bureau of Economic Analysis (BEA), and
5. the updated version of the income and wage shares tables by Piketty and Saez.

Then we explain the different non-farm business concepts across the sources, provide detailed information on how compensation, hours, and employment are computed, and finally we lay out all the variables used in the main text.

A.1 Labor Productivity and Costs (LPC)

The major LPC program of the Bureau of Labor Statistics (BLS) produces measures of, among many other things, GDP, labor productivity, compensation, employment, and hours for the private non-farm sector of the U.S. economy. Below we list the relevant data from the LPC data set used to construct many of the variables used in the main text. All are available quarterly (seasonally adjusted) and annually from 1948 onward.

A.1.1 Universe

According to the 2002 North American Industry Classification System (NAICS), the U.S. economy comprises 20 major (2-digit) sectors; these 20 sectors can be classified as either "Agriculture," "Goods-producing," "Services-providing" or "Public Administration."[48]

[48] The "Agriculture" category includes one major sector, the Agriculture, forestry, fishing, and hunting industry, classified as NAICS 11. The "Goods-producing" industries category contains NAICS 21: Mining, quarrying, and oil and gas extraction; 22: Utilities; 23: Construction; and 31-33: Manufacturing. The "Services-providing" industries regroup: NAICS 42: Wholesale trade; 44-45: Retail trade; 48-49: Transportation and Warehousing; 51: Information; 52-53: FIRE; 54-56: Professional, Scientific, and Various services; 61-62: Educational and Health Care services; 71: Arts, Entertainment, Recreation; 72: Accommodation and Food services; 81: Other services. Finally, the Public Administration sector is classified as NAICS 92, and includes general government employees as well as government enterprises.

LPC covers the non-farm business sector of the U.S economy. More specifically, LPC excludes, within the "Agriculture" category, the farm industries (2002 NAICS 3-digit industries 111, and 112), but does cover the other agricultural industries (i.e. 2002 NAICS 3-digit industries 113, 114, and 115) within the "Agriculture" category. The "Households and non-profit institutions" industry, classified as 2002 NAICS 814 (3-digit),[49] is excluded, as well as public administration employees, except government enterprises at the federal, state, and local levels. Finally, note that self-employed individuals are included in LPC's non-farm business universe. Table A.1 summarizes the universe for all four major data sources used in the main text.

Universe Definitions			
LPC	**CES**	**CPS**	**NIPA**
All U.S. economy, **less**: (1) Farm sector (2) Public administration: General government. (3) Households & Institutions **Does include: * Agricultural services, forestry, fishing and related activities. * Self-employed; * Government services.	All economy, **less:** (1) All agriculture, i.e.: Farm sector; Agricultural services, forestry, fishing and related activities. (2) Total Public administration: General government; Government services. (3) Households & Institutions (4) Self-employed workers.	All economy, **less:** (1) All agriculture, i.e.: Farm sector; Agricultural services, forestry, fishing and related activities. (2) Total Public administration: General government; Government services. (3) Households & Institutions (4) Self-employed workers.	All economy, **less:** (1) Farm sector (2) Public administration: General government. Government services. (3) Households & Institutions (4) Self-employed workers. **Does include: * Agricultural services, forestry, fishing and related activities.

Table A.1. Universe definitions for the main data sources.

A.1.2 Data definitions

Here we explain how LPC constructs measures of aggregate compensation, hours, and employment for the non-farm business sector defined above.

Compensation Total compensation from the LPC data set comprises a "wages and salaries" component, and a "supplements" component.[50] The "wages and salaries" component is based on earnings data from the **Quarterly Census of Employment and Wages (QCEW)**, previously known as the BLS ES-202 program. The QCEW is "a cooperative program involving the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor and the State Employment Security Agencies... [and] produces a complete tabulation of employment and wage information for workers covered by State unemployment insurance (UI) laws and Federal workers covered by the Unem-

[49] The "Households and non-profits institutions" is classified under major sector NAICS 81: "Other services."

[50] The proportion of wages and salaries in total compensation has been trending downward in a constant way through time, from around 91% of total compensation in the mid-1960s to 80% in 2010.

ployment Compensation for Federal Employees program."[51] This represents about 98 percent of all U.S. jobs. The definition of labor earnings in the QCEW is very comprehensive. Specifically: "Wage and salary disbursements consist of the monetary remuneration of employees (including the salaries of corporate officers, commissions, tips, bonuses, and severance pay); employee gains from exercising nonqualified stock options; distributions from nonqualified deferred compensation plans; and an imputation for pay-in-kind (such as the meals furnished to the employees of restaurants)." Detailed information on the earnings from the QCEW can be found in the State Personal Income Methodology on the BEA website, or at: www.bea.gov/national/pdf/chapter10.pdf.

The "supplements" component of total compensation consists of employer contributions for employee pension and health and welfare plans, and employer contributions for government social insurance.[52] To derive total compensation according to the non-farm business definition above, the LPC takes compensation from the whole domestic economy, and subtracts compensation of employees working in:

- the farm sector
- non-profit institutions and private households
- public administration offices[53]
- finally, the LPC adds aggregate compensation of self-employed individuals.[54]

The total compensation measure we use from LPC is series ID: PRS85006063 (in levels), continuously updated each quarter at: www.bls.gov/lpc/special_requests/msp_dataset.zip. Note that only the total compensation series is available in LPC (the breakdown between "wages and salaries" and "supplements" is not available).[55]

Hours and Employment Both hours and employment in LPC are based on CES data. As described below, CES has different concepts and coverage than LPC. Consequently, LPC supplements CES employment and hours series with its own estimates to have a consistent coverage of the

[51] See the overview of the QCEW at www.bls.gov/cew/cewover.htm.

[52] The estimates for the "supplements" portion of total compensation come from various sources, such as the IRS, the Medical Expenditure Panel Survey or the American Council of Life Insurers. The estimates are compiled by the BEA.

[53] As stated in the non-farm business definition above, while workers employed in "general government" are not included in LPC's universe, employees in "government enterprises" are.

[54] To get an aggregate measure of total compensation for self-employed workers, LPC multiplies self-employed workers' average hours estimated from CPS data with the LPC average hourly compensation for the rest of the non-farm business sector.

[55] However, the breakdown is available in the NIPAs (see subsection below for details).

non-farm business sector. There are various steps in LPC's estimation of employment and hours for the various subsectors not covered by CES.

- First, and as described below, the CES employment series covers all workers in the private non-agriculture sector but collects hours on a "paid" basis only for production and non-supervisory employees.[56] Consequently, LPC multiplies the hours series for production and non-supervisory employees with ratios of hours worked-to-hours paid to get an aggregate series of hours worked for these workers.[57]

- Second, LPC must estimate hours for non-production and supervisory employees. For each industry[58] in the CES private non-agricultural sector, CPS[59] average weekly hours of non-production and supervisory workers are divided by those of production and non-supervisory workers. These ratios are then multiplied by the average weekly hours of CES production and non-supervisory workers, yielding an estimate of average weekly hours of non-production and supervisory workers.[60] Employment for these workers is simply the difference between the CES all-employees series and the CES production and non-supervisory employees series. Total hours for non-production and supervisory employees are computed as the product of employment and average weekly hours.

- Third, employment and hours coming from the sectors not covered by CES and from non-employees workers must be estimated by LPC. These are: agricultural services, forestry, fishing, and related activities ("other agricultural industries"); government enterprises; and self-employed workers.

  – **Other agricultural industries:** Some industries such as agricultural services, forestry, fishing, etc. (more specifically, 2002 NAICS 3-digit industries 113, 114, and 115) are not

[56] In 2006 CES started to collect hours and earnings for all employees in the private non-agricultural sector. This is discussed in the main text.

[57] Since 2000, these ratios are provided by the National Compensation Survey (NCS) at a disaggregated industry level. NCS uses detailed data on wages, hours worked and hours of leave to compute these ratios of hours worked to hours paid. Before 2000, the ratios were computed using the BLS Hours at Work Survey.

[58] The same industry disaggregation level is used as in the estimation of the hours-worked to hours-paid ratios. This disaggregation is done at the 2- and 3-digit industry level, resulting in 14 subsectors for the private non-agricultural sector: Natural Resources and Mining, Construction, Durable Manufacturing, Non-durable Manufacturing, Transportation and Warehousing, Retail Trade, Wholesale Trade, Utilities, Information, Financial Activities, Professional and Business Services, Education and Health Services, Leisure and Hospitality, and Other Services.

[59] As LPC looks at "jobs" in the economy, when using CPS data LPC always tries to measure "jobs" instead of persons (i.e. it accounts for multiple job holding).

[60] Since, in the first step, LPC converted CES hours to an "hours-worked" basis, these average weekly hours series for non-production and supervisory employees are also on a "worked" basis.

covered by CES, apart from the logging industry (2002 NAICS 1133). LPC sums the employment numbers from the QCEW for 2002 NAICS industries 113, 114, and 115. LPC uses CES average weekly hours from the logging industry (NAICS industry 1133) as a proxy for the entire agricultural services sector. Total hours worked for the sector are simply the product of average weekly hours from NAICS 1133 and the employment series from QCEW.

- **Government enterprises**: According to the Bureau of Economic Analysis, these entities are "government agencies that cover a substantial portion of their operating costs by selling goods and services to the public and that maintain their own separate accounts."[61] Since neither the CES nor CPS can identify employees of government enterprises, LPC uses the employment series coming from the NIPAs, broken down into federal, state and local components.[62] To get a total hours series for this subsector, LPC uses CPS average weekly hours series for the Postal Service and Public Administration as a proxy for federal and state and local government enterprises, respectively.[63] These average weekly hours series are again multiplied with the respective employment series to get an aggregate measure of hours for the government enterprises sector.
- **Self-employed workers**: LPC estimates self-employed individuals' employment and hours from the CPS.

The total hours measure we use is LPC series ID: PRS84006033, while employment series ID is PRS85006013 (both are in levels). As for compensation, they are available (and continuously updated each quarter) at www.bls.gov/lpc/special_requests/msp_dataset.zip.

A.2 Current Employment Statistics

The CES is an establishment survey of employment, wages and hours conducted monthly by the BLS on a voluntary basis. The CES grew from about 166,000 to about 330,000 establishments between 1980 and 1993, and then to about 554,000 establishments in 2014. While the CES reports data for all employees as far back as 1939, it reports earnings and hours from 1964 onward and only for production workers in the goods-producing sector and non-supervisory workers in the service-providing sector.[64] Below we list the relevant data used from the CES data set to construct some

[61] See www.bea.gov/glossary/glossary.cfm.

[62] The employment data from the NIPAs is in annual terms. To get quarterly series, LPC converts the annual data using a quadratic-minimization program that estimates quarterly data points based on year-to-year trends.

[63] Average hours from the CPS are seasonally adjusted before they are multiplied with employment to get the quarterly aggregate hours series.

[64] As mentioned earlier, since March 2006 the CES publishes series of weekly earnings and hours that cover all employees in the private non-agricultural sector.

of the variables used in the main text. All of them are available monthly, quarterly (seasonally adjusted) and annually.

A.2.1 Universe

CES's non-farm business sector coverage excludes all industries related to the agricultural sector (i.e. 2002 NAICS 3-digit industries 111 to 115). Households and non-profit institutions (2002 NAICS 3-digit industry 814) are excluded, as well as all public administration and government enterprises employees. Finally, because CES is a survey of establishments, it does not cover self-employed individuals. The CES private non-agriculture universe is summarized in Table A.1.

A.2.2 Data definitions

Here, we detail the construction of the aggregate compensation, hours and employment series done in the CES data.

Earnings Chapter 2 of the BLS Handbook of Methods states that: "Aggregate payrolls include pay before deductions for Social Security, unemployment insurance, group insurance, withholding tax, salary reduction plans, bonds, and union dues. The payroll figures also include overtime pay, shift premiums, and payments for holidays, vacations, sick leave, and other leave made directly by the employer to employees for the pay period reported. Payrolls exclude bonuses, commissions, and other lump-sum payments (unless earned and paid regularly each pay period or month), or other pay not earned in the pay period (such as retroactive pay). Tips and the value of free rent, fuel, meals, or other payments in kind are not included." As noted above, earnings are recorded only for production and non-supervisory workers. More details can be found at www.bls.gov/opub/hom/homch2.htm.

Hours and Employment Total hours in the CES are recorded on an "hours-paid basis." Chapter 2 of the BLS Handbook of Methods states that: "Total hours during the pay period include all hours worked (including overtime hours), hours paid for standby or reporting time, and equivalent hours for which employees received pay directly from the employer for sick leave, holidays, vacations, and other leave. Overtime and other premium pay hours are not converted to straight-time equivalent hours." While hours are collected only for production and non-supervisory workers, employment is computed for all workers and the time series goes back to 1939. More details can be found at www.bls.gov/opub/hom/homch2.htm.

A.3 The Current Population Survey (CPS)

The CPS, a monthly survey of about 60,000 households sponsored by the U.S. Census Bureau and the BLS, collects a variety of information on households' demographics and labor force status, and is the official source behind the U.S. national unemployment rate. Since we mainly analyze earnings and hours in this paper, we want to gather information on both from the CPS. However, earnings and hours questions are not asked of all CPS respondents each month. Specifically, an interviewed individual appears in the CPS for two periods of four consecutive months, separated by eight months during which the individual is left out of the survey. Since 1979, individuals at the end of each of their four-month rotations, i.e. months 4 and 8, are asked additional questions such as their usual weekly earnings and usual weekly hours worked. These individuals are called the Outgoing Rotation Groups (ORGs).[65] Hence, from 1979 onward, one-fourth of the CPS sample is asked about earnings and hours each month. Between 1973 and 1978, the CPS asked all the respondents in the sample about their usual earnings and hours once a year only, in May, in what is called the "May supplements." After removing observations with missing earnings or hours, individuals under 16 years of age, self-employed, out of the labor force and unemployed individuals, the May supplements yield an average of 42,037 observations per year between 1973 and 1978, while the ORG files yield an average of 173,925 observations per year from 1979 onward.

Following Abraham, Spletzer, and Stewart (1998) and Lemieux (2006), we use the earnings and hours information from the CPS May supplements and the ORG extracts to create annual series of (weighted) average weekly earnings and (weighted) average weekly hours from 1973 onward. The individual weights used in this calculation are provided by the CPS to make the resulting sample representative of the U.S. workforce.

Lastly, note that the CPS ORG extracts (1979-2013) we use are taken directly from the Center for Economic Policy Research (CEPR).[66] The CEPR provides more useful documentation than the NBER on the CPS ORGs and many variables in the CEPR ORG extracts are made consistent throughout the sample.[67] We use this documentation to replicate the CEPR's manipulations of the ORGs to the CPS May Supplement files (which were downloaded from the NBER website) between 1973 and 1978. Consequently, all the relevant variables we use in the CPS ORGs and May supplements available from 1973 to 2013 are coded consistently.

[65] For more documentation on the CPS ORGs, see Feenberg and Roth (2007).

[66] See Center for Economic and Policy (CEPR) Research. 2014. CPS ORG Uniform Extracts, Version 1.9. Washington, DC. (http://www.ceprdata.org/).

[67] For instance, the coding of some variables in the CPS survey changes through time, e.g. the variable "education." The CEPR ORGs are formatted such that there is consistency in each variable throughout the sample.

A.3.1 Universe

The CPS is representative of the U.S. population and thus is not restricted to a specific non-farm business sector. Because of the industry and occupational information contained in the CPS micro data, we can restrict our CPS sample to almost any non-farm business definition. As we explain in the main text, we try to replicate the private, non-agriculture coverage of the CES. As a result, we exclude from the CPS all individuals employed in industries related to the agricultural sector (i.e. 2002 NAICS 3-digit industries 111 to 115, inclusively), in the Households and non-profit institutions industry (2002 NAICS 3-digit industry 814), and in all public administration and government enterprises occupations. Finally, we take out all self-employed individuals. The CPS private non-agriculture universe is summarized in Table A.1.

A.3.2 Data definitions

Here we explain how we use earnings and hours information in the CPS to construct the CPS average earnings variables in the paper.

Earnings Workers in the CPS May/ORGs can report earnings in two different ways, depending on whether they are salaried or paid by the hour. They are first asked if they are "paid by the hour" at their main job; if not, they are considered to be "salaried" workers and are then asked to report their usual weekly earnings at their main job, defined as compensation normally received, including bonuses, overtime, tips and commissions (OTC) if paid and earned each period, but excluding payments in kind, stock options, any other form of irregular bonuses, and any supplements to wage earnings. On the other hand, if they answer affirmatively to the "paid-by-the-hour" question, then they are asked what is their usual hourly wage rate, which is exclusive of OTC earnings or any form of irregular pay. Finally, they are also asked their usual weekly earnings, as asked of salaried workers. Hence, CPS earnings contain some fraction of bonuses and OTC if paid and earned each period, but no irregular form of compensation. To create a consistent average aggregate hourly (and weekly) earnings series from the CPS May / ORG data, three issues need to be addressed. The first issue concerns the computation of OTC earnings for hourly-paid workers; the second concerns the topcoding of high earnings; and the third is about converting earnings and hours from a "person" to a "job" basis.

The first issue with creating a consistent average hourly wage series from CPS data concerns the treatment of OTC earnings for hourly-paid workers. As described above, the CPS asks hourly-paid workers to report their hourly wage rate first, and then their weekly earnings. The problem with this approach when one wants to create an average wage series for the aggregate economy is that the reported hourly wage rate is straight pay and does not incorporate any OTC earnings, whereas the reported usual weekly earnings does. This would not be an issue if hourly-paid workers were always reporting usual weekly earnings as the salaried workers do, but this does not seem to be the case. Some hourly-paid workers do not report their usual weekly earnings, so the CPS automatically imputes their usual weekly earnings as their hourly wage rate times their usual weekly hours, while some report usual weekly earnings that are smaller than the product of their hourly wage rate and their usual weekly hours, suggesting reporting errors.[68] Moreover, starting in 1994, the CPS introduced an additional question only to hourly-paid workers specific to their weekly OTC earnings, with the objective of decreasing reporting errors and having better estimates of usual weekly earnings of hourly-paid workers.[69] The consequence of this additional question is a more accurate measurement of OTC earnings for hourly-paid workers starting in 1994, at the cost of creating a small discontinuity in hourly-paid workers' average weekly earnings between 1993 and 1994 (Figure A.1).[70] Below we describe how we deal with this issue when constructing an average weekly earnings series for the aggregate economy.

The second issue to address is the topcoding of high earnings in the CPS. The CPS limits (i.e. topcodes) publicly available data of individuals with high earnings to a maximum value that varies over time and depends on whether a worker is salaried or paid by the hour. For the latter, the CPS topcodes the hourly rate at \$99.99, a threshold rarely crossed.[71] For the former (i.e. salaried workers), the CPS topcodes weekly earnings at \$999 until 1989; \$1923 between 1989 and 1997; and \$2884 from 1998 onward. For certain years, this puts a substantial share of workers above

[68] One explanation for this is that some hourly-paid workers could report their gross hourly wage rate but their net usual weekly earnings.

[69] This was part of a major overhaul by the BLS that culminated in 1994 with the CPS survey redesign. Among other things, the 1994 CPS redesign also affected the way hours were reported by individuals in the ORGs. See the hours description below for more information.

[70] For example, before 1994, hourly-paid workers provided their hourly wage (not including OTC earnings), and then were asked to provide their usual weekly earnings (supposedly including OTC earnings), but this process was not without flaws. Polivka (2000) writes: "Prior to 1994, workers identified as paid by the hour were simply asked to report their hourly rate, the number of hours they worked and then a weekly amount in addition. The repetitive process of asking these questions irked some respondents provoking statements such as, "Well, figure it out yourself." (Polivka and Rothgeb, 1993)." The new question about OTC earnings starting in 1994 was a way to bypass this repetitive problem and get a more accurate measure of hourly-paid workers' average weekly earnings.

[71] Actually, from 1973 to 1984, hourly wage rates are topcoded at \$99.99 per hour, a threshold almost never crossed. From 1985 onward, the topcode depends on the number of hours worked and is selected such that weekly earnings do not exceed the weekly earnings topcode value. When we examine the data, we realize that this topcode is not uniformly applied; for instance, some workers have wages at \$99/hour and a workweek of 35 or 40 hours, implying weekly earnings much higher than the most recent topcode level of weekly earnings (i.e. \$2884). All in all, the number of hourly-paid workers with topcoded earnings is very small.

the topcode, which may lead to earnings discontinuities around topcode changes.[72] To reduce this risk of discontinuities, we multiply topcoded weekly earnings of salaried workers by a factor of 1.3. While this constant-factor adjustment is standard in the labor literature (e.g. Abraham et al., 1998; Lemieux, 2006), it does not completely eliminate the possibility of discontinuities from topcode changes. Alternatively, one can use more sophisticated adjustment methods that estimate mean earnings of individuals above the topcode from the cross-sectional distribution of earnings below the topcode. The most popular among these methods is based on the Pareto distribution which, for certain years, has been shown to provide a better approximation of actual earnings in confidential CPS samples.[73] In the main text (and detailed below), we provide a new method to account for topcoding, by using IRS data from Piketty and Saez (2003) on the top income earners in the United States.

The third and final issue concerns the fact that LPC and CES earnings data are computed on a job basis, while the CPS records earnings and hours on a person basis. Adjustments to the CPS earnings and hours series are thus needed to make the series comparable to LPC and CES. Before 1994, scarce information on multiple job-holding is available: the May supplements up to 1980 contain a multiple job-holding flag, as well as the May 1985, 1989, and 1991 supplements. Moreover, the 1985 and 1989 May supplements contain information on earnings and hours on the second job. From 1994 onward, monthly multiple job-holding information is available in the ORG extracts. While second job information such as hours, industry, occupation, and class of worker is available in the ORGs, earnings are not. Consequently, we use Abraham et al.'s (1998) approach and adjust weekly earnings and hours in every year according to the following formulas:

$$\begin{aligned} W\_adjusted_t &= \frac{W_t\left(1 + MJH_t * \frac{W^{2nd}}{W^{main}}\right)}{(1 + MJH_t)} \\ H\_adjusted_t &= \frac{\left(1 + MJH_t * H^{2nd}\right)}{(1 + MJH_t)}, \end{aligned}$$

where W_t represents average weekly earnings on the main job, $\frac{W^{2nd}}{W^{main}}$ is the ratio of average weekly earnings on the second job to average weekly earnings on the main job among the population of multiple job-holders, H_t^{2nd} represents average weekly hours on the second job, and MJH denotes the multiple job-holding rate. Using the May supplements from 1973 to 1980, 1985, 1989, and 1991, the ORGs 1994 onward, and some extrapolation for the missing years, we can compute the MJH for each year from 1973 onward. Using information from the May 1985 and 1989 supplements, we

[72] For example, this could induce spurious CPS average earnings volatility starting in the late 1980s, since all the topcode changes occurred after 1988.

[73] See Feenberg and Poterba (1993), Polivka (2000) and Schmitt (2003).

compute the ratio $\frac{W^{2nd}}{W^{main}}$ to be around 30% and assume that it is constant throughout the sample. Finally, we take the average of weekly hours on the second job (H^{2nd}) from the ORG extracts (1994 to 2013), and use this average number of hours throughout the whole sample. Note that we compute the multiple job-holding rate (MJH) and average weekly hours on the second job (H^{2nd}) for different sectors or groups of workers. For example, for the non-farm business sector, the multiple job-holding rate varies between 3.4% to 4.8%, while average hours on the second job are roughly constant, around 15.3 hours per week. This hides some heterogeneity; for instance, in the services-providing sector the multiple job-holding rate varies between 3.7% and 5.3%, with multiple job-holders working about 15.1 hours per week on their second job, while in the goods-producing sector the multiple job-holding rate is much lower, varying between 1.5% and 2.3%, and with second job holders working about 16.2 hours per week.

Average weekly earnings

To compute average weekly earnings, we proceed differently for salaried and hourly-paid workers. For salaried workers, we simply use the reported usual weekly earnings in the CPS May supplements and ORGs extracts for the whole sample (1973-2013). For hourly-paid workers, because of the 1994 CPS redesign mentioned above, we use an adjustment to account for OTC earnings of hourly-paid workers to avoid any discontinuity in the average weekly earnings of hourly-paid workers between 1993 and 1994. First, from 1994 onward, we use the separate information on OTC earnings and compute weekly earnings of hourly-paid workers as $\max\{W, w * h + OTC\}$, where the W in the brackets refers to the reported usual weekly earnings, h to usual weekly hours worked, OTC to weekly OTC earnings, and w to the reported hourly wage rate. Second, we take the ratio for each group i in every t year 1994 onward:

$$ratio_{i,t} = \frac{\max\{W_{i,t}, w_{i,t} * h_{i,t} + OTC_{i,t}\}}{w_{i,t} * h_{i,t}}$$

and apply it to the product of the hourly wage and weekly hours (i.e. $w_i * h_i$) for each group i every year between 1973 and 1993. Specifically, we divide the hourly-paid workers into four groups of i based on education and gender,[74] and take the average ratio for each group between 1996 and 2000.[75] Finally, to estimate hourly-paid workers' weekly earnings from 1973 to 1993 that avoid any major discontinuity between 1993 and 1994, we apply the relevant average $\overline{ratio}_{i,1996-2000}$ to each

[74] The two education groups are those with a college degree or more (i.e."skilled"), and those with less than a college degree (i.e. "unskilled"). The other group is based on gender. The combination of gender and education yields a total of four groups.

[75] We take the average ratio from 1996 instead of 1994 to avoid using the "kink" in weekly earnings apparent between 1993 and 1995. Taking the average from 1994 to 2000, or 1994 to 2013, does not change significantly the ratios.

hourly-paid worker's earnings (i.e. $w_i * h_i$) in every year between 1973 and 1993 according to that worker's group i. The resulting usual weekly earnings (containing OTC earnings) for hourly-paid is thus $\overline{ratio}_{i,1996-2000} * w_{i,t} * h_{i,t}$ between 1973 and 1993, and $\max\{W_{i,t}, w_{i,t} * h_{i,t} + OTC_{i,t}\}$ from 1994 onward.[76]

Figure A.1 shows the resulting CPS hourly wage, along with two other CPS average hourly wage series. The first one, labelled "CPS no OTC," is computed as in the main text, but we do not use any OTC information for hourly-paid workers (neither pre-94 nor 94 onward); consequently, hourly-paid workers' earnings are computed as their hourly wage rate times their average weekly hours. The second CPS average hourly wage series, labelled "CPS with OTC" is computed as in the main text, but we account for hourly-paid workers' OTC simply by taking the max of reported hourly wage times usual weekly hours plus OTC earnings and reported usual weekly earnings.[77] As seen in Figure A.1, this procedure does not seem to do a good job before 1994 in accounting for OTC earnings, since there is a clear "kink" between 1993 and 1994 relative to the "CPS no OTC" series where no OTC earnings information is used for hourly-paid workers. Consequently, we favor the "CPS with OTC adjustment as in paper" series, which is the one used throughout the main

[76] As mentioned in the main text, to compute average weekly earnings across all workers in the CPS sample, we use a weighted average of individual weekly earnings, where the weights are individual weights provided in the CPS May / ORGs extracts.

[77] Before 1994, we take $\max\{W_t, w_t h_t\}$, while after 1994 we take $\max\{W_t, w_t h_t + OTC_t\}$.

text.

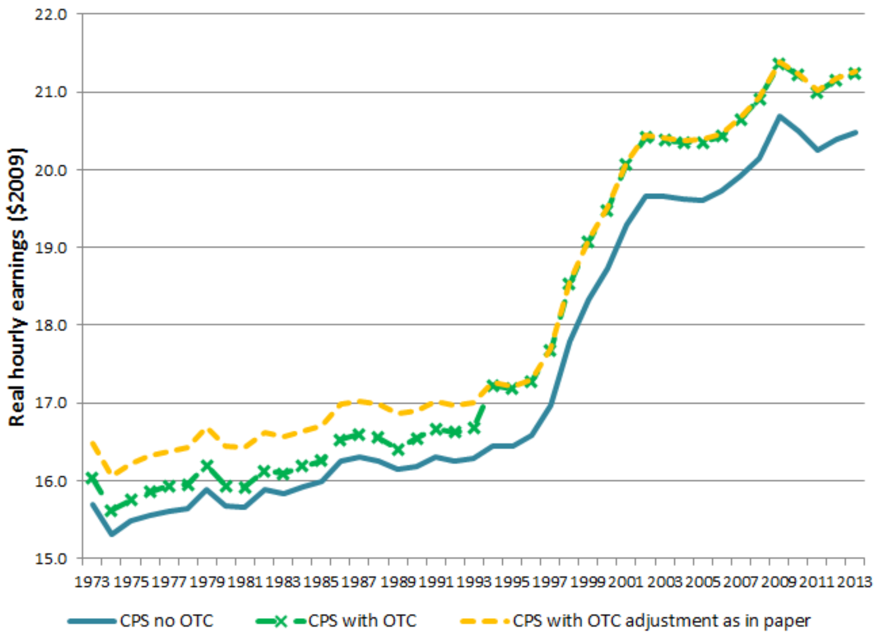

Figure A.1. Effects of different procedures to account for hourly-paid workers' OTC earnings on the CPS average hourly wage.

Hours Hours in the CPS May / ORGs are recorded as the usual number of hours per week worked on the main job.[78] By definition, hours are recorded on an "hours-worked" concept. As for compensation above, the CPS redesign in 1994 created a small consistency problem with hours; from 1994 onward, the redesigned CPS allowed respondents to indicate that their "hours vary" and thus have a missing value for usual weekly hours. As Schmitt (2003) notes: "a sizeable share of workers (typically, 6-7%) chose to report that their hours vary. Since the distribution of hourly earnings for these workers may differ systematically from that of workers whose hours generally do not vary, simply excluding the group of workers whose hours vary may reduce comparability of wage series across the 1994 redesign." The CEPR CPS ORG extracts we use in this paper impute weekly hours for these individuals who respond that their hours vary and thus have missing values.[79] Note that whenever individuals have reported that their "hours vary" along with both their usual weekly earnings and their hourly wage rate, we replace the CEPR-imputed hours value by dividing weekly earnings by the hourly wage rate.

[78] As for earnings above, we only use hours on the "main job."

[79] See Schmitt (2003) for more details on the imputation procedure.

A.4 National Income and Product Accounts (NIPAs)

In the NIPAs produced by the BEA, detailed information on compensation of workers at the national and industry levels is available along the usual macroeconomic variables found in the national accounts. Contrary to LPC, the NIPAs provide separate information on the "wage and salaries" and "supplements" parts of total compensation (while LPC only provides information on total compensation). We use this separate information to supplement the CPS series in the main text (see below for details). The compensation data are available from 1948 onward on a quarterly (and annual) basis.

A.4.1 Universe

The national accounts are representative of the U.S. economy and thus are not restricted to a specific non-farm business sector. Because of the industry information contained in the NIPAs, we can restrict the universe to almost any non-farm business definition. As we explain in the main text, we try to get as close as possible to the private non-agriculture universe of the CES. However, because the BEA reclassified industries in 2000 from 1987-SIC to 2002-NAICS definitions, it became difficult to remove the "agricultural services, forestry and fishing" industries from the sample. For example, some detailed industries classified under "agricultural services" in the 1987-SIC were reclassified outside the agricultural sector and into the "services" industries.[80] For consistency, we decide to exclude only industries related to the farm sector (i.e. 2002 NAICS 3-digit industries 111 and 112), as in LPC; we also exclude industries related to the households and non-profit institutions sector (2002 NAICS 3-digit industry 814), and to the whole public administration sector (i.e. excluding general government employees and government enterprises). Finally, note that the self-employed are not covered in our NIPA universe. The NIPA private non-farm universe is summarized in Table A.1.

A.4.2 Data definitions

In this subsection, we explain how we use compensation information from the NIPAs to supplement the CPS average earnings series in the main text.

[80] Specifically, before 2000 the BEA divides the 2-digit "Agriculture" sector into "Farms" (1987 SIC major industries 01 and 02) and "Agricultural services, Forestry, and Fishing" (1987 SIC major industries 07, 08, and 09). After 2000, the BEA uses the 2002 NAICS definitions and the "Agriculture" sector is divided into "Farms" (2002 NAICS industries 111 and 112) and "Forestry, Fishing, and related activities" (2002 NAICS industries 113, 114, and 115). The reclassification from SIC to NAICS problem occurs because many "Agricultural services" industries (SIC 07) were reclassified not under NAICS industry 115 but outside the agriculture sector and into services industries.

Compensation As in the LPC database, total compensation is computed as the sum of "wages and salaries" and "supplements"; the "wages and salaries" portion of total compensation is based on earnings data from the Quarterly Census of Employment and Wages (QCEW), and the "supplements to wages and salaries" is computed from various sources by the BEA.

- The total compensation measure is taken from the NIPAs Table 6.2, where we compute a private non-farm equivalent as defined in the universe subsection above.
- The "wages and salaries" portion of total compensation is taken from NIPAs Table 6.3, where again we compute a private non-farm equivalent as defined in the universe subsection above.

We then compute the "supplements" for the private non-farm sector by subtracting "wages and salaries" from total compensation.

A.5 Piketty-Saez income shares database

The Piketty and Saez (P-S henceforth) data set, based on IRS administrative tax data, was first released with their seminal 2003 *Quarterly Journal of Economics* paper and has been frequently updated to 2013 since then (for income shares data) and to 2011 for wage shares data.[81] Their data set contains information on top-income and top-wage shares, as well as top-income and wage threshold values and average levels for the U.S. economy.

A.5.1 Universe

The P-S data cover the whole U.S. economy, and do not provide any industry breakdown. Consequently, we cannot infer values from the P-S data for the private non-agriculture sector of the U.S. economy.

A.5.2 Data definitions

P-S provide an analysis of inequality at two levels: (1) at the income level (with and without capital gains) and (2) at the wages and salaries level. Since our work focuses on the wage and salary portion of compensation, we will use their data on "wage inequality" instead of income inequality, because the earnings concept from the P-S wage inequality data is the same as the earnings concept in the QCEW (detailed above).[82] In their data set, P-S provide wage shares (of total wages and salaries),

[81] See Piketty and Saez's (2003) original *Quarterly Journal of Economics* paper for details. The income and wage shares data are being updated every year and are available on Emmanuel Saez's website (eml.berkeley.edu/~saez).

[82] As mentioned earlier, the Piketty-Saez income data are updated up to 2013, but the wages and salaries data are available only up to 2011.

threshold values, and average wages and salaries levels for the top 10%, top 5%, top 1%, top 0.1%, top 0.01%, etc. fractiles within the top 10%. Below, we will use these wages and salaries average levels and thresholds values to estimate mean earnings for topcoded observations in the CPS data. Note that only annual earnings are available in the P-S data set; we divide by 52 to get average weekly earnings for the average and threshold values.

A.6 List of Variables

A.6.1 Average Earnings and Hours variables

- **Average hourly earnings (LPC, CES, CPS):** We compute LPC average hourly compensation, as well as CES and CPS average hourly earnings, by dividing average weekly compensation (earnings) with average weekly hours from the respective data sets.

- **Average weekly earnings (LPC, CES, CPS)**: We compute LPC average weekly compensation, as well as CES and CPS average weekly earnings, by taking the ratio of compensation (earnings) to employment for each respective data set, and dividing these ratios by 52 to get weekly averages.

- **Average weekly hours (LPC, CES, CPS):** LPC, CES and CPS average weekly hours are computed dividing by 52 the ratios of total hours to total employment for each data set.

- **"LPC private non-agriculture" average weekly earnings**: This is the LPC series, slightly modified, since we take out government enterprises employees and self-employed workers.

- **"CPS + supplements" average weekly earnings**: This series is computed as taking CPS average weekly earnings, and adding average weekly supplements calculated from the NIPAs.

  - To get **average weekly supplements**, we simply use the NIPA supplements described above (total compensation less wages and salaries from the NIPAs), and divide the series by private non-agriculture LPC employment.[83] We then divide the resulting series by 52 to get average weekly supplements that we add to the "CPS" weekly earnings series.

- **"CPS + supplements & P-S topcode corrected" average weekly earnings**: This series is computed by using the "CPS + supplements" series above, adding the P-S topcode adjustment (described below) to the CPS observations that have topcoded earnings.

[83] This is LPC employment less government enterprises and self-employed workers.

- **CPS 0-95, 95-100 average weekly earnings**: These two series are average weekly earnings from our CPS sample for the highest 5% earners ("CPS 95-100") and for the rest of the workforce ("CPS 0-95"). These two series cover the whole U.S. economy (not the private non-agriculture sector, as with all the other series).

- **P-S 0-95 and 95-100 average weekly earnings**: These average weekly earnings are taken directly from the P-S data set as annual earnings averages. We then divided these values by 52 for weekly averages. These two series cover the whole U.S. economy (not the private non-agriculture sector, as with all the other series).

- **CES replications 1 and 2 average weekly earnings:** Computed from CPS data to replicate the CES average weekly earnings series. See details below in the appropriate section.

A.6.2 Macro Variables

The different macro variables used throughout the main text are:

- **Output**: Gross Domestic Product, Non-farm business, Chained-$2009. From the NIPA tables of the BEA. Series ID: A358RX1. We divide this series by the U.S. population (see below) to get a per capita measure when extracting the business cycle components for second moments.

- **Total hours**: Total hours come from the LPC database. See LPC subsection above.

- **Price deflator**: The main series we use is the PCE deflator, from the NIPA tables of the BEA; index, 2009=100. Series ID: A002RD3.

- **Population**: Non-civilian population, 16 years old and over; from the BLS Labor Productivity and Costs program. Series ID: LNU00000000.

B Using Piketty-Saez top-wage income data to estimate means above the topcode in the CPS

We use the information in the P-S data set on average and threshold wages and salaries values for various fractiles within the top 10% of income earners. Then, using the proportion of CPS respondents with topcoded earnings each year in the CPS May and ORGs, we can impute values for weekly earnings to these respondents using the P-S earnings data. Below we lay out the detailed steps we follow to compute the assigned weekly earnings from the P-S data to the topcoded earnings in the CPS May / ORGs) in each year:[84]

[84]As mentioned earlier, as of July 2015 the top-wage and salary data in Piketty-Saez are available up to 2011.

1. Gather, for the years 1973 to 2011, average (nominal) annual earnings for the top 5%, top 1%, top 0.5%, top 0.1%; and gather threshold values for the 95th, the 99th, the 99.5th, and the 99.9th percentiles from the P-S data set.[85]

2. Convert these annual values to weekly earnings (divide annual earnings by 52).

3. Gather, from the CPS May / ORGs, the densities (%) of workers with topcoded weekly earnings in each year.[86]

4. Estimate the values to assign from the P-S data to the topcode earnings observations in the CPS May / ORGs for each year.

Steps (1) to (3) are straighforward, but step (4) is more complicated. There are two main reasons why the assignation of P-S values to topcoded observations is not simple. First, the P-S average and threshold earnings values do not correspond exactly to the densities of observations with topcoded earnings in the CPS. As a result, we need a procedure that uses some average and/or threshold fractiles values from P-S to estimate earnings values to assign to CPS topcoded observations. Second, as mentioned above, the topcode value changes twice throughout the sample in the CPS, resulting in sharp changes in the densities of topcoded observations. For example, in 1988, the proportion of observations with topcoded weekly earnings (for the whole economy) was 4.24%, while in 1989 it drops to 0.45%. The same pattern is observed between 1997 and 1998, the other moment the topcode value changes in the CPS: in 1997, the density of topcoded earnings is 1.52%, while in 1998 it drops to 0.60%. These changes in density occurring when the topcode value changes are important because they can guide us in imputing reasonable values to the topcoded observations. For instance, even if earnings are topcoded at $999/week in 1988, we assume it is highly improbable in that year (or before) that more than 0.45% of individuals made above $1923/week, since in 1989 only 0.45% of observations are topcoded at $1923/week. Consequently, even though 4.24% of individuals had topcoded earnings at $999/week in 1988, we assume that no more than 0.45% are assigned a value higher than $1923/week.[87] Let us next turn to the actual assignment procedure from the P-S data set.

[85] Ideally, we would like to use more precise threshold values that coincide exactly with the densities of observations at the topcode in the CPS, but P-S provide only these average and threshold values for earnings. We thus need to estimate the earnings values to assign to topcoded observations in the CPS from the available P-S data.

[86] Note that, for simplicity, we only consider salaried workers as potential workers with topcoded weekly earnings. The reason behind this is that the topcode level for the hourly wage is $99/hour, a threshold almost never crossed throughout the sample. Moreover, we use the "all economy" sample, since the P-S data are not restricted to the non-farm business sector but to all workers. Specifically, in the CPS we define "all economy" as all workers less private households and military workers (since they are not asked the earnings questions).

[87] Of course, this assumption eliminates the possibility of large swings in high incomes due to business cycles that would change the density of people with topcoded earnings in the CPS. The reason we make this assumption is

- For years where the density (%) of topcoded earnings is lower than 1%, we use wage information in P-S for fractiles within the top 1% to impute values to these topcoded observations. For example, in 1975, the density (%) of topcoded earnings was 0.21%. For this year, we assign to 0.1% of observations the top 0.1% average weekly earnings value in P-S (labelled "$P(99.9-100)$", for the average weekly earnings of the top 0.1%), and to the remaining topcoded values (i.e. 0.21%-0.1% = 0.11%) we assign the P-S average earnings value $P\,(99.5-99.9)$, i.e. the average earnings for individuals with wages between the 99.5 and 99.9 fractiles, since we do not have the exact average earnings value from P-S for those remaining 0.11% observations. The detailed formula to estimate the assigned weekly earnings in 1975 is thus

$$\text{assigned weekly earnings} \;=\; \frac{0.1}{0.21} * P\,(99.9-100) \;+\; \frac{(0.21-0.1)}{0.21} * P\,(99.5-99.9)\ .$$

- For years where the density (%) of topcoded earnings is higher than 1%, we use an average earnings value for the top 1% (i.e. $P\,(99-100)$), and a weighted average of the $P95$ and $P99$ percentiles thresholds for the rest of topcoded observations (again, we proceed accordingly because in the P-S data we only have the exact values for $P(95-99)$, $P95$, and $P99$ between the 95th and 99th percentiles). Take the year 2005 as an example (where the density of topcoded earnings is 1.21% in the CPS); the detailed formula to estimate the weekly earnings (in 2005) from P-S to assign to CPS topcoded observations is thus

$$\begin{aligned}\text{assigned weekly earnings} \;&=\; \frac{1}{1.21} * P\,(99-100) \\ &\quad + \frac{(1.21-1)}{1.21} * \left[\frac{0.21}{4} * P95 + \frac{(4-0.21)}{4} * P99\right]\end{aligned}$$

  where, as above, PXX corresponds to the weekly earnings threshold for the $XXth$ percentile.

- Finally, between 1973-88 or 1989-97, we ensure that the estimated values from P-S are consistent with our assumption above[88] such that a fraction not greater than the density in the year the topcode changes is assigned a higher value than the new topcode value in that year.

that when we do not take into account these sharp drops in densities when the topcode value changes, we obtain unrealistically large decreases in CPS average wages in the years after the topcode value changes.

[88] Recall that topcode values in the CPS change two times throughout the sample (i.e. the topcode changes from \$999/week between 1973-1988 to \$1923/week between 1989-1997; and finally to \$2884/week 1998 onward). Our assumption is that we find it implausible that in 1988 (or before), more than 0.45% of individuals made above \$1923/week, since in 1989, only 0.45% of individuals made more than \$1923/week. The same analogy applies from 1989 to 1997: in these years, we assume that no more than 0.60% of individuals made above \$2884/week, since this is the proportion of individuals with topcoded earnings (at \$2884/week) in 1998.

To illustrate more clearly how we implement our assumption, take for example the year 1988, where the topcode density is 4.24%. We use the procedure described above to assign an earnings value to the top 0.45% (i.e. the density in 1989 after the topcode level changes in the CPS from $999/week to $1923/week); for the rest of the topcoded observations (i.e. 4.24% - 0.45% = 3.79%), we follow the same procedure as above unless the assigned topcode value exceeds $1923/week. In that case, we simply use a 1.3 multiplicative factor (times the CPS topcode value in 1988, i.e. $999*1.3), as in Sections 1 and 2 of the main text. The detailed formula to compute the assigned weekly earnings in 1988 is

$$\begin{aligned}\text{assigned wkly earnings} \quad = \quad & \frac{0.45}{4.24} * \left[\frac{0.1}{0.45} * P(99.9 - 100) + \frac{(0.45 - 0.1)}{0.45} * P\left(99.5 - 99.9\right)\right] \\ & + \frac{(4.24 - 0.45)}{4.24} * 1.3 * 999 \ ,\end{aligned}$$

where the top row shows the assigned earnings values to the top 0.45%, and the bottom row shows that all remaining topcoded observations (3.79%) were assigned $999/week times 1.3, since the assigned P-S value estimated was higher than the CPS topcode level in 1989 (i.e. $1923/week). By using a simple 1.3 multiplicative factor, we rule out the possibility of assigning earnings values higher than $1923/week.

C CES Replications: Details

This section provides the details of the replications of the CES average weekly earnings series using CPS data. The idea behind these replications exercises is to use detailed industry and occupation information in the CPS to replicate the "production and non-supervisory" workers coverage of the CES. Because the CES and CPS have similar earnings concepts, we can evaluate whether the resulting average earnings series evolve similarly as the CES both in terms of trends and business cycle volatilities.

"CES replication 1" uses the BLS definitions for "production and non-supervisory" employees to identify individuals in the CPS with reported occupations that would be classified in this group. More specifically, to identify production and non-supervisory employees, we first distinguish goods-producing from service-providing industries (**Goods-producing**: SIC 1987 major industries B, C, and D, i.e. Mining, Construction, and Manufacturing. **Services-providing**: SIC 1987 major industries E, F, G, H, I, i.e. Transportation, Communications, Electric, gas, and sanitary services, Wholesale trade, Retail Trade, FIRE, and Services). Then, production and related workers in Mining and Manufacturing, construction employees in Construction, and non-supervisory employees in the services-providing industries (laid out above) are referred to as "production and non-supervisory" employees.[89]

As explained in the main text, "CES replication 1" fails to replicate both the CES average weekly earnings trend and business cycle volatility. A possible explanation is that employers in the CES survey report for a group of employees different than that called by the CES definitions. For instance, Abraham, Spletzer, and Stewart (1998) report that "outside the goods-producing sector, the production and non-supervisory classification is not one that employers would use for any other purpose. At least some employers might, for example, be supplying earnings data for hourly-paid workers instead [...] Another possibility is that some employers are reporting the earnings of non-exempt workers, a larger group that includes hourly-paid workers and, moreover, a group that they would need to be able to identify for other purposes." Consequently, we follow Abraham, Spletzer, and Stewart's (1998) insights and construct a second CES replication ("CES replication 2"), which tries to identify CPS respondents whom employers would classify as being non-exempt under the Fair Labor Standards Act. The differences between the first and second CES replication are: (1) every hourly-paid worker in Services-providing industries is categorized as non-exempt, regardless of industry and occupation; (2) for salaried workers, workers classified as non-exempt are purely based on occupation, not by industry and occupation. For example, outside of Manufacturing, "Managerial and Professional Specialty occupations" were generally included in "CES replication 1" but excluded from the non-exempt group and thus from "CES replication 2."[90] The "CES replication 2" thus covers the same workers as in "CES replication 1" for goods-producing industries, but covers workers paid by the hour and who are likely to be exempt under the Fair Labor Standards Act in Services-providing industries.

Figure 8 in the main text provides a graphical representation of average weekly earnings from the two CES replications, along with CPS and CES. Figure A.2 shows CES replication 2's average weekly earnings for goods-producing and services-providing industries separately, along with the

[89] See Chapter 2 of the BLS handbook of Methods, p. 2 (www.bls.gov/opub/hom/pdf/homch2.pdf). Our STATA codes are available upon request.

[90] According to the United States Bureau of the Census (1981), "Managerial and Professional Specialty Occupations" include 3-digit occupations 001 to 199.

CES counterparts (see Section 4.4 of the main text for discussion).

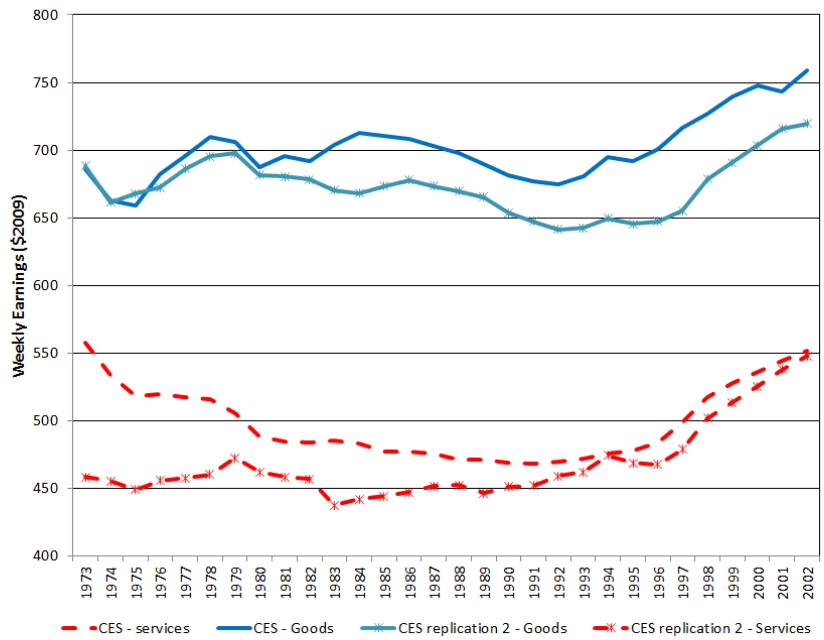

Figure A.2. Real average weekly earnings for Goods and Services related industries, CES replication 2 and CES.

D Robustness

This section presents alternative results from those reported in the main text. Table A.2 presents correlation estimates between the various wage series and non-farm business output and non-farm business LPC hours. Tables A.3 to A.6 present the same output as Tables 2, 4, 5 and 6 of the main text, but here using first-differenced data.

As mentioned in the main text (and shown in Table A.2 below), all three average hourly wage series experienced a drop in their business cycle correlations with non-farm business output and hours. It is worth noting that the CES average hourly wage experienced - by far - the largest drop in correlation. In the pre-1984 sample, the CES wage was strongly procyclical, and then became negatively correlated with the business cycle in the post-1984 period. On the other hand, both the LPC and CPS hourly wages have correlations that are not significantly different from zero in both subsamples. However, the sign of their correlation went from positive before 1984 to positive thereafter, also signalling a change in the correlation of wages with the business cycle.

	Correlations w/ GDPnfb			Correlations w/ Hours		
	Pre-84	*Post-84*	*Post - Pre 84*	*Pre-84*	*Post-84*	*Post - Pre 84*
Quarterly data						
LPC wage	0.31	-0.09	-0.39	0.14	-0.28	-0.41
	(0.16)	(0.10)		(0.13)	(0.13)	
CES wage	0.60	-0.43	-1.03	0.45	-0.46	-0.90
	(0.12)	(0.16)		(0.13)	(0.14)	
Annual data						
LPC wage	0.32	-0.08	-0.41	0.12	-0.27	-0.39
	(0.28)	(0.14)		(0.26)	(0.19)	
CPS wage	0.29	-0.38	-0.67	0.21	-0.36	-0.57
	(0.24)	(0.22)		(0.30)	(0.16)	
CES wage	0.64	-0.42	-1.05	0.51	-0.45	-0.96
	(0.24)	(0.24)		(0.21)	(0.21)	

Notes : Total sample extends from 1964Q1 to 2013Q4 for quarterly data; from 1973 to 2013 for annual data. HP-filtered data. PCE-deflated hourly w ages (2009 dollars). Non-farm business sector. Cyclical indicators are: (1) real chained-$ non-farm business GDP (NIPAs) per capita, and (2) total hours per capita from LPC. Standard errors appear in parentheses below estimates.

Table A.2. Correlations between various hourly wage series and non-farm business output and hours.

Tables A.3 to A.6 replicate Tables 2, 4, 5 and 6 of the main text using a first-difference filter instead of the HP-filter to compute the second moments. Overall, first-differencing the data corroborates the results obtained in the main text.

	Standard Deviation			Relative Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*	*Pre-84*	*Post-84*	*Post/Pre-84*
Quarterly data						
Output	1.45	0.80	0.55	1.00	1.00	1.00
	(0.10)	(0.12)				
LPC wage	0.54	0.88	1.65	0.37	1.10	3.00
	(0.05)	(0.08)		(0.03)	(0.14)	
CES wage	0.54	0.40	0.74	0.37	0.49	1.34
	(0.19)	(0.06)		(0.05)	(0.04)	
Annual data						
Output	3.92	2.22	0.57	1.00	1.00	1.00
	(0.31)	(0.38)				
LPC wage	0.96	1.52	1.58	0.25	0.69	2.79
	(0.19)	(0.20)		(0.04)	(0.17)	
CPS wage	1.24	1.28	1.03	0.32	0.58	1.83
	(0.20)	(0.24)		(0.05)	(0.16)	
CES wage	1.47	1.08	0.73	0.37	0.49	1.30
	(0.19)	(0.11)		(0.05)	(0.08)	

Notes : Total sample extends from 1964Q1 to 2013Q4 for quarterly data; from 1973 to 2013 for annual, 1st-differenced data. PCE-deflated w ages (2009 dollars). Non-farm business sector. PCE-deflated hourly w ages. P-values are reported for a test of equality of variances across the tw o subsamples. Standard errors computed using GMM and the delta method appear in parentheses below estimates.

Table A.3. Business cycle volatilities.

	Standard Deviation			Relative Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*	*Pre-84*	*Post-84*	*Post/Pre-84*
1st-difference						
Output (nfb)	3.92	2.22	0.57	1.00	1.00	1.00
	(0.31)	(0.38)				
LPC total compensation	1.30	1.40	1.07	0.33	0.63	1.89
	(0.26)	(0.21)		(0.06)	(0.15)	
LPC total compensation (private non-agri)	1.30	1.35	1.04	0.33	0.61	1.83
	(0.28)	(0.21)		(0.06)	(0.15)	
CPS	1.17	1.26	1.08	0.30	0.57	1.91
	(0.16)	(0.28)		(0.06)	(0.17)	
CPS + Supplements	1.27	1.19	0.94	0.32	0.54	1.66
	(0.17)	(0.26)		(0.05)	(0.16)	
CPS + Supplements & P-S topcode values	1.25	1.28	1.03	0.32	0.58	1.82
	(0.17)	(0.22)		(0.05)	(0.15)	

Notes : Total sample extends from 1973 to 2013, except for P-S topcode adjusted series which ends in 2011. Annual data. PCE-deflated wages (2009 dollars). 1st-differenced data. Standard errors computed using GMM and the delta method appear in parentheses below estimates.

Table A.4. Business cycle volatilities for various average weekly earnings series.

	Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*
Percentiles			
P-S P0-95	1.44	0.99	0.69
	(0.30)	(0.16)	
CPS P0-95	1.26	1.09	0.86
	(0.17)	(0.23)	
P-S P95-100	1.75	3.90	2.23
	(0.25)	(0.30)	
CPS P95-100	2.11	2.39	1.13
	(0.27)	(0.58)	

Notes: CPS May-MORG data and Piketty-Saez "Top income shares" database. Real Average Weekly Earnings (2009 dollars). Annual data from 1973 to 2011. All economy. 1st-differenced data.

Table A.5. Effect of high-income earners on average earnings volatility.

	Standard Deviation		
	Pre-84	*Post-84*	*Post/Pre-84*
1st-difference			
CPS	1.17	1.41	1.21
	(0.16)	(0.27)	
CES replication 1	1.36	1.39	1.02
	(0.15)	(0.23)	
CES replication 2	1.76	1.40	0.79
	(0.10)	(0.28)	
CES	1.97	1.25	0.64
	(0.26)	(0.18)	

Notes : CPS May-MORG data. Real Average Weekly Earnings (2009 dollars). Annual data. Sample: 1973 to 2002.

Table A.6. Replicating average real earnings volatility from the CES with CPS data.

E Computation of Standard Errors

Standard errors and relative standard errors in the text are obtained using the delta method from GMM-based estimates. In the first stage, define

$$f(x_{it},\mu)=\begin{bmatrix} x_{1t}-\mu_1 \\ \dots \\ x_{Nt}-\mu_N \\ x_{1t}x_{1t}-\mu_{11} \\ \dots \\ x_{Nt}x_{Nt}-\mu_{NN} \end{bmatrix},$$

where x_{it} are the time series of interest for $t=1,...,T$; $\mu_i=E(x_{it})$ for $i=1,...,N$; and $\mu_{ij}=E(x_{it}x_{jt})$ for $i,j=1,...,N$. The GMM estimator sets $\widehat{\mu}$ such that $\frac{1}{T}\sum_{t=1}^{T}f(x_{it},\mu)=0$. The asymptotic distribution of the GMM estimator is given by

$$\sqrt{T}(\widehat{\mu}-\mu)\longrightarrow N\left(0,\left\{D'S^{-1}D\right\}^{-1}\right),$$

where

$$D=E\left[\left(\frac{\partial f(x_{it},\mu)}{\partial\mu'}\right)\right]'$$

is the Jacobian matrix (N x N since our GMM procedure is just-identified), and where

$$S = \sum_{j=-\infty}^{\infty} E\left[f(x_t,\mu)f(x_t,\mu)'\right].$$

Next, compute the covariance matrix for the standard errors

$$COV(\mu) = \frac{\left\{D'S^{-1}D\right\}^{-1}}{T}.$$

To construct a sample analog of S, we use the Newey-West estimate of S:

$$\widehat{S}_T = \sum_{j=-k}^{k} \left\{ \left(\frac{k-|j|}{k}\right) \frac{1}{T}\sum_{t=1}^{T} f(x_t,\widehat{\mu})f(x_{t-j},\widehat{\mu})' \right\}.$$

Then, our moments of interest are standard deviations and relative standard deviations (nonlinear functions of the moments found above), so we use the delta method to estimate the standard errors of these standard deviations and relative standard deviations. For example, consider the standard deviation of a random variable x_{it}:

$$\sigma_x = (E(x_t^2) - E(x_t)^2)^{1/2}.$$

Here we interpret σ_x as a function of the population moments $E(x_t)$ and $E(x_t^2)$. Moreover, define

$$\mu = \begin{bmatrix} E(x_t) & E(x_t^2) \end{bmatrix} \equiv \begin{bmatrix} \mu_x & \mu_x \end{bmatrix},$$

and thus

$$\sigma_x(\mu) = (\mu_{xx} - \mu_x^2)^{1/2} = X(\mu_x, \mu_{xx}).$$

The delta method states that

$$\sqrt{T}(\widehat{X} - X) \longrightarrow N\left(0, \frac{\partial X}{\partial \mu}\left\{D'S^{-1}D\right\}^{-1}\frac{\partial X'}{\partial \mu}\right).$$

Since $D = \frac{\partial f}{\partial \mu} = -I$, where I denotes the identity matrix of appropriate dimension, $\left\{D'S^{-1}D\right\}^{-1}$ reduces to S. Furthermore, we can compute the derivative of X with respect to μ

$$\frac{\partial X}{\partial \mu} = \frac{\partial \sigma_x}{\partial \mu} = \begin{bmatrix} \frac{\partial \sigma_x}{\partial \mu_x} \\ \frac{\partial \sigma_x}{\partial \mu_{xx}} \end{bmatrix} = \begin{bmatrix} -\mu_x/\sigma_x \\ 1/(2\sigma_x) \end{bmatrix}.$$

With these in hand, along with the estimate of S, $\widehat{S}_T$, we can compute the standard error of σ_x.

We use the same procedure to find the standard errors for relative standard deviations (e.g. the ratio of the standard deviations of wages and output), where the derivative of X with respect to μ is

$$\frac{\partial X}{\partial \mu} = \frac{\partial \left\{ \sigma_x / \sigma_y \right\}}{\partial \mu} = \begin{bmatrix} \frac{\partial \sigma_x}{\partial \mu_x} \\ \frac{\partial \sigma_y}{\partial \mu_y} \\ \frac{\partial \sigma_x}{\partial \mu_{xx}} \\ \frac{\partial \sigma_y}{\partial \mu_{yy}} \end{bmatrix} = \begin{bmatrix} \frac{-\mu_x}{\sigma_x \sigma_y} \\ \frac{\mu_y X}{\sigma^2} \\ \frac{1}{2\sigma_x \sigma_y} \\ -\frac{1}{2}\frac{X}{\sigma^2} \end{bmatrix}.$$

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