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Abstract
This paper presents a change to the BLS methodology for estimating hours worked for its productivity measures. The current methodology uses the CES production-worker hours series as the primary source of data. Nonproduction worker hours are estimated by calculating the ratio of nonproduction worker to production worker hours using Current Population Survey (CPS) data, and then multiplying that ratio by production worker hours. We examine several issues related to the current methodology, including classification of production and nonproduction workers in CPS, differences in the accuracy of hours reporting between worker types, and differences in industry classification between CPS and CES. We then develop a new hours series based on the CES all-employee series, which requires a different set of adjustments including an adjustment for off-the-clock hours. We compare the all-employee-hours based series to the current methodology and find that the long-run growth in aggregate hours worked is about the same as the growth using the current methodology. However, there are larger differences in quarterly growth rates, which result in the two series telling slightly different stories about the timing of productivity growth.

JEL codes: E24, J21, J22

Keywords: hours worked, productivity, off-the-clock work, labor

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I. Introduction

Labor is an important input to the production process, and the correct measurement of hours worked is critical for calculating productivity. The Bureau of Labor Statistics (BLS) collects hours data in its establishment survey, the Current Employment Statistics (CES) survey, and its household survey, the Current Population Survey (CPS). The BLS productivity program uses the CES as its primary source of hours data, because: (1) output data come from establishments and hours from establishments are thus more likely to be consistent with the output data, (2) industry coding in the establishment survey is more accurate and more consistent with output data, (3) the larger sample in the establishment survey provides better industry coverage and reduces the variability of industry-level estimates, and (4) employment estimates from the establishment survey are benchmarked annually to the employment universe by industry. [1]

However, for productivity measurement, the CES hours data have several drawbacks. First, the CES measures hours paid rather than hours dedicated to the production of output, which is the appropriate concept. Thus, paid time off should be excluded, and off-the-clock hours should be added in.[2] Second, the CES, until 2006, collected hours data only for production and nonsupervisory employees (henceforth, production workers).[3] Third, the CES does not

[1] The CES sample is six times larger than the CPS sample and is stratified by industry, while the CPS sample is not stratified by industry. CPS sample weights are benchmarked to match the Census population totals. It is worth noting that the weights for inter-Census years are not adjusted. This could result in discrete jumps in levels when the new weights are introduced, but virtually no change in most ratios. New population controls are typically introduced two years after the Decennial Census is released.
[2] Short breaks of 15 minutes or less during the workday are assumed to be productive time.
[3] The CES instructs respondents to classify workers as production or non-production workers in goods-producing industries and as nonsupervisory or supervisory workers in service-providing industries. This results in some inconsistencies in how some workers are classified. For example, an accountant who does not supervise other workers would be classified as a non-production worker if employed in a goods-producing industry, but classified as a non-supervisory worker in a services-providing industry. Moreover, a Record Analysis Survey (BLS, 1983) from the 1980s showed that respondents do not always follow CES instructions when classifying their employees.

collect data for unincorporated self-employed and unpaid family workers, and does not collect hours for government enterprise workers[4].

To make the CES data consistent with concepts used for productivity measurement, the BLS productivity program makes several adjustments. First, it supplements the CES hours-paid data with data on paid leave from the National Compensation Survey (NCS). The NCS data are used to adjust the CES production worker hours data from an hours-paid to an hours-worked basis using information on annual leave earned and usual sick leave taken. Note that this adjustment does not account for off-the-clock work. Second, the productivity program combines CES data with CPS data to estimate hours worked by nonproduction and supervisory employees (henceforth, nonproduction workers). Nonproduction worker hours are calculated as the ratio of nonproduction workers to production worker average weekly hours worked estimated using CPS data (henceforth, the CPS ratio) multiplied by the adjusted CES production worker average weekly hours. Third, CPS data are used directly to measure hours worked by the unincorporated self-employed and unpaid family workers, who made up about 8 percent of employment in the nonfarm business sector in 2019. Because hours worked by self-employed and unpaid family workers are estimated using only CPS data, they are out of scope for this study.

In March 2006, CES started publishing hours-paid data for all employees as a research series—and as an official series starting in 2010.[5] Using these all-employee hours data, adjusted to an hours-worked basis, is a more direct approach compared to the current BLS methodology. However, as noted above, the CES hours-paid measure does not include off-the-clock hours worked by salaried and commission-only workers (henceforth, salaried workers), because the

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[4] Government enterprise hours are developed from the National Income and Product Accounts and CES estimates of employment and CPS data on average weekly hours. See Technical Information About the BLS Major Sector Productivity and Costs Measures.

[5] We use the terms workers and employees interchangeably throughout this article.

CES questionnaire instructs respondents to report hours for these workers based on their standard workweeks—not actual hours worked.[6] Nonproduction workers are about 20 percent of CES employment and, according to the CPS, about 70 percent of them are salaried, which translates to about 14 percent of CES total employment. This issue also affects production worker hours because about 30 percent of production workers are salaried, which translates into about 24 percent of CES total employment. The current methodology for estimating nonproduction worker hours captures some of the variation in off-the clock hours, because the CPS ratio is calculated using actual hours worked. But there is no adjustment for salaried production workers.

This study evaluates the advantages and disadvantages of using the new CES all-employee-hours series for productivity measurement and develops a methodology to make the series consistent with the hours-worked concept. Our analysis covers the nonfarm business sector, with some additional analyses for major industry groups. In the next section, we describe the current methodology for estimating hours worked. Section III discusses several advantages to using the all-employee hours series. Section IV describes proposed adjustments to the CES all-employee-hours series to estimate actual hours worked. Section V compares the current hours series to measures constructed from the CES all-employee hours data over the 2007–2019 period Section VI discusses and concludes.

II. The Current Methodology for Estimating Hours Worked

The BLS uses three sources of data to estimate hours worked by wage and salary workers for measures of productivity. The main data source is the CES, which is a monthly payroll survey that covers about 689,000 establishments. The CES collects data on employment and total

[6] This is the best that can be done from payroll data, because employers are not required to keep track of hours worked by non-hourly workers.

hours paid for all employees and for production workers. Employment includes all employees who worked or were on paid leave during the pay period that includes the 12th of the month. As noted above, paid hours include hours worked during the pay period plus hours of paid leave, but do not include unpaid overtime. Total pay period hours are converted to total weekly hours using conversion factors that vary depending on the number of days in the pay period (and the month for monthly and semi-monthly payrolls).[7] CES calculates average weekly hours as total weekly hours paid divided by employment.

The productivity program currently estimates hours for production and nonproduction workers separately. To convert CES production worker hours to an hours-worked basis, the productivity program calculates an hours-worked-to-hours-paid (HWHP) ratio from the NCS, which is an establishment survey that collects data on all forms of compensation—including paid leave.[8] As noted above, this ratio captures changes in annual leave earned (including paid holidays) and usual sick leave taken, and therefore removes non-work time from hours paid, but the ratio does not capture off-the-clock work or variation in actual leave taken.[9] Where possible, BLS applies these ratios at the three-digit NAICS industry level. More formally, production worker hours are calculated as:

$$(1) \qquad Hours\ Worked_{P}^{Current} = \left[AWH_P^{CES} \times \left(\frac{HW}{HP}\right)_P^{NCS}\right] \times EMP_P^{CES} \times 52$$

where AWH_P^{CES} is quarterly average weekly hours for production workers from the CES, $\left(\frac{HW}{HP}\right)_P^{NCS}$ is the HWHP ratio for production workers from the NCS, and EMP_P^{CES} is average

[7] For monthly and semi-monthly pay periods, this will depend on the number of days in the month.
[8] The primary use of the NCS data is to construct the Employment Cost Index (ECI). Prior to 2000, the HWHP ratio was estimated using data from the now discontinued Hours at Work Survey.
[9] It is implicitly assumed that production workers are paid hourly and, therefore, do not work off the clock.

production worker employment for the quarter from the CES.[10] The weekly hours estimate is multiplied by 52 to "annualize" the data.

To estimate nonproduction worker hours, BLS uses additional data from the CPS, which is a monthly survey of about 60,000 households that collects demographic and job-related data on all workers. The CPS collects self-reported information about actual hours worked during the week that usually includes the 12th of the month plus information on workers' industry and occupation.[11] Workers are first classified as production or nonproduction workers using industry and occupation codes. Next, data on actual hours worked are used to calculate the ratio of nonproduction-worker average weekly hours to production-worker average weekly hours (the CPS ratio). Hours from the CPS are not used to directly estimate nonproduction worker hours because the CPS sample is not stratified by industry, and therefore employment totals will not necessarily match CES totals by industry. Also, at the time this methodology was developed, there were concerns about biased reporting of hours in the CPS.[12] The CPS ratio is multiplied by production worker average weekly hours. Thus, nonproduction worker hours are calculated as:

$$(2)\quad Hours\ Worked_{NP}^{Current} = \left[AHW_P^{CES} \times \left(\frac{HW}{HP}\right)_P^{NCS}\right] \times \frac{AWH_{NP}^{CPS}}{AWH_P^{CPS}} \times (EMP_{all}^{CES} - EMP_P^{CES}) \times 52$$

[10] The CES data are published monthly. The quarterly AWH estimate is constructed by averaging total hours for the three months of the quarter and dividing by the corresponding average production worker employment. Quarterly employment, N_P^{CES}, is an average of the three months of the quarter. BLS annualizes the quarterly hours estimates so that they are comparable with annual hours estimates. The NCS ratio is a 3-year moving average of annual ratios. Quarterly values are interpolated using the Denton procedure.

[11] Reference weeks in November and December are sometimes moved up to avoid conflicts with the Thanksgiving and Christmas holidays. The CPS goes to great lengths to collect actual hours worked. CPS respondents are asked to report their usual hours on their main and second jobs. For their main job, they are then asked if they took time off or worked extra hours during the previous week, and then to confirm actual hours worked. For second jobs, they are asked to report actual hours worked during the previous week.

[12] These concerns were based largely on research by Robinson and Bostrom (2004). Subsequent research by Frazis and Stewart (2004, 2007, 2009, 2010) shows that average weekly hours calculated from the CPS data are accurate on average, although some groups over-report hours while others under-report hours.

where AWH_{NP}^{CPS} and AWH_{P}^{CPS} are the CPS estimates of average weekly hours worked for nonproduction and production workers, EMP_{all}^{CES} is the CES all-employee count, EMP_{P}^{CES} is the CES production-worker employment, and $(EMP_{all}^{CES} - EMP_{P}^{CES})$ is nonproduction worker employment from CES.[13] The BLS productivity program began using the CPS-ratio methodology in 2004.[14]

III. Why Switch to the CES All-employee Hours Data?

The current methodology for estimating hours worked for all employees is based primarily on CES production worker hours data. However, with 15 years of CES all-employee hours data now available, it is feasible to consider replacing the current methodology with one based on the all-employee hours data. There are three compelling reasons to do so: (1) the all-employee hours are more reliable than production worker data, (2) the ability to replicate the CES sample using CPS data has diminished, and (3) there is new evidence of bias in the CPS ratio.

First, the CES all-employee data are more reliable than the CES production worker data, because the production worker employment is more subject to sampling error and nonresponse bias. Unlike total employment, production worker employment is not estimated directly, and it

[13] To construct the nonfarm business sector measures, BLS estimates hours worked by production and nonproduction workers for the NIPA industries, the hours are aggregated and then hours of those working at nonprofit institutions are removed. Total hours worked for all persons is the sum of production and nonproduction worker hours, and hours worked by the unincorporated self-employed, unpaid family workers, and employees of government enterprises. Hours worked by the unincorporated self-employed and unpaid family workers are obtained directly from the CPS. Employment counts for employees in agricultural services, forestry and fishing come from the BLS QCEW program, which is based on administrative records from the unemployment insurance system. The number of employees for government enterprises is calculated using NIPA series, a CES postal series, and a CES series of state & local government employment, while average weekly hours for government enterprise employees come from the CPS.

[14] The ratio method begins with 1979 data and is linked to the historical data. Prior to 2004, BLS adjusted the hours of production workers in the manufacturing sector using the ratio of office to non-office worker hours extrapolated from a survey that was last conducted in 1978. In the non-manufacturing sector, OPT assumed that supervisory workers worked the same hours as nonsupervisory workers. See Eldridge, Manser, and Otto (2004) for more details.

is not benchmarked to the Quarterly Census of Employment and Wages (QCEW).[15] Respondents report the number of production workers in goods-producing industries and the number of nonsupervisory workers in service-producing industries. Within each estimating cell (defined by industry and establishment size), production worker employment is calculated as the product of total employment and the ratio of production worker employment to total employment for establishments in that cell. Both are estimated from the sample, but only total employment is benchmarked to the QCEW. In addition, non-response is significantly higher for production worker employment than for all-employee employment. Thus, estimates of production worker employment could be biased if the production worker ratio is different for respondent and non-respondent establishments—even though all-employee employment is correct (after benchmarking).[16] It is also important to note that past studies have showed that some respondents had difficulty classifying workers as production (goods-producing industries) or nonsupervisory (services-providing industries). Although there are no studies to determine whether this has gotten worse over time, but it was an important factor in why the CES program emphasizes the collection of all-employee hours data over production worker hours data.[17]

The second reason for replacing the current methodology is based on an observed change in the data. The current methodology relies on the CPS ratio and our ability to replicate the CES

[15] BLS Handbook of Methods: Chapter 2. Employment, Hours, and Earnings from the Establishment Survey, see page 5.

[16] It is worth noting that the response rate for both production worker and all-employee hours is significantly lower than the response rate for total employment. The response rate for reporting all-employee counts varies by establishment size, but is about 53 percent on average. Conditional on reporting an all-employee count, the response rate for hours is about 57 percent, which translates to an unconditional response rate of about 30 percent. BLS has studied the impact of non-response on earnings using data from the Quarterly Census of Employment and Wages (QCEW) and found a downward bias due to non-response (Bureau of Labor Statistics, 2013). The QCEW does not collect data on hours, so the study compared CES hours to hours data from the CPS. See also Frazis and Stewart (2010).

[17] Getz, Patricia, "CES program: changes planned for hours and earnings series," *Monthly Labor Review*, October 2003, pages 38-39. Clinton, Angie, and John Coughlan, and Brian Dahlin,"New all-employee hours and earnings from the CES survey," *Monthly Labor Review*, March 2010, pages 34-40.

production worker concept using industry and occupation data from the CPS. Figure 1, which shows the fraction of wage and salary workers who are classified as nonproduction workers in the CES and the CPS, casts doubt on this assumption. From 1994 through the mid-2000s, the two series track each other fairly closely. In both series, the nonproduction worker share of total employment was in the 18.2–20.4 range with no obvious trend. But beginning around 2006, the two series begin to diverge. The CES series reached its peak of 19.2 percent in early 2004, but then declined 1.7 percentage points to 17.5 percent early in 2008 with little movement in the ratio thereafter. In contrast the CPS series started increasing in 2006, increasing from about 18.5 percent to about 21 percent by the end of 2019. Thus, the two series went from being within 2 percentage points of each other pre-2006 and tracking each other fairly closely to diverging and differing by over 3 percentage points. There are changes to both surveys that could have contributed to this divergence. In particular, the CES introduced the probability sample by industry and a state-based design between 2000 and 2003, making the sample more representative and improving data quality.[18] Apart from the changes, CES respondents have always found classifying workers as production or nonproduction to be difficult, which was identified as one of the motivations for collecting all-employee earnings and hours.[19] It is possible that these changes may have caused the observed decline in the share of nonproduction workers in the CES data. Besides the changes to the CES, the Census occupation codes used by the CPS changed significantly between 2002 and 2003 to include a number of "First-line supervisor" codes. Even though we cannot identify the source of the divergence, the share of

[18] See Appendix X for more information about the CES redesign and changes to Census occupation codes.
[19] See Getz (2003). She noted: "Another impetus for the transition to an all employee definition is the increasing difficulty that many respondents have compiling information for the production and nonsupervisory worker definitions presently used by the CES program. Most payroll recordkeeping does not allow for the easy identification of workers defined by CES categories of production and nonsupervisory workers."

nonproduction workers identified in the CPS no longer tracks the share of nonproduction workers in the CES as closely.

The third reason for adopting the CES all-employee hours data is that there is new evidence of bias in the CPS ratio. Because the current methodology relies on the CPS ratio of the average weekly hours for nonproduction workers relative to the average weekly hours of production workers, it implicitly assumes that any bias in average weekly hours worked is the same for both groups of workers.

After the CPS-ratio methodology was developed and implemented, the BLS introduced the American Time Use Survey (ATUS) that provides a method for testing bias in hours reports in the CPS.[20] Research by Frazis and Stewart (2004, 2007, 2009 and 2010) has compared CPS hours data to hours data from ATUS and found self-reported hours in the CPS data to be accurate on average. However, they also found variation in reporting accuracy across demographic groups (Frazis and Stewart, 2004). In particular, more-educated workers overstated their hours, while less-educated workers understated their hours. This suggests that the CPS ratio could be biased because, on average, production workers have less formal education than nonproduction workers. In addition, Eldridge and Pabilonia (2010) found that nonproduction workers are more likely to bring work home from their workplaces, which could make it more difficult for them to recall their hours worked.

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[20] Misreporting in the CPS was a concern at the time of implementation because research by Robinson and Bostrom (1994) cast doubt on the accuracy of hours-worked data from household surveys. Comparing responses to retrospective questions to time-diary data, which are considered to be more accurate, they found that respondents answering retrospective questions tend to report longer work hours and that the difference between responses to retrospective and time-diary estimates had increased over time. However, there are a number of issues with the Robinson and Bostrom (1994) study. In particular, the time-diary surveys they used collected hours data, but the questions differed across surveys and time periods. Frazis and Stewart (2004) show that responses to “usual hours” and “actual hours” questions differ significantly. The question wording matters. In addition, it is not clear what sample weights were used in the former study nor how work was defined in the time-diary data.

To examine the bias in the CPS ratio, we compared ratios calculated from CPS and ATUS data. We consider the ATUS measure to be the more accurate hours measure given it is less likely to be subject to recall bias and aggregation bias (Juster et al. 1985). In Table 1, we can see that there is an upward bias in the CPS ratio in almost every year, and that the bias varies over time and over the business cycle. It is larger in the early 2000s than after 2011, and it is especially large in 2007 and 2008. The details of our analysis are in the Appendix.

To summarize, there are issues with classifying workers as production or nonproduction in both the CPS and CES. In the CES, there are two issues: (1) respondents may not have records that would enable them to classify production workers correctly, and (2) the production worker employment is not estimated directly and is not benchmarked. There is also evidence that the CPS data no longer replicate the share of nonproduction workers in the CES sample. Finally, there is evidence that nonproduction workers may overreport their hours while production workers underreport hours leading the CPS ratio itself to be biased upwards. More importantly, this bias varies over the business cycle. Putting these pieces together, we conclude that using the CES all-employee data to estimate hours, rather than primarily relying on production worker data, would improve data quality.

IV. Creating an Hours-Worked Series using the CES All-employee Hours Data

As we noted in the introduction, the establishment survey collects “hours paid,” while the correct concept of work for productivity measurement is “hours worked.” Thus, to use the CES all-employee hours data, it is necessary to adjust the data to an hours-worked concept. Recall, that the current hours-worked-to-hours-paid (HWHP) ratio from the NCS adjusts hours-paid data to exclude paid leave. However, this adjustment does not account for unpaid hours worked above a worker's standard hours.[21] As we noted in the introduction, about 70 percent of nonproduction workers and about 30 percent of production workers are salaried, which translates to about 38 percent of wage and salary employment.[22]

Given the large fraction of workers who are salaried, it is essential to adjust for OTC hours in addition to excluding paid leave. We can write the ideal HWHP adjustment ratio as:

$$(3)\ \ HWHP = \frac{Hours\ Worked}{Hours\ Paid}$$

$$= \frac{Hours\ Paid -\ Hours\ of\ Paid\ Time\ Off +\ Off\ The\ Clock\ Hours}{Hours\ Paid}$$

The HWHP ratio is greater than one if off-the-clock (OTC) hours are greater than hours of paid time off (PTO), and less than one if the OTC hours are less than hours of PTO.

As we noted earlier, the NCS HWHP ratio removes non-work time from hours paid, and therefore only accounts for hours of PTO. This ratio can be written as:

$$(4)\qquad HWHP^{NCS} = \left(\frac{Hours\ Paid -\ \ Hours\ of\ PTO}{Hours\ Paid}\right)^{NCS}$$

To see how equation (4) fits into the ideal HWHP ratio in equation (3), we decompose equation (3) into two components:

$$(5)\ \ HWHP = \left(\frac{Hours\ Paid -\ \ Hours\ of\ PTO}{Hours\ Paid}\right)$$

$$\times \left(\frac{Hours\ Paid -\ \ Hours\ of\ PTO + OTC\ Hours}{Hours\ Paid -\ \ Hours\ of\ PTO}\right)$$

[21] The importance of off-the-clock work has been recognized by previous research. For example, Aaronson and Figura (2010) examine the cyclicality of off-the-clock hours, Frazis and Stewart (2010) consider whether the difference in hours concepts (worked versus paid) can explain the divergent trends of CES and CPS hours, and Eldridge and Pabilonia (2010) examine whether increasing amounts of unpaid overtime work brought home from the office may bias estimates of productivity growth.

[22] Because the current CPS ratio uses data on actual hours worked, it captures most of the hours above the standard work week for salaried nonproduction workers. It does not capture all OTC hours, because the ratio does not account for OTC hours worked by production workers in the CES.

The first term in parentheses is a ratio of "paid work hours" to hours paid and is conceptually the same as the NCS HWHP ratio, which we will refer to as a PTO adjustment or PTO ratio. The second term is an OTC adjustment, or OTC ratio, and is a ratio of "hours worked" to "paid work hours," keeping in mind that this ratio differs from how OTC hours are defined in previous research.[23] Note that the PTO adjustment is always less than one, while the OTC adjustment is always greater than one.

We propose substituting the NCS HWHP ratio in equation (4) into the first term in equation (5), and calculating the second term in equation (5) using CPS data, giving us:

$$(5') \quad HWHP = \left(\frac{Hours\ Paid - \ Hours\ of\ PTO}{Hours\ Paid}\right)^{NCS} \times \left(\frac{Hours\ Paid - \ Hours\ of\ PTO + OTC\ Hours}{Hours\ Paid - \ Hours\ of\ PTO}\right)^{CPS}$$

For the rest of the paper, we will refer to the NCS ratio as the PTO adjustment or PTO ratio. Note also that the OTC term in equation (5′) is calculated as hours worked relative to paid work hours rather than usual hours paid, ensuring that the OTC term is consistent with the PTO term.

To estimate the OTC adjustment, we need information on hours worked, hours paid, and hours of paid-time-off. The CPS collects actual and usual hours worked but does not collect hours paid or hours of paid time off. However, the CPS collects other information that, when combined with a few reasonable assumptions, can be used to estimate hours paid and hours of paid time off. Using this information, it is possible to construct the three variables in the second term of equation (5′): Hours Paid, Hours of PTO, and OTC Hours.

[23] Both Aaronson and Figura (2010) and Frazis and Stewart (2010) calculate hours worked and simulated hours paid directly from the CPS. The difference between the two measures is OTC hours. Our ratio approach is constructed in the same spirit, but we multiply the HWHP ratio by actual CES all-employee hours, which were not available when these papers were written.

Estimating the OTC Ratio[24]

CPS data are collected on a person basis. As such, an individual who has two jobs will be counted as 1 person employed. The CES data are measured on a jobs basis, such that employment is captured for each job. Because our primary data source is the CES, it is important to convert the CPS data to a jobs concept. The CPS collects data on primary and secondary jobs. We can use this information to convert the CPS from a person basis to a jobs basis.

For each job, we need information on hours worked, hours paid, and PTO. The CPS collects some of this information, but some pieces must be estimated. For each job, the CPS collects actual and usual hours worked.[25] The CPS does not collect information on hours paid or PTO, but we estimate these using other information in the CPS.

We also make a few simplifying assumptions. We assume that people are paid hourly on their second jobs and that they do not receive PTO. We also assume that hourly-paid workers do not work any OTC hours. Thus, OTC hours can only be worked by salaried workers on their main jobs.

For salaried workers, we need to estimate both hours paid and paid time off. We estimate hours paid for salaried workers as usual hours worked, topcoded at standard workweeks (40 for full-time workers and 20 for part-time workers).[26] Respondents may report that their usual hours worked vary. In these instances, we assume usual hours paid is 40 if it is their primary job and they report that they usually work fulltime and 20 if it is their primary job and they report that they usually work part-time. For second jobs where hours vary, we assign the 20-year average for major industry group.

[24] A more detailed description can be found in the Appendix.

[25] We topcoded actual and usual hours worked at 84 hours per week (7 × 12 hours per day).

[26] The value of the cap has virtually no effect on the growth rate of hours and labor productivity. It does have a small impact on levels.

Next, we estimate a measure of paid time-off. Time off is calculated as the difference between usual hours paid and actual hours worked. If actual hours worked is greater than usual hours paid, then time off equals zero. Once we have calculated time off, it is necessary to determine whether the worker was paid for the time off. If a worker reports that their actual hours worked equals zero, the CPS asks respondents if they were paid for the time off.[27] If the worker worked part of the week, they are not asked if they were paid for their time off, and thus we must estimate this variable.

Our approach to PTO for part-week workers is to estimate the probability that the time off was paid, prob(PTO), and then multiply that probability by time off. For example, if time off is 16 hours and the prob(PTO) = 0.75, then we assume that 12 of the 16 hours were paid.[28] To estimate the probability that the time off was paid, we used the subsample of people who were employed but did not work during the reference week to estimate a probit regression of PTO (1 = time off was paid) on a set of demographic variables, industry, and occupation. The coefficients from this probit regression were used to generate predicted values for the rest of the sample.

The final variable we need for the OTC adjustment is actual hours paid. The calculation is different for hourly and salaried workers, because we assume hourly workers are paid for all of the hours they work and that they never work OTC hours.[29] For salaried workers, actual hours paid is equal to min(actual hours worked + PTO; usual hours paid). For hourly workers, it is simply PTO plus actual hours worked.

[27] For individuals who are not asked about paid-time off, we impute whether time-off is paid, see Appendix.

[28] This is equivalent to adjusting the sample weights. The sample weights indicate the number of people that the observation represents. If the observation's weight is 2,400, this is equivalent to assuming that 1,800 people were paid for all of their time off and that time off for the remaining 600 was unpaid.

[29] The CPS identifies workers are hourly or nonhourly. The latter group typically includes those who receive a salary, commission-only, or who are paid in kind from a private employer. We refer to these workers as salaried throughout. hourly status is only collected in the CPS outgoing rotation groups (ORG), HRMIS=4,8, and thus is not available in months in sample (HRMIS) 1-3 and 5-7. In order to use the full dataset to calculate *hours paid*, it is necessary to impute this variable for these months in sample (1-3 and 5-7). see Appendix.

The final complication is that we only know hourly/salaried status for one-quarter of the sample (months in sample 4 and 8—the outgoing rotation groups). Along the lines of how we estimated prob(PTO), we use the sample of employed workers in the outgoing rotation groups to estimate the probability that workers are paid hourly. We estimated a probit regression of hourly/salaried status (hourly = 1) on a set of demographic variables, industry, and occupation (the same variables as in the PTO probit). As we did above, the coefficients from the probit regression were used to generate predicted values for the rest of the sample. For each observation, actual hours paid is equal to the weighted average of actual hours paid for hourly and salaried workers, where the weights are equal to prob(hourly) and (1 – prob(hourly).[30]

The OTC ratio is equal to actual hours worked divided by actual hours paid. It is important to note that the OTC ratio differs from that in Aaronson and Figura (2010), which is actual hours worked divided by usual hours paid. The reason is that the denominator in the OTC ratio must be the same (at least conceptually) as the numerator in the PTO ratio (see the Appendix for further details).

VI. Impact of Using All-employee Hours Methodology

In this section, we examine the impact of changing the methodology for measuring hours of work. We calculated estimates of hours worked using the CES all-employee hours, adjusted for paid time off and off-the-clock hours for each of the 13 major industry sectors. We then aggregated those estimates into an estimate of total hours worked for the nonfarm business sector.[31] We compare the CES all-employee hours paid series adjusted for PTO and OTC hours

[30] As with prob(PTO), this is equivalent to adjusting the sample weights.

[31] The LPC program builds up its estimates of hours from more-detailed industries. For the NCS HWHP ratio, LPC builds up from 3-digit NAICS industries. For the CPS nonproduction/production worker ratio, LPC builds up from the 14 supersectors. We are continuing work to create estimates for the Natural Resources and Mining sector.

(CES_PTO_OTC) series to the following series: the current OPT hours worked series (OPT), the CES all-employee hours **paid** series (CES), and the CES all-employee hours paid series adjusted for PTO (CES_PTO)). Figure 2 shows hours worked for these series. All four series have the same general trend, which is not too surprising because changes in hours are driven primarily by changes in employment and all series use the CES as their primary data source; however, they differ in levels. The unadjusted CES series is the highest, while the CES_PTO series is the lowest. The CES_PTO_OTC series lies between them, showing that the impact of the PTO adjustment is greater than the impact of the OTC adjustment. The hours worked levels for the CES_PTO_OTC series that we are proposing are about 3.7 percent higher than the current OPT series (Table 2). We believe that the CES_PTO_OTC series more accurately reflects the actual number of hours worked, which accounts for OTC hours worked by a portion of the 39 percent of workers who are not paid hourly.

Next, we consider differences in growth rates, which are more important than levels for measuring productivity growth. Figure 3 shows the long-run growth in aggregate hours worked as measured by the OPT and CES_PTO_OTC series. Both series are expressed as indexes with a base period of 2007q1. The two series lie almost on top of each other, showing that long run growth rates are nearly identical. For the business cycle that spans the fourth quarter (Q4) of 2007 to Q4 of 2019, both series show an annual average growth rate of 0.6 percent (Table 3). Within this business cycle, the CES_PTO_OTC series declines 5.2 percent during the recession from Q4 of 2007 to Q2 of 2009, while the OPT series decline 5.1 percent. During the post-recessionary period, the series grow together at an annual average rate of 1.8 percent. That said, the series are not identical, which suggests that they tell different stories about quarter-to-quarter growth.

Figure 4 shows the quarterly growth rates for the two hours worked series using annualized quarterly growth rates. The growth rates of the two series track each other pretty closely, but the growth rates are generally different in any given quarter. As we can see in Figure 5, most of the differences are less that 0.5 of a percentage point. The largest differences are around the Great Recession. The growth rate of the CES_PTO_OTC series was 1.3 percentage points higher than the OPT series in 2009q4 and 1.3 percentage points lower in 2010q1.

Industry Detail

Our comparison so far has focused on the aggregate nonfarm business sector data. However, industry detail is also important for two reasons: (1) BLS builds its aggregate hours estimates from industry data, and (2) BLS publishes productivity estimates at the industry level.

Figures 6A-M compare the hours series for 13 major industry groups over the 2007–2019 period. We see that the hours worked levels in the OPT series are lower than the CES_PTO_OTC series for all industries except Nondurable goods manufacturing, where the levels are very close. In Table 2, we show the percent difference in the levels for 2019 q4. There is a definite difference across industries. Durable Goods Manufacturing and Retail Trade experience the smallest shift in hours level, around 1%.[32] In contrast, information, financial activities, professional and technical, and transportation and warehousing experience a level shift greater than 6%.[33] The CES_PTO_OTC series is about 3 percent higher than the OPT series in construction, where approximately 40% of employees are non-hourly. Table 3 shows hours growth rates for the last business cycle using the two series. Most sectors have long-run growth

[32] Approximately 39% of employees in Durable Goods manufacturing are non-hourly, and 27% of retail trade employees.
[33] Approximately 53% of information employees are non-hourly, 62% of employees in financial activities, 57% in professional and technical, and 38% in transportation and warehousing.

over the business cycle within 1 percentage point of the published series, with the exception of Retail Trade, Transportation and warehousing, and Information.

VII. Discussion and Conclusion

Labor is an important input to the production process, and the correct measurement of hours worked is critical for accurately measuring productivity. Yet, it is very hard to properly measure hours worked because the ideal data do not exist. The current BLS methodology was implemented in an effort to more accurately measure the hours of nonproduction workers and to provide a way to account for “off-the-clock” hours worked by nonproduction workers. However, the methodology relies on a number of assumptions.

The current methodology assumes that we can replicate the CES classification of workers as production or nonproduction and into industries. We identified several reasons why this assumption may not hold. CES respondents may not have the records required to correctly classify workers, and the CES production worker counts are not estimated directly and are not benchmarked. Further, the current methodology assumes that any misreporting of hours in the CPS is the same for production and nonproduction workers. But our comparison of CPS hours reports to those from ATUS indicates that there is a slight bias in the CPS ratio and that the bias varies over time and over the business cycle.

Finally, the current methodology assumes that production workers are paid for all of the hours they work. In fact, about 30 percent of production workers are non-hourly. Therefore, if production workers are working off-the-clock hours, these will be missed are missed and production worker hours will be under-estimated. There is also a second-order effect, because an under-estimate also causes nonproduction worker hours to be under-estimated.

The CES all-employee hours data provide a new source of data on hours worked. By using the all-employee hours data, it is no longer necessary to classify workers as production or non-production, but the data must be adjusted to account for OTC hours and paid time off (PTO). The OTC adjustment that we constructed using CPS data accounts for hours worked by salaried workers over and above their paid work hours.

All of the CES all-employee-based hours series that we present exhibit long-run trends that are similar to the long-run trend of the corresponding OPT series. They also generate similar estimates of long-run labor productivity growth. The main difference is in the quarter-to-quarter movements, especially those around the time of the Great Recession, and that difference is driven by how well each measure captures OTC work. Another consideration is that OPT publishes level data. As we saw in Figure 2, the different hours series generate different estimates of total hours worked. From the analysis of the 13 industry sectors, we see more variation.

The next phase of the research will focus on industry detail. Specifically, we will examine the feasibility of estimating these ratios quarterly at the 3-digit industry level, as is done with the NCS-based ratios. Our preliminary tabulations indicate that annual estimates of these ratios are feasible at the 3-digit level.

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Table 1. Bias in CPS ratio

Year	CPS ratio	ATUS ratio	3-year MA of ATUS ratio	Diff. in ratios CPS-ATUS(MA)
2003	1.138	1.088	1.091	0.047
2004	1.136	1.098	1.105	0.031
2005	1.133	1.128	1.110	0.023
2006	1.130	1.103	1.091	0.039
2007	1.133	1.041	1.077	0.056
2008	1.139	1.087	1.073	0.066
2009	1.151	1.091	1.131	0.021
2010	1.153	1.213	1.128	0.025
2011	1.152	1.079	1.140	0.013
2012	1.146	1.126	1.127	0.019
2013	1.142	1.177	1.136	0.006
2014	1.140	1.105	1.161	-0.021
2015	1.132	1.201	1.123	0.009
2016	1.131	1.061	1.128	0.004

Notes: CPS ratios were calculated using the basic annual CPS data. The ATUS ratio is corrected for sample composition and rotation group bias. The 3-year moving averages for the endpoints are calculated by using the endpoint twice.

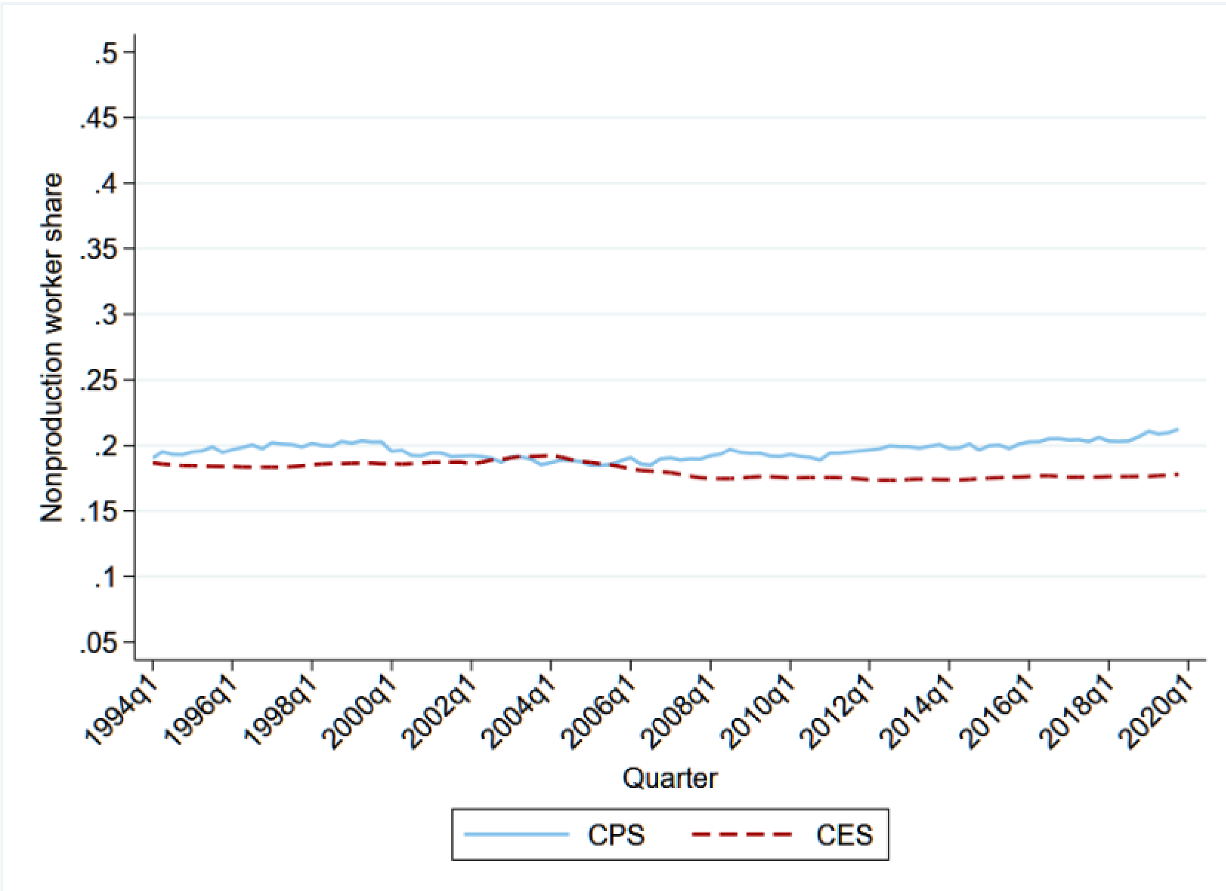
Table 2. Percent Change in Hours Levels between OPT hours and Proposed Hours (2019Q4)

Sector	Percent Change
Private Nonfarm Business	3.70
Construction	2.93
Durable Goods Manufacturing	1.07
Nondurable Goods Manufacturing	0.00
Wholesale Trade	5.19
Retail Trade	1.02
Transportation and Warehousing	6.42
Utilities	2.92
Information	6.30
Financial Activities	5.90
Professional and Technical	6.91
Education and Health Care	4.05
Leisure and Hospitality	2.85
Other Services	5.58

Table 3. Growth in Hours during the Business Cycle (average annual percent change)

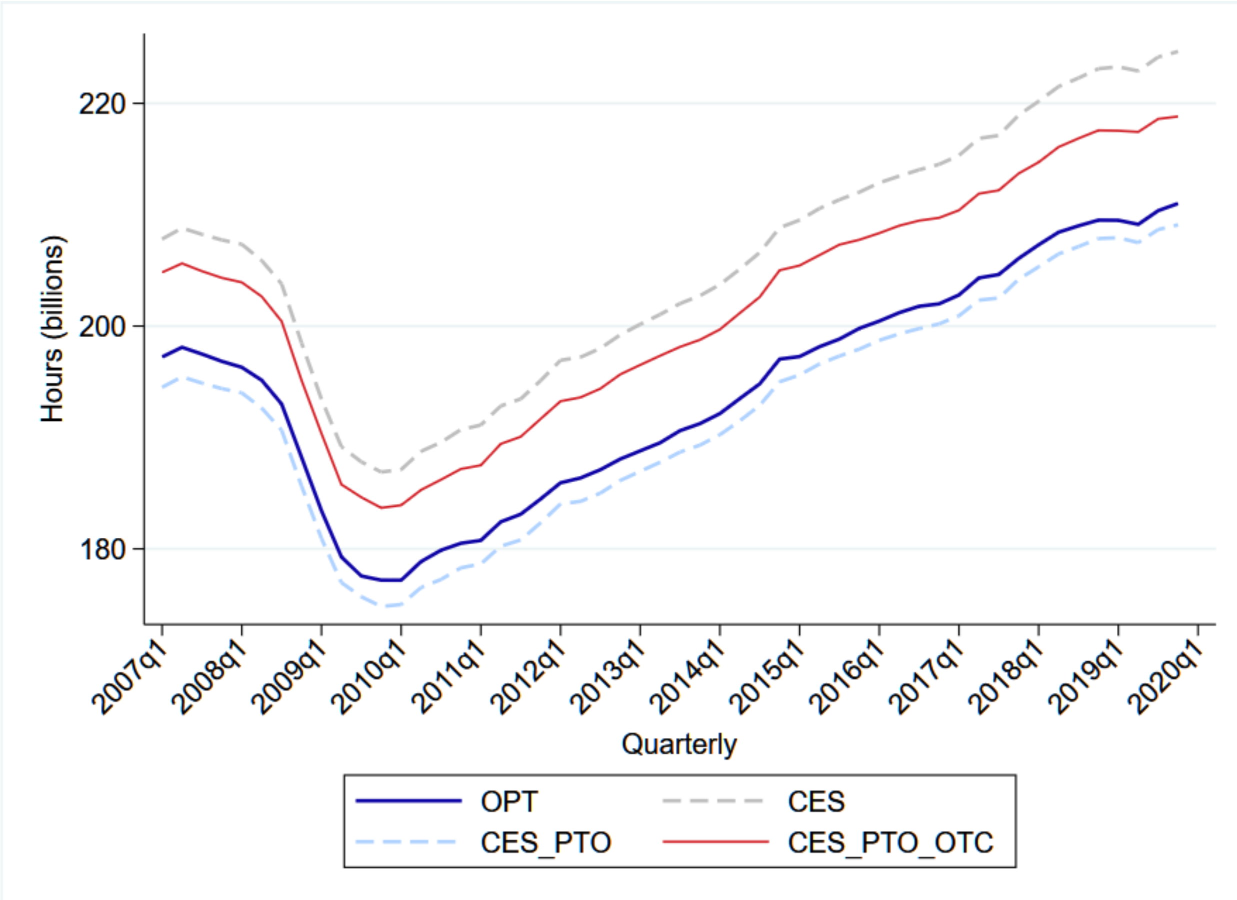
SECTOR	Business cycle 2007Q4-2019Q4		Recession 2007Q4-2009Q2		Post-recession 2009Q2-2019Q4	
	Hours	Proposed Hours	Hours	Proposed Hours	Hours	Proposed Hours
Private Nonfarm Business	0.6	0.6	-5.1	-5.2	1.8	1.8
Construction	0.1	0.2	-14.5	-14.3	3.2	3.4
Durable Goods Manufacturing	-0.7	-0.7	-10.8	-10.7	1.5	1.5
Nondurable Goods Manufacturing	-0.4	-0.4	-6.5	-6.6	0.9	0.9
Wholesale Trade	0.0	-0.1	-5.1	-5.0	1.0	0.9
Retail Trade	0.1	-0.4	-4.1	-4.8	0.9	0.5
Transportation and Warehousing	2.2	1.8	-5.0	-5.1	3.7	3.2
Utilities	0.0	0.1	-0.5	-0.6	0.1	0.2
Information	-0.7	-0.4	-4.5	-4.2	0.1	0.4
Financial Activities	0.7	0.6	-2.9	-3.1	1.4	1.4
Professional and Technical	1.4	1.4	-4.4	-4.7	2.6	2.7
Education and Health Care	2.5	2.6	2.7	2.7	2.4	2.6
Leisure and Hospitality	1.6	1.7	-2.9	-2.9	2.5	2.7
Other Services	0.7	0.7	-3.6	-3.3	1.5	1.5

Figure 1. Share of Nonproduction Workers in Private Nonfarm Sector in CPS and CES, 1994Q1–2019Q4



Notes: Sample excludes logging and agricultural services.
Source: Authors' calculations based on seasonally-adjusted CES and CPS data.

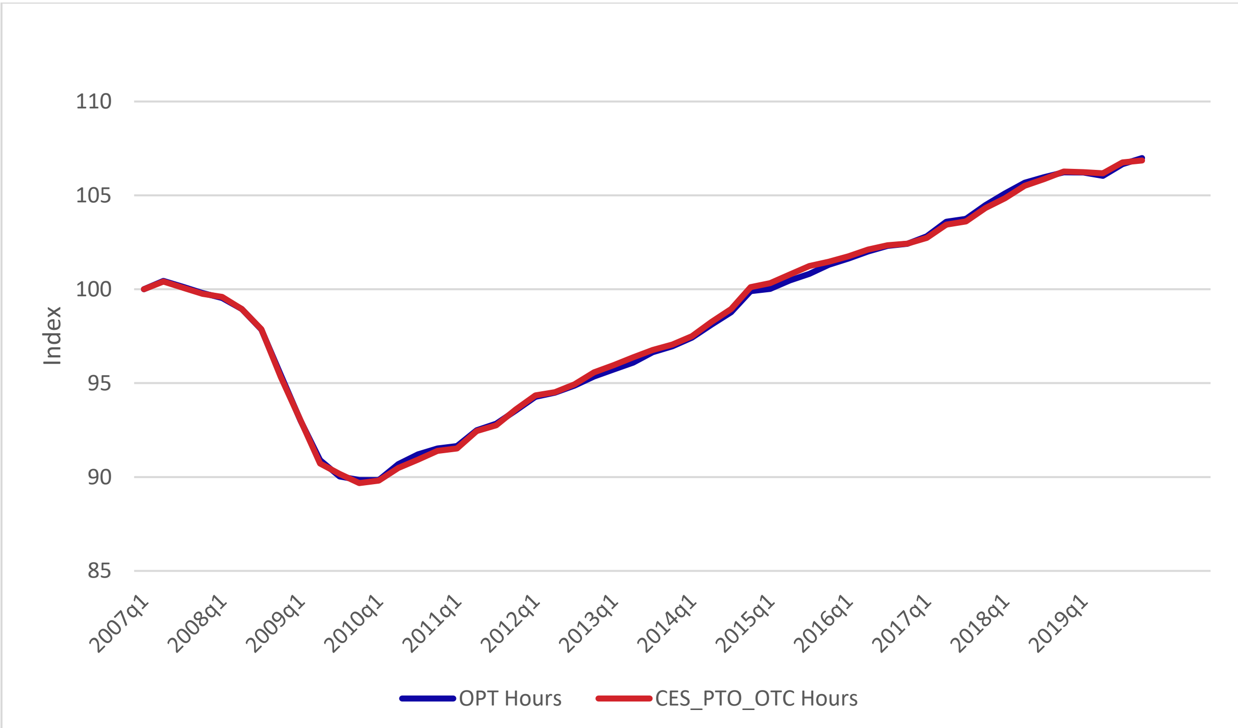
Figure 2. Hours Levels (Nonfarm Business Sector, 2007Q1–2019Q4)



Notes: OPT is current hours for productivity measurement. CES is hours paid. CES_PTO is hours paid with a paid-time-off adjustment. CES_PTO_OTC is hours paid with a paid-time-off and off-the-clock hours adjustment.

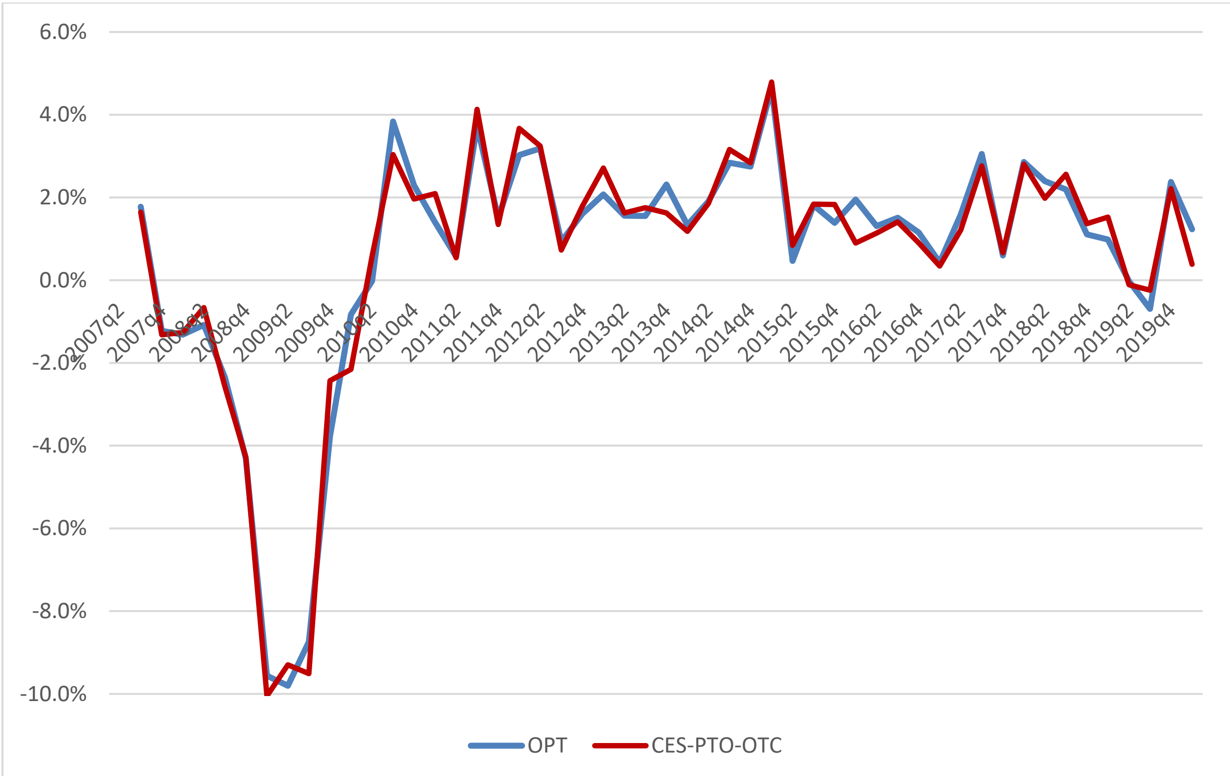
Source: Authors' calculations based on U.S. Bureau of Labor Statistics

Figure 3. Comparison of Cumulative Hours Growth 2007Q1–2019Q4 (Nonfarm Business Sector)



Source: Authors' calculations based on U.S. Bureau of Labor Statistics

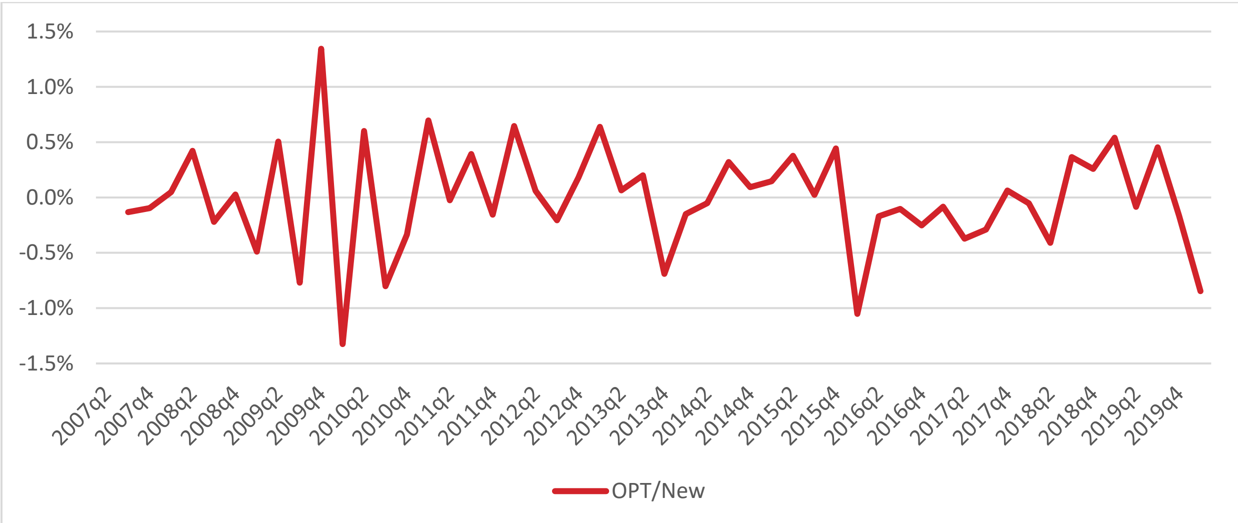
Figure 4. Annualized Quarter-to-Quarter Growth in Hours Worked (Nonfarm Business Sector, annual average percent change)



Source: Authors' calculations based on U.S. Bureau of Labor Statistics

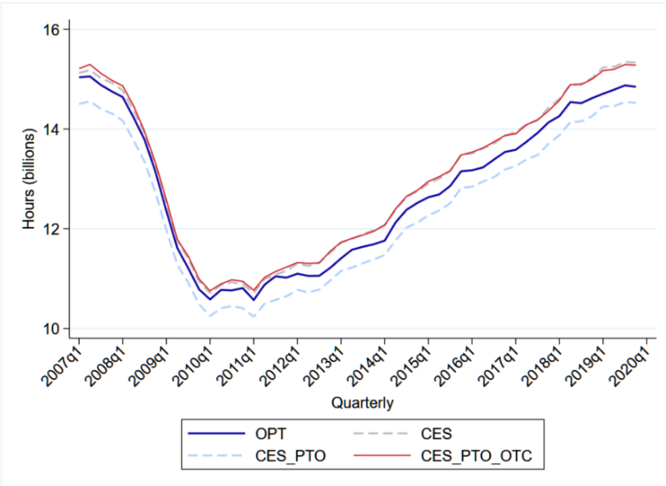
Figure 5. Difference in the Quarter-to-Quarter Growth in Hours Worked (Proposed - OPT)

(Nonfarm Business Sector, annual average percent change)

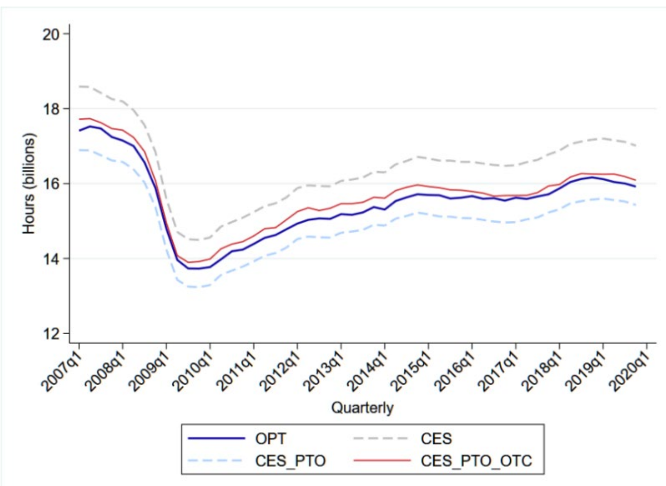


Source: Authors' calculations based on U.S. Bureau of Labor Statistics

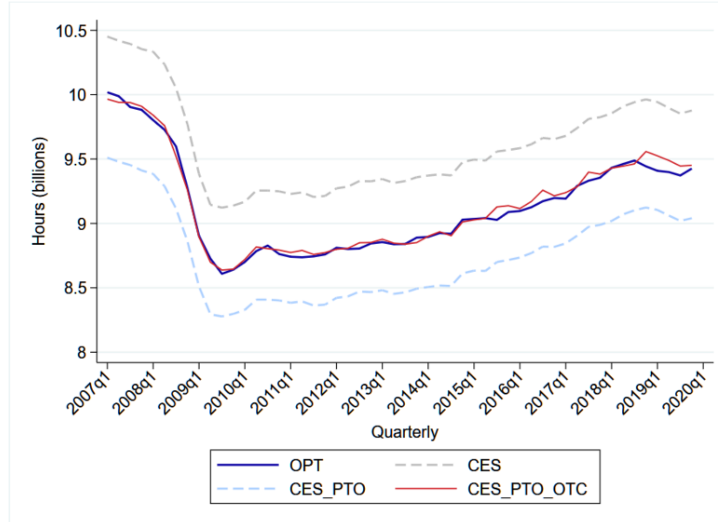
Figure 6 A-M. Hours Levels by Major Industry



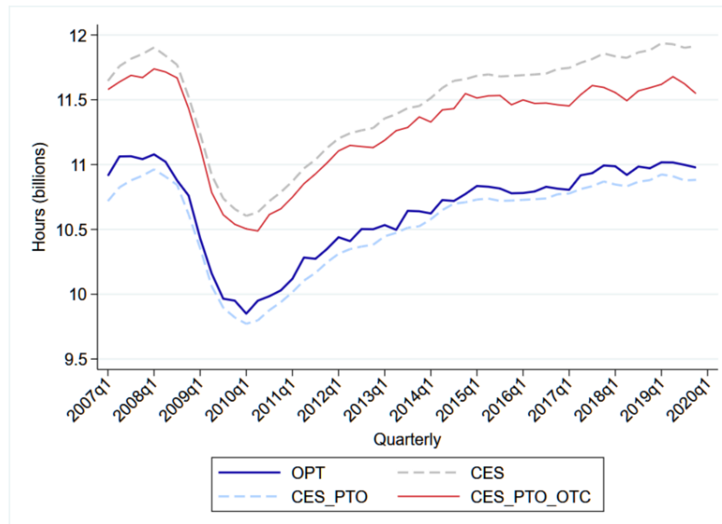
A. Construction



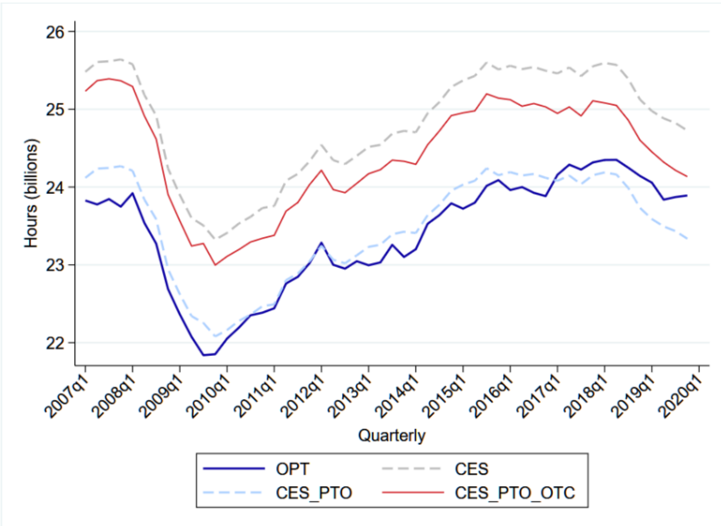
B. Durable Goods Manufacturing



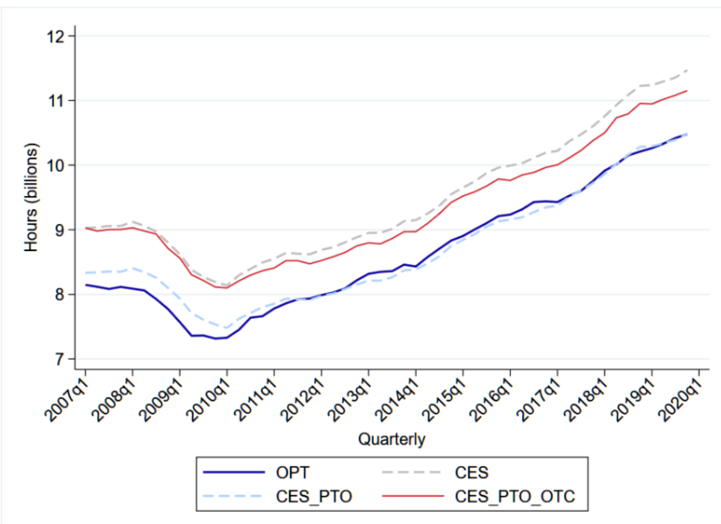
C. Nondurable Goods Manufacturing



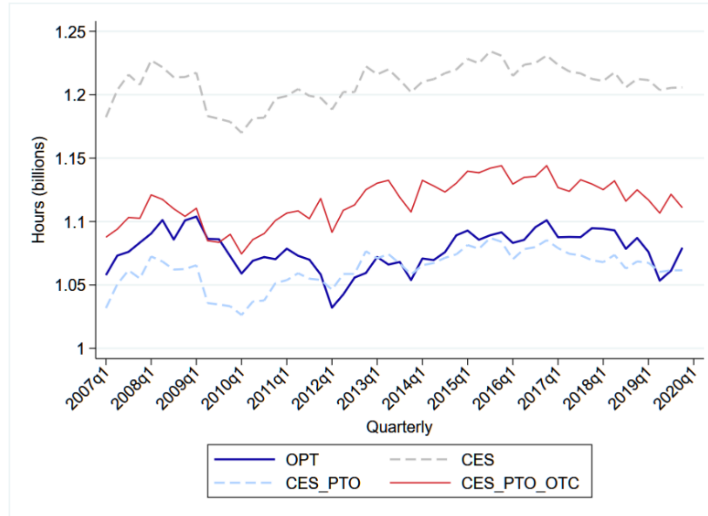
D. Wholesale Trade



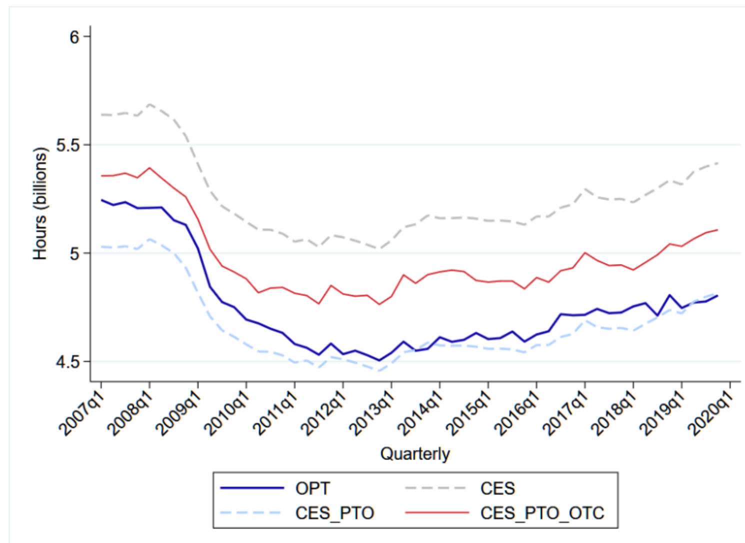
E. Retail Trade



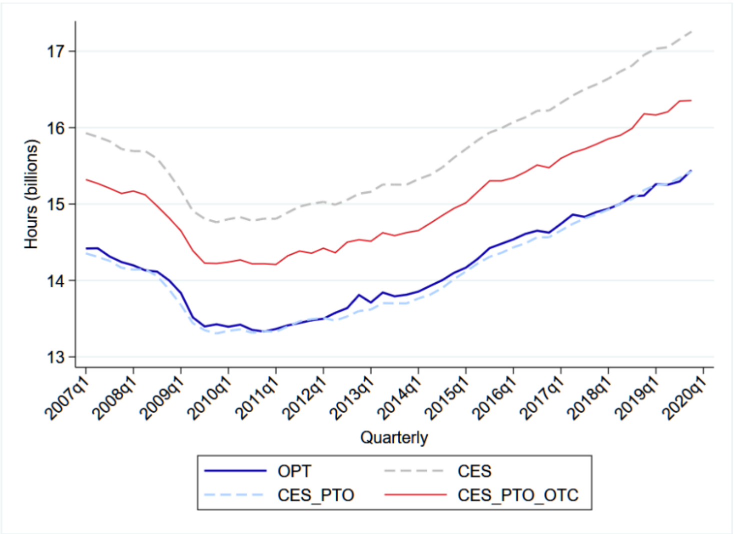
F. Transportation and Warehousing



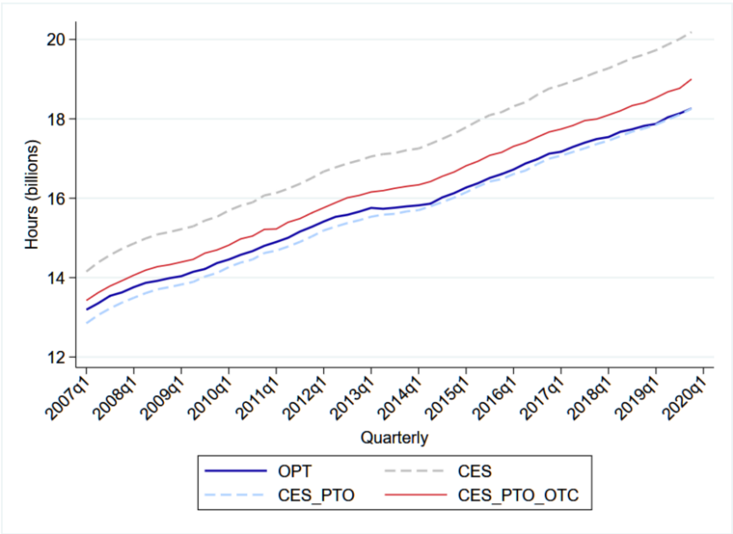
G. Utilities



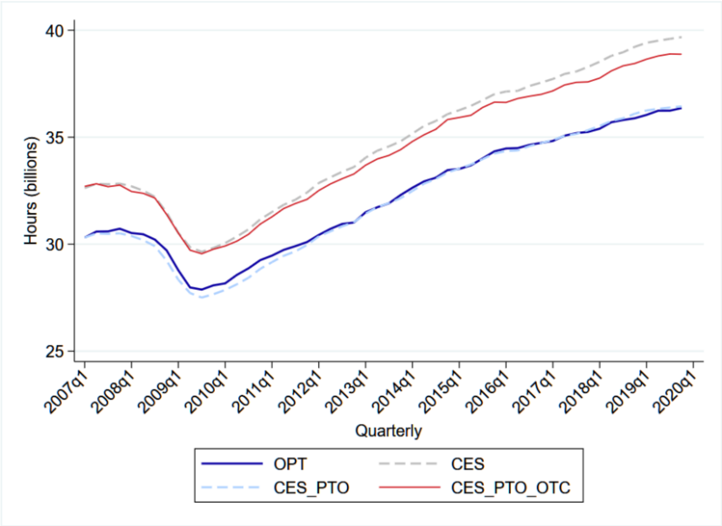
H. Information



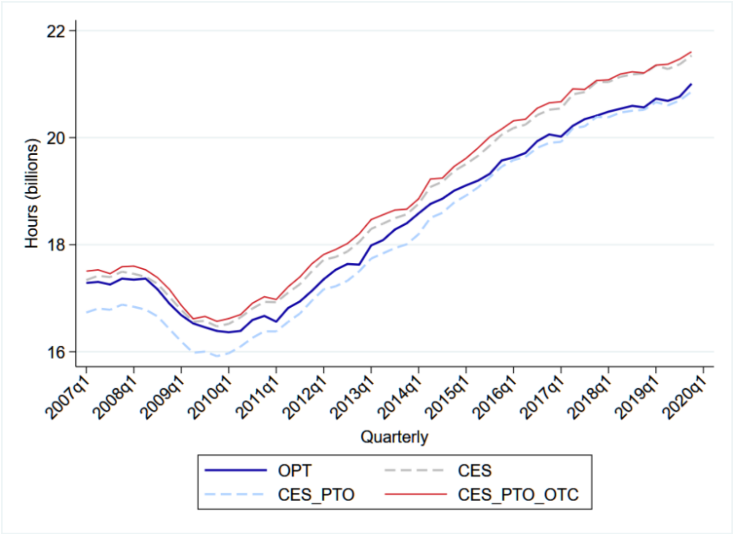
I. Financial Activities



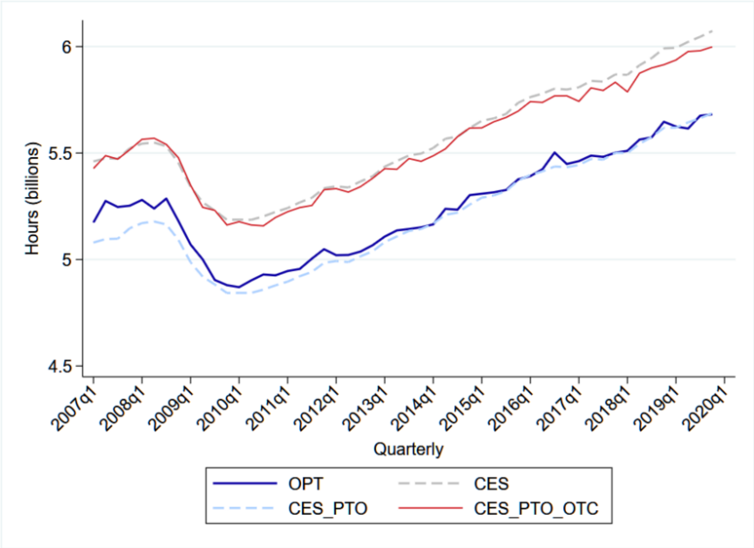
K. Education and Health Care



J. Professional and Technical



L. Leisure and Hospitality



M. Other Services