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Supervision and Work Content: Industry level evidence

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Abstract

The existence of a trade-off between supervision and wages has proven to be a challenging empirical issue due to the lack of direct measures of supervision and its simultaneous setting with wages. This article proposes a novel measure of supervisory frequency and an explanation based on an old idea, namely that firm's choice depends on how difficult it is to monitor the workers they employ. We test this hypothesis using occupational level data on the frequency of supervisory detailed work activities and measures of work content. At the industry level the analysis suggests supervision increases with the complexity of the activities performed by workers, hence, in striking contrast to previous studies relying on the ratio of supervisors to employees, industries that employ more workers performing non-routine cognitive activities also rely on supervision the most. Moreover, at the individual level there is no evidence of a trade-off but only weak evidence of a positive relation between wages and supervision which seems to be a complement rather than a substitute to wage incentives.

Keywords: Labour Economics, Industrial Relations, Supervision, Monitoring, Efficiency Wages, Job Polarization.

JEL: $J01$, $J31$, $J50$, $O33$

Introduction

Supervision of work is recognized as an instrument of employee discipline in efficiency wage models (Shapiro and Stiglitz, 1984; Bowles,1985) with evidence of extensive use of monitoring in the workplace (Dickens et al., 1989; Jayadev and Bowles, 2006). Other authors have argued, though, that supervision might have a deleterious effect on productivity (Falk and Kosfeld, 2006) as it undermines intrinsic motivations and social (gift) exchange (Barkema, 1995). Attempts to mend together this contrasting views have thus far relied on different impacts of monitoring incentives on performance in the short (positive) and long run (negative) (Bénabou and Tirole, 2003) and between personal and impersonal relationships (Frey, 1993).

The existence of a trade-off between wages and supervision is a matter of debate in efficiency wage models. If supervision is determined endogenously and together with wages the presence of a trade-off is not guaranteed and there might be a positive relation between wages and supervisory intensity (Schmidt-Sørensen, 1990).

Indeed empirical evidence has delivered mixed results. While some confirm the trade-off (Rebitzer, 1995; Krueger, 1991), others have interpreted a positive or the absence of a correlation as evidence against the shirking version of efficiency wages (Leonard, 1987; Neal, 1993).

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Two problems in particular contributed to make this trade-off empirically challenging for researchers. First, supervisory workers often perform activities other than monitoring employees. Hence, some degree of substitution between supervisors and production worker might induce a positive correlation between wages and supervision since an increase in wages might lead firms to increase employment of supervisory workers.

Second, both wages and supervision are the result of a firm's choice. If these are set simultaneously and the underlying factor to guide this decision is omitted we should expect biased estimates of the relation among supervision and wages (Sessions, 2008, p.655).

The following pages rely on a novel measure of supervision to test an old explanation for this choice between internal and external incentives to labour productivity. It is the actual feasibility of properly supervising work to dictate the amount of employee supervision, that is, industries or firms that employ workers in harder-to-monitor occupations will supervise them to a greater extent.

To test this hypothesis we rely on work content and the importance of abstract, non-routine work activities as a measure of how difficult or ineffective supervision is in a certain industry. Two arguments underpin this relation. First, abstract work that require decision making, creative thinking and interpretation, to give a few examples, are certainly harder to verify than more structured, tangible work such as dealing with customers or operating industrial equipment. Second, whenever the final product of work is not directly measurable and standardized, even if it is possible to verify the activities performed by an employee, it is difficult to fix a maximum or desired performance standard to be achieved. Take for instance an architect, it is virtually impossible to know with certainty how good a project developed for specific requirements of a particular client could actually be. Note that the second argument is perhaps more general and may apply to workers in more occupations than the first such as sales, personal care and protective services.

This idea - that supervision depends on how difficult or imperfect monitoring is - although already present in Shapiro and Stiglitz (1984), precedes efficiency wage models. Williamson (1967) argued that an increase in firm size led to loss of control by employers. This argument was later shown to be valid only if employees know when they are being monitored (Calvo and Wellisz, 1978). Empirically as well there is evidence of wage *premia* for workers in larger, hence, harder to monitor work groups (Ewing and Payne, 1999).

There are however grounds to contest the use of firm or work group size as a measure of imperfect monitoring. Size and the organization of work depend fundamentally on production technology, and so does the intensity of supervision. Edwards (1979) identifies three different systems of employee control: simple, technical and bureaucratic. While the first, implies direct supervision and may be subject to the difficulties related to firm size, the second relies on machinery and the organization of production to dictate work pace. Thus, in a large production line, for instance, a great number of employees may be fairly easy to monitor[1]. The third system, bureaucratic control, instead, relies on internal labour markets and human resource management with systems of promotion and seniority that induce employees to exert effort by increasing their cost of jobloss.

The next section briefly summarizes previous empirical evidence on supervision and the existence of a trade-off with wages. We then use data from the Current Population Survey's Outgoing Rotation Group (CPS-ORG) to test our hypothesis. In order to surpass the two main empirical problems mentioned above we rely on data from the Occupational Information Network (O*NET). The detailed occupational characteristics make it possible to (*i.*) compute the frequency of supervision in all occupations based on 55 work activities directly related to supervision and monitoring and (*ii.*) to calculate the industry means of non-routine cognitive and routine work content, based on measures by Acemoglu

[1] Although the cost of loafing, even when detected, might be high.

and Autor (2011) and Autor and Handel (2013).

The empirical analysis that follows first considers a panel with 250 3-digit industries from the 2012 U.S. Census Industry Classification ranging from 2003 to 2016. Industry mean non-routine cognitive and routine activities are good predictors of industry average supervision, with positive and negative coefficients, respectively, in fixed and correlated random effects models.

There is also a striking difference between our measure of supervisory frequency and the traditional ratio of supervisors[2] to employees by industry, as seen in figure 1 below. Such a remarkable difference between the two measures is due to the great number of occupations, 210 out of 467, that perform at least some supervisory activities.

Then to analyze the presence of a trade-off between supervision and wages we rely on the CPS-ORG structure to estimate first-difference regressions[3] for all workers and for those that perform no supervision whatsoever. In order to circumvent the simultaneous setting of wages and supervision industry mean non-routine cognitive activities are used as an instrument for industry average supervision. While the estimates find no evidence of a relation between supervision and wages in the full sample, once only workers that perform no supervision are considered our estimates suggest a positive relation. Thus, there might be a complementarity between supervision and wages as both increase with the complexity of work.

A brief literature review

The general empirical evidence and main challenges to estimate supervision's influence on wages were already outlined in the introduction. This section provides further details on the strategies previously employed by authors and their results. Additionally, a brief overview of the empirical findings on employee autonomy and routine-biased technological change is presented in order to, later, contrast those with our own results.

Most of the empirical research on the trade-off between supervision and wages dates back to the late 1980s and early 1990s, after the publication of seminal contributions to the efficiency-wage literature. The overall results are mixed, while some reject the trade-off and interpreted it as evidence against the shirking version of efficiency wages other authors did find a negative relation between monitoring and pay.

These studies, some of which are summarized in table 1, differ in terms of the industries studied and measures of supervisory intensity adopted. In particular, it seems relevant to distinguish between single and inter-industry studies. While all of the former (Groshen and Krueger, 1990; Krueger, 1991; Rebitzer, 1995) suggest the existence of a trade-off, the later deliver mixed results. Since our measure of supervisory frequency is defined at the industry level the following results do not exclude the existence of a trade-off between firms in the same industry.

The different measures of supervision also vary substantially and are often indirect. With the single exception of Neal's (1993) use of the actual frequency of supervision reported by production workers, all other studies rely on indirect measures or other factors that might affect supervision in specific contexts. Groshen and Krueger (1990) use regional dummies to capture specific local regulations that determine, exogenously, the required supervisor-to-staff ration in hospitals. In Krueger (1991) employees are found to earn higher wages in company owned fast-food restaurants with respect to

[2] Workers in supervisory occupations.

[3] Individuals are interviewed 8 times for a period of 16 months and are often present in two consecutive years of the survey.

those in franchises, since the franchisees have a greater incentive to monitor workers than managers in the company owned restaurants.

Table 1: Summary of previous results on the wage-supervision trade-off

Reference	Tade-off	Industry	Measure of supervision	Year	Country	Methodology
Leonard (1987)	No	High tech. industries	Supervisors/employees	1982	U.S.	OLS
Groshen and Krueger (1990)	Yes	Hospitals	Supervisors/employees, instrumented by regional dummies	1985	U.S.	2SLS
Krueger (1991)	Yes	Fast-food restaurants	Ownership as proxy for incentive to monitor employees	1982	U.S.	Random Effects
Neal (1993)	No	Inter-industry	Frequency of supervision	1977	U.S.	OLS
Rebitzer (1995)	Yes	Petrochemical	Third part safety supervision	1990	U.S.	Ordered probit
Brunello (1995)	Yes - non-manual workers No - manual workers	Inter-industry	Supervisors/employees, instrumented by ratio of managers to supervisors	1975-1982	U.K.	2SLS
Ewing and Payne (1999)	Yes	Inter-industry	Size of work groups	1989	U.S.	OLS

A more generalist approach is due to Brunello (1995) where the ratio of managers to supervisors, as a proxy of the quality of supervision, is used as an instrument for the supervisor-to-staff ratio. Evidence of a trade-off, after accounting for the endogeneity of supervision, is found for non-manual workers only. Ewing and Payne (1999) test the hypothesis proposed by Williamson (1967) that larger work groups are harder to monitor and, thus, there is a wage *premia* associated to their size. Despite the positive results, the relation of work group size to supervision is theoretically questionable (Calvo and Wellisz, 1978) and may only be considered a very indirect evidence of supervision at best.

The first part of the empirical analysis below considers the determinants of supervisory frequency at the industry level, which to some extent is an instrument to discipline and restrict worker autonomy. The literature on employee discretion relates higher skill and employee commitment to greater autonomy for individual workers (Gallie et al., 2004; Green, 2008). However, while skill levels and commitment have increased over the past decades there has been a decline in employee discretion, more pronounced among part-time and temporary workers, since the early 1990s (Gallie, 2012). Therefore, other factors must account for the fall in discretion.

As shown in the following pages there has been an overall increase in supervision in the U.S. economy between 2003 and 2016 which, according to out argument, is related to the increase in the relative employment of harder to monitor occupations with greater non-routine cognitive work content[4]. Still, it also reveals that supervision is more frequent in industries that employ high-skill workers. That is, although the employment of complex work is related to more intense supervision, the later doesn't seem to be the exact inverse of employee discretion.

Finally, let us consider recent studies, summarized by Autor (2015), that have focused on the automation of routine work, due to the progress of information technology, and its effects on employment

[4] As well as the fall in occupations that perform routine work.

and wages. In this framework technology replaces routine jobs concentrated in middle skill, middle wage occupations such as industrial blue collar workers. Evidence on the slower employment growth of routine occupations relative to high and low-skill jobs, particularly during the 1990s in the U.S. and Europe is presented in Acemoglu and Autor (2011) and Goos, Manning and Salomons (2009). Moreover, the loss of middle skill jobs has been connected to employment changes in the business cycle and jobless recoveries (Jaimovich and Siu, 2012) and to changes in wage inequality (Autor and Handel, 2013).

So far no studies have yet considered a connection between the decline of routine work and trends in employee supervision, to the best of our knowledge. The next sections describe the data employed in this study and the main variables built from O*NET data, namely the industry mean supervisory frequency, non-routine cognitive and routine work activities.

Empirical analysis

Sample

Two different samples build from the CPS-ORG (Center for Economic and Policy Research. 2017) ranging from 2003 to 2016 constitute the basis of the following empirical analysis and provide data on wages and demographics of individual workers as well as their respective occupations and industries. The choice to start from 2003 and not earlier is due to a large scale revision in the occupational codes that would require significant aggregation in occupations and, hence, a considerable loss of information on our supervisory frequency and work content variables.

For the first part of the analysis below we build a panel with 250 3-digit industries that sums up to 3,947 observations. The descriptive statistics of all the variables constructed, mostly industry averages, are presented in table A.4 at the data appendix. The second sample makes use of the CPS-ORG structure to identify workers interviewed in two consecutive years of the survey in order to obtain first-difference estimates. Usual sample restriction are applied to include full time[5] workers aged between 17 and 64. All observations correspond to employed workers in the private sector[6].

Additionally, observations with imputed earnings and hours, since part of the hourly wages are calculated based on worked hours, are excluded from the sample to avoid an artificial reduction of wage variation between occupations (Mouw and Kalleberg, 2010, p.413). Workers with real hourly wages in the bottom and top percentile are also excluded, as well as those who change occupation or industry between the two years they are observed. Hence, the final sample that includes 72,779 individual workers and 145,558 observations, out of which 44.3% do not perform any supervisory activities.

The measures of supervisory frequency, non-routine abstract and routine work content are constructed from work activities, work content, detailed work activities and task variables from O*NET 21.3 (ONET, 2017). In order to make them compatible with the CPS occupation codes the O*NET occupations are first aggregated to Standard Occupational Classification (SOC 2010) codes and then to the 2010 Cencus Occupation Codes using averages weighted by the relative employment of each SOC 2010 occupation obtained from the 2015 Occupational Employment Statistics provided by the Bureau of Labor Statistics.

The next section describes in greater detail our main variables and their construction before the results are presented.

[5] All those reporting 35 weekly hours or more in the week before their interview.
[6] Excluding self-employed.

Main variables

The bulk of the empirical analysis is based on three variables henceforth described in greater detail. Namely, *i.*) industry mean frequency of supervision and *ii.*) measures of non-routine cognitive and *iii.*) routine work. Moreover, a raw measure of the proportion of employees in 15 supervisory occupations[7] to the total number of workers by industry, displayed on the right side of figure 1, is computed to provide some comparison to our measure of frequency.

Supervisory frequency is first calculated for each CPS occupations (s_i) based on O*NET task frequencies aggregated into detailed work activities. Each task in the database contains a measure of frequency in seven discrete categories from yearly or less to hourly or more ($f_{s,k}$), to which we attribute values in times per year such a task is performed, presented in table A.1. Then an average of these values weighted by the proportion of respondents that report them (θ_k) is taken for each task.

In the O*NET job content model (Onetcenter, 2017) tasks are occupation specific, but can be aggregated to detailed work activities that are common to all occupations. The measure of supervisory frequency in each occupation is then obtained as the sum of the frequencies of all tasks associated to 55 supervisory activities , represented by the subscript m, over the sum of the frequencies of all tasks associated to all detailed work activities, described by subscript l in equation 1. Table A.2, in the data appendix, lists the 55 supervisory activities considered which include, to mention a few; to investigate work related complaints to determinate corrective actions, to evaluate employee performance, to verify employee information, to supervise employees and to inspect work to ensure standards are met.

$$s_i = \frac{\sum_{m=1}^{55}\sum_{k=1}^{7} f_{s,k}\theta_{,k}}{\sum_{l}\sum_{k=1}^{7} f_k\theta_{,k}} \tag{1}$$

Hence, s_i represents the ratio between the frequency of supervisory activities (m) and the frequency of all detailed work activities (l) in each occupation (i). The empirical analysis, however, considers industry mean frequency of supervision (S_j) which is equal to the average of s_i in all the occupations employed in that industry weighted by their relative employment ϕ_i. The industry mean non-routine cognitive ($nrcog_j$) and routine work activities ($rout_j$) are obtained in a similar fashion[8]. After the occupational codes transformation described in the previous section, we take the industry averages weighting each occupation by the inverse of the frequency of supervision. The industry level variables for supervisory frequency, non-routine cognitive and routine work activities are described in equations 2, 3 and 4, respectively.

$$S_j = \sum_{i=1}^{n} s_i\phi_i \tag{2}$$

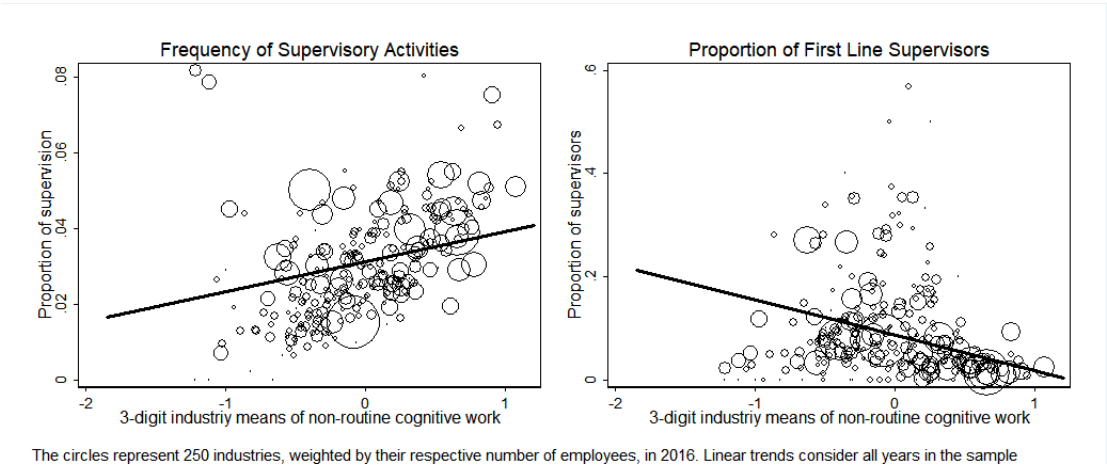
$$nrcog_j = \sum_{i=1}^{n} nrcog_i\phi_i(1 - s_i) \tag{3}$$

$$rout_j = \sum_{i=1}^{n} rout_i\phi_i(1 - s_i) \tag{4}$$

[7] Table A.6 in the data appendix contains a list of the 2010 Census Occupation Codes supervisory occupations.
[8] The O*NET work activities used to build these two variables are listed in table A.3 in the data appendix

Figure 1 plots industry mean supervision and the ratio of supervisors to employees as a function of industry mean non-routine cognitive activities, as a proxy to the difficulty to supervise employees in the x-axis. As mentioned earlier, the frequency of supervision increases with the content of non-routine cognitive activities in an industry and has a negative correlation to the ratio of supervisors to employees. The complete list of 3-digit occupations with their respective frequency of supervision is provided in the appendix and although a great number of occupations perform some supervision, more often than not it sums up to a small fraction of total work activities. Among the workers that perform supervision more frequently are, as expected, allocated in many first-line supervisors, management and human resources occupations.

Figure 1: Supervisory frequency (left) and ratio of supervisors to employees (right) by industry



The circles represent 250 industries, weighted by their respective number of employees, in 2016. Linear trends consider all years in the sample

A final caveat about the variables build from O*NET is worth some attention. CPS-ORG data from several years is matched to a single version of the O*NET. It is so due to the lack of a longitudinal dimension in the O*NET whose different releases calculate occupational work activities and content variables based on observations from multiple years. Thus, the change in time in the industry level supervisory frequency (2) and work content variables (3) and (4) reflects the evolution of the employment composition in each industry and not in the intensive margin.

The next section presents the estimates, first at the industry level and then on the trade-off between supervision and wages and draws comparisons with previous studies.

Findings

The first results presented in table 2 regress supervisory frequency on industry level characteristics. The increase of supervision between 2003 and 2016, most of it concentrated between 2007 and 2012, is plotted in the four graphs of figure 2, whose supervisory frequency is an average of S_j for all industries weighted by their respective size in number of employees.

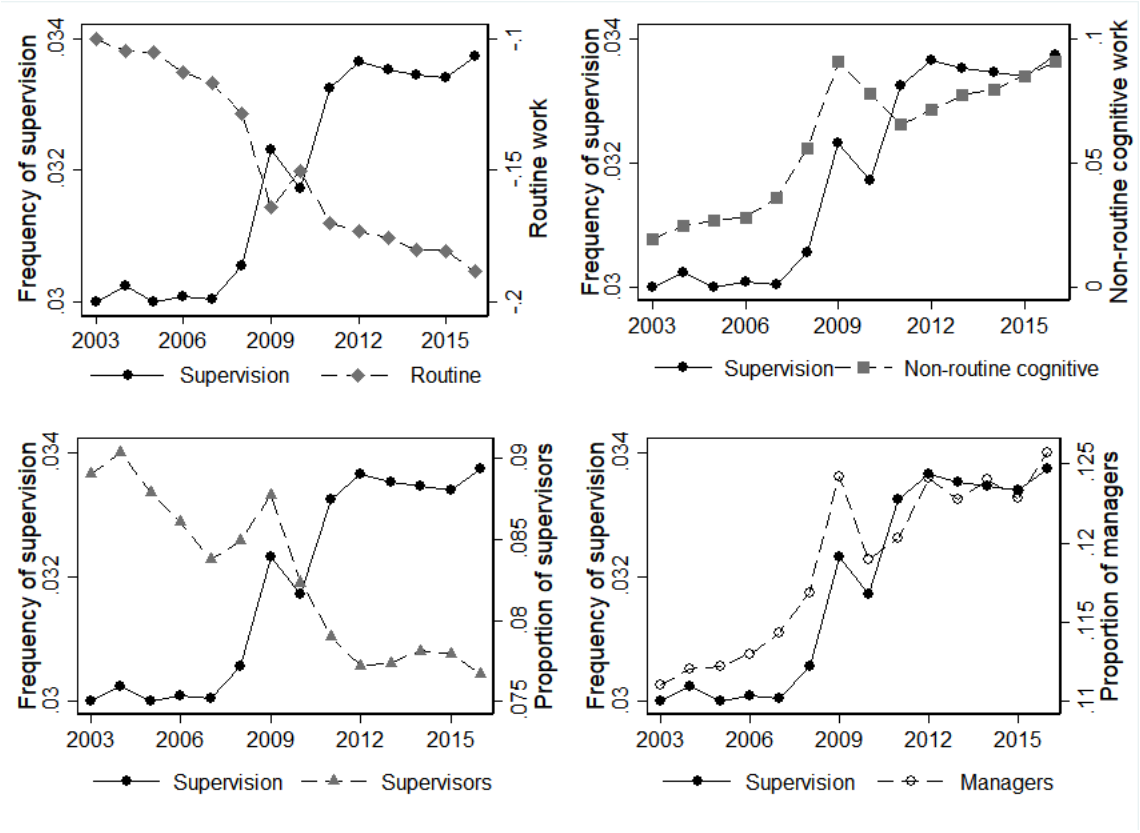
The two top graphs show an inverse relation with routine work and an increasing trend in both supervision and non-routine cognitive work. Just as supervision the routine and non-routine variables

experience greater variation from 2007 to 2011 which is in line with Jaimovich and Siu (2012) argument that most of the routine jobs are lost during economic downturns, thus reducing overall routine content in the composition of U.S. employment.

A possible explanation for the increase in supervision during the global financial crisis is that most of the occupations that perform some form of monitoring, such as managers and human resources workers, typically rank higher in firms' hierarchies and were less likely to lose their jobs during the recession. However, it should be noted that the higher level of supervision shows no decreasing trend in the years of sluggish economic recovery that followed the crisis.

The south-west quadrant graph shows once again the negative relation between our frequency of supervision measure and the ratio of supervisors to workers that has fallen about 1.5% since 2003. Finally, the bottom-right plot depicts a great similarity in the trends of supervision and the percentage of workers in managerial positions. The ratio of non-production to production workers has been previously explored in Gordon (1990) where it is shown to have increased from the 1960s to the mid 1980s in Japan, West Germany, Sweden and the U.S.

Figure 2: Increase in supervisory intensity and selected variables



The industry level estimates in table 2 confirm the intuition provided by the previous graphs. A unity increase in mean non-routine cognitive work activities, which corresponds to 2.2 standard deviations[9], is associated to an increase of about 2% in supervision. Note that this effect is way larger than the actual increase in supervisory frequency for the U.S. economy presented in figure 2, of 0.4%.

Routine activities also present the expected sign with a unit increase in industry average routine content associated to a reduction of 0.76% in the frequency of supervision[10]. The coefficient for the percentage of workers in managerial occupations coefficient is positive and slightly smaller than that of non-routine cognitive activities, but is statistically different from zero only in the correlated random effects estimates in column (3). Finally, unionisation rates are also related to lower supervisory frequency but with a much smaller coefficient than industry mean routine work, since a variation of 100% in unionisation rate, which corresponds to roughly 10 standard deviations, reduces supervision by one percentage point.

Table 2: Industry level estimates of Supervisory frequency

	(1) $FE-OLS$	(2) $FE-OLS$	(3) $Mundlak$
Non-routine cognitive	0.0195***	0.0197***	0.0197***
	(0.0044)	(0.0044)	(0.0013)
Routine	-0.0074**	-0.0076**	-0.0076***
	(0.0028)	(0.0027)	(0.0013)
Percentage of managers	0.0177	0.0169	0.0169***
	(0.0114)	(0.0106)	(0.0034)
Log industry size		0.0005	0.0005
		(0.0014)	(0.0005)
Percentage of female		0.0038	0.0038+
		(0.0052)	(0.0022)
Unionization rate		-0.0108*	-0.0108**
		(0.0047)	(0.0035)
% of workers with university degree		-0.0061	-0.0061**
		(0.0047)	(0.0020)
Average age/10		0.0036+	0.0040***
		(0.0020)	(0.0010)
N	3,497	3,497	3,497
$Groups$	250	250	250
R^2 $within$	0.193	0.203	0.203
R^2 $overall$	0.273	0.274	0.428

All models include a constant. Standard errors in parentheses are clustered by industry in models (1) and (2). Model (3) includes group means for all variables.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[9] The descriptive statistics for the variables in table 2 are listed in the data appendix table A.4. A unity increase is certainly large since $nrcog_j$ values range from -1.85 to 1.21 and is unlikely to be found within a single industry in the period considered but rather between them.

[10] For routine a unit corresponds to 2.05 standard deviations with minimum and maximum value of -1.69 and 1.88.

The results presented above suggest that the shift in the U.S. productive structure and employment towards relatively more complex occupations and away from routine work, either due to technological progress and automation or to offshoring, contributed to the observed increase in supervision. Our take on this relation is that non-routine cognitive work is harder to monitor and, despite being characterized by higher average skill and wages, employers attain to a certain level of supervision that allow them to evaluate and possibly boost employee effort.

In that spirit a parallel between the estimates in table 2 and Edwards' (1979) systems of employee control is rather interesting. The contemporaneous decrease in routine work, largely present in industrial blue-collar occupations, and increase in supervision somehow strengthen the idea of technical control, whereby machinery pace dictates the speed of work, which happens to be in most cases highly standardized, thus mitigating the need for direct supervision.

Our results, however, are at odds with bureaucratic control. Even though high-skill workers performing complex work might enjoy higher wages, fringe benefits and gains from seniority the industries that employ them also seem to rely more on supervision. That is, although employees carrying out non-routine cognitive work are more likely t face a greater cost of losing their current positions the difficulty to properly asses their effort is such that it requires a greater degree of supervision from the employers.

The estimates so far say nothing about the existence of a trade-off between wages in supervision. The second part of the results focus on individual workers that appear for two consecutive year in the CPS-ORG from 2003 to 2016. A similar application of CPS data is presented by Addison, Orgul and Si (2017) who describe the survey characteristics that allow for such longitudinal link in greater detail.

First a sample of all workers consistently identified twice in the same occupation and industry is considered in columns (1) to (3) of table 3 and then a sub-sample excluding workers in the 210 occupations that perform some supervision[11] in columns (4)-(6). The measure of supervisory frequency from O*NET detailed work activities also provides support to the hypothesis that supervisors perform other work activities. In no occupation the frequency of supervision is greater than half of all activities performed and among all the occupations that supervise only around 7% of their work, in average, is dedicated to monitoring.

Therefore, the estimates in columns (3) and (6) use industry average non-routine cognitive work ($nrcog_j$) as an instrument for industry mean supervisory frequency. Moreover, the regressions in table 3 do not include the measures of non-routine cognitive and routine work for the occupations associated to each individual worker. Given that only workers that remain the the same occupation are considered their respective measures of work content are also fixed, while industry averages change due to different composition of employment through the years.

[11] The list of all such occupations and their relative frequency of supervision is presented in the data appendix table A.7.

Table 3: First-difference estimates of log hourly wages on supervision

	All workers			Only non-supervisors†		
	(1)	(2)	(3)	(4)	(5)	(6)
	FD	*FD*	*IV − FD*	*FD*	*FD*	*IV − FD*
Supervision	0.295	0.080	0.690	0.046	-0.158	1.090^{+}
	(0.212)	(0.215)	(0.539)	(0.308)	(0.306)	(0.612)
Union		0.036^{***}	0.036^{***}		0.051^{***}	0.051^{***}
		(0.010)	(0.010)		(0.013)	(0.013)
Age/10		0.414^{***}	0.414^{***}		0.346^{*}	0.345^{*}
		(0.081)	(0.081)		(0.144)	(0.144)
Age^2/100		-0.024^{**}	-0.024^{**}		-0.020	-0.020
		(0.008)	(0.008)		(0.014)	(0.014)
Potential experience/10		0.041	0.041		0.101	0.100
		(0.062)	(0.062)		(0.097)	(0.097)
Potential experience^2/100		-1.240^{+}	-1.231^{+}		-1.615	-1.609
		(0.749)	(0.747)		(1.079)	(1.083)
Married		-0.003	-0.003		0.005	0.005
		(0.005)	(0.005)		(0.008)	(0.008)
U.S. citizen		-0.035	-0.035		0.075^{+}	0.074^{+}
		(0.041)	(0.041)		(0.038)	(0.039)
Education						
High school		-0.002	-0.002		-0.003	-0.003
		(0.013)	(0.013)		(0.0168)	(0.017)
Some college		0.010	0.010		-0.001	-0.002
		(0.018)	(0.018)		(0.025)	(0.025)
College		0.031	0.031		0.029	0.028
		(0.034)	(0.034)		(0.050)	(0.050)
Advanced degree		0.038	0.038		0.055	0.054
		(0.043)	(0.043)		(0.066)	(0.066)
N	145,558	144,324	144,324	64,424	63,836	63,836
Workers	72,779	72,162	72,162	32,212	31,918	31,918
Kleibergen − Paap F statistic			3625.4^{***}			2142.1^{***}
Endogeneity test $\chi^2(1)$			1.43			4.94^{*}
R^2 *within*	0.000	0.008	0.008	0.000	0.010	0.009

Standard errors clustered by industry in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

†Only non-supervisors considers exclusively workers in occupations that perform no supervisory activities.

The left-side estimates, considering all workers, do not support a trade-off between industry level supervision and wages. In fact, there seems to be no systematic relation between supervision and pay. Neither is there evidence that supervision is endogenous in the IV-FD regression (3). However, it might be the case, given the large number of occupations that perform supervision, that we are comparing the level of industry supervision with the wages of the supervisors themselves thus cancelling out the

negative effect of supervision on production workers with the positive one it might have to supervisors.

The results are slightly different when the non-supervisors sub-sample is considered, but still no evidence of a trade-off is found. Indeed, column (6) actually suggests wages are higher for production workers in industries with greater intensity of supervision, though the estimated coefficient is only marginally statistically different from zero. A one percent increase in mean supervisory intensity is associated to hourly real wages 1.09% higher.

In contrast to the regression in column (3), the estimates in (6) reject the exogeneity of supervision. Furthermore, the validity the difficulty to monitor employees, proxied by $nrcog_j$, as an instrument is tested using the Keinbergen-Paap F-statistic (Keibergen and Paap, 2006; Kleibergen and Schaffer, 2015) which does not require i.i.d. residuals as the Cragg-Donald (1993) test, rejecting the null hypothesis of a weak instrument.

The results above offer no support for a trade-off between wages and supervision at the industry level, and suggest instead a weak positive relation. The frequency of supervision seems to increase with the complexity and difficulty to monitor the workforce in an industry. Even if this results are due to workers that perform supervision themselves earning higher wages, although the industry work content variables in equations (3) and (4) assign a greater to occupations that don't supervise, it remains that the level of supervision in these industries is higher and has been increasing contemporaneously with the relative employment of workers in occupation that perform more complex work[12] in the U.S. economy.

Discussion

Two results from the previous empirical analysis stand out. First, the frequency of supervision seems to increase with the difficulty to monitor the workers employed in an industry as seen by the estimates of a positive relation with non-routine cognitive and a negative one routine work content. Second, it does not support a trade-off between supervision and wages and instead offer some weak evidence of a positive relation for workers that perform no supervision.

It seems that there might be a complementarity between wages and supervision. Which would make sense in the framework presented above since performing more complex, abstract work is related to higher wages (Autor and Handel, 2013) but is also harder to monitor.

Still, our analysis does not exclude the existence of a trade-off between firms, within an industry as found in other empirical studies. If that is the case there would be a minimum level of supervision desired by firms given the type of occupations they employ, in order to sustain a certain level of control and discipline over the workforce, above which the typical trade-off suggested in efficiency wage models could operate.

Another interesting point raised concerns the great number of workers that perform some supervisory activities, which begs the question who bosses whom? A more refined analysis with supervision and its impact at the individual worker level was previously impossible due to limitations in the data. However, the advent and quick diffusion of employee monitoring software (Solon, 2017; Lohr, 2014) should soon open up a new wave of studies on the effects of supervision on employee pay and performance.

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[12] And the relative decrease of routine, easy to monitor, occupations in total employment.

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Data Appendix

Supervisory frequencies Each of the work activity variables in the O*NET data is further disaggregated into detailed work activities (DWA), which are common for all occupations. A measure of frequency for each DWA is provided in seven categories to which the values in the left table below are attributed. These correspond to the approximate number of times a year that activity is performed in a certain occupation. In the final step the frequency values are weighted by the percentage of respondents in each occupation that reports them.

Table A.1: Task frequency categories and values

	Category	Value
1-	Yearly or less	1
2-	More than early	4
3-	More than monthly	12
4-	More than weekly	48
5-	Daily	251
6-	Several times a day	1004
7-	Hourly or more	2008

Table A.2: Supervisory detailed work activities

	Supervisory Detailed Word Activities
1	Investigate work related complaints to determine corrective actions.
2	Monitor food services operations to ensure procedures are followed.
3	Monitor loading processes to ensure they are performed properly.
4	Inspect cargo to ensure it is properly loaded or secured.
5	Monitor operational procedures in technical environments to ensure conformance to standards.
6	Monitor performance of organizational members or partners.
7	Monitor activities of individuals to ensure safety or compliance with rules.
8	Monitor operations to ensure compliance with safety or security policies or regulations.
9	Evaluate personnel practices to ensure adherence to regulations.
10	Monitor operational activities to ensure compliance with regulations or standard operating procedures.
11	Monitor medical facility activities to ensure adherence to standards or regulations.
12	Inspect work to ensure standards are met.
13	Inspect completed work to ensure proper functioning.
14	Inspect completed work to ensure proper installation.
15	Evaluate effectiveness of personnel policies or practices.
16	Evaluate performance of educational staff.
17	Evaluate current or prospective maintenance employees.
18	Evaluate skills of athletes or performers.
19	Evaluate employee performance.
20	Evaluate performance of applicants, trainees, or employees.
21	Verify employee information.
22	Verify patron or staff credentials.
23	Analyze jobs using observation, survey, or interview techniques.
24	Analyze data to inform personnel decisions.
25	Maintain personnel records.
26	Document work hours or activities.
27	Record personnel information.
28	Meet with coworkers to communicate work orders or plans.
29	Confer with managers to make operational decisions.
30	Communicate dining or order details to kitchen personnel.
31	Warn individuals about rule violations or safety concerns.
32	Resolve personnel problems.
33	Supervise maintenance workers.
34	Supervise engineering or other technical personnel.
35	Supervise trainees.
36	Supervise service workers.
37	Supervise production or support personnel.
38	Direct activities of subordinates.
39	Supervise information technology personnel.
40	Supervise clerical or administrative personnel.
41	Supervise activities of other legal personnel.
42	Supervise scientific or technical personnel.
43	Supervise medical support personnel.
44	Supervise workers providing client or patient services.
45	Supervise employees.
46	Supervise patient care personnel.
47	Supervise technical medical personnel.
48	Supervise sales or support personnel.
49	Supervise laboratory work.
50	Supervise workers performing environmentally sustainable activities.
51	Direct activities of agricultural, forestry, or fishery employees.
52	Coordinate personnel recruitment activities.
53	Coordinate activities of food service staff.
54	Coordinate activities of production personnel.
55	Coordinate project activities with other personnel or departments.

The same procedure is repeated for all the DWAs performed by supervisors. From these we select 16 that are directly associated with employee supervision, listed on the right table above. The ratio between the frequency value of supervisory and the sum of all DWA by occupation provides the adjustment which is attributed to supervisors in the final dataset.

Non-routine cognitive and routine work activities

Table A.3: Non-routine cognitive and routine work activities variables

Non-routine cognitive		Routine	
Analytical		Manual	
4A2a4	Analyzing data/information	4C3d3	Pace determined by speed of equipment
4A2b2	Thinking creatively	4A3a3	Controlling machines and processes
4A1a1	Interpreting information for others	4C2d1i	Spend time making repetitive motions
Interpersonal		Cognitive	
4A4a4	Establishing and maintaining personal relationships	4C3b7	Importance of repeating the same tasks
4A4b4	Guiding, directing and motivating subordinates	4C3b4	Importance of being exact or accurate
4A4b5	Coaching/developing others	4C3b8	Structured v. Unstructured work (inverse)

The codes are the reference for the variables in the O*NET job content model

Descriptive statistics

Table A.4: Industry level descriptive statistics for variables in table 2

Variable	Mean	s.d.
Supervision	0.029	0.015
Non-routine cognitive	-0.052	0.450
Routine	-0.078	0.486
Percentage of managers	0.115	0.080
Log industry size	4.744	1.277
Percentage of female workers	0.378	0.213
Unionization rate	0.088	0.109
Pct. of workers with university degree	0.583	0.183
Average age	40.89	3.081

Table A.5: Worker level descriptive statistics for variables in table 3

Variable	Mean	s.d.	Variable	%
Real hourly wages	24.71	14.77	Ethnicity	
Log real hourly wages	3.06	0.53	White	76.1
Supervision	0.03	0.01	Black	6.3
Union	0.10	0.31	Hispanic	11.7
Age	42.81	11.08	Asian	4.9
Age^2	1956.0	9496.0	Other	1.0
Potential experience	22.93	113.07	Education	
Potential $experience^2$	65.39	53.05	Less than high school	6.6
Married	0.65	0.47	High school	30.3
Metropolitan area	0.80	0.40	Some college	29.5
U.S. citizen	0.92	0.27	College	22.4
Female	0.42	0.49	Advanced degree	11.2
N				144,324
$Workers$				72,162

Supervisory occupations

Table A.6: Supervisory occupations used in figure and table 1.

3-digit supervisory occupations	2010 COC
First-line supervisors of correctional officers	3700
First-line supervisors of fire fighting and prevention workers	3720
First-line supervisors of food preparation and serving workers	4010
First-line supervisors of housekeeping and janitorial workers	4200
First-line supervisors of landscaping, lawn service, and groundskeeping workers	4210
First-line supervisors of gaming workers	4300
First-line supervisors of personal service workers	4320
First-line supervisors of retail sales workers	4700
First-line supervisors of non-retail sales workers	4710
First-line supervisors of office and administrative support workers	5000
First-line supervisors of farming, fishing, and forestry workers	6005
First-line supervisors of construction trades and extraction workers	6200
First-line supervisors of mechanics, installers, and repairers	7000
First-line supervisors of production and operating workers	7700
Supervisors of transportation and material moving workers	9000

List of all occupation that perform supervisory detailed work activities

Table A.7: Occupations that perform supervision and their respective frequency

Occupation	Freq.
Payroll and timekeeping clerks 43-3051	0.453
1st-line supervisors/managers landscape, lawn, grounds workers 37-1012	0.390
1st-line supervisors/managers housekeeping & janitorial workers 37-1011	0.337
Compensation, benefits, and job analysis specialistst 13-1141	0.282
Medical and health services managers 11-9111	0.267
Pest control workers 37-2021	0.257
Human resources assistants, except payroll and timekeeping 43-4161	0.253
Compensation and benefits managers 11-311	0.246
Food servers, nonrestaurant 35-3041	0.240
Human resources workers 13-1070	0.238
Public relations managers 11-2031	0.230
Purchasing managers 11-3061	0.228
Urban and regional planners 19-3051	0.224
1st-line supervisors/managers farming, fishing, and forestry workers 45-1011	0.222
Gaming managers 11-9071	0.212
First-line supervisors/managers of non-retail sales workers 41-1012	0.199
Fundraisers 13-1131	0.195
Transportation, storage, and distribution managers 11-3071	0.189
Dietitians and nutritionists 29-1031	0.188
Financial managers 11-3031	0.185
Education administrators 11-9030	0.184
Social and community service managers 11-9151	0.182
Ushers, lobby attendants, and ticket takers 39-3031	0.173
1st-line supervisors/managers office & admin support workers 43-1011	0.171
Biological technicians 19-4021	0.166
Human resources managers 11-3121	0.164
Medical records and health information technicians 29-2071	0.162
Lodging managers 11-9081	0.158
Athletes, coaches, umpires, and related workers 27-2020	0.150
Chefs and head cooks 35-1011	0.142
First-line supervisors/managers of personal service workers 39-1021	0.139
Residential advisors 39-9041	0.139
Marketing and sales managers 11-2020	0.128
1st-line supervisors/managers mechanics, installers, repairers 49-1011	0.126
Crossing guards 33-9091	0.125
Lifeguards and other recreational, and all other protective service workers 33-909X	0.122
Medical scientists and life scientists, all other 19-10XX	0.112
Miscellaneous agricultural workers, incl animal breeders 45-20XX	0.111
Biological scientists 19-1020	0.109
Lawyers, Judges, magistrates, and other judicial workers 23-1011	0.101
Chemists and materials scientists 19-2030	0.099
Materials engineers 17-2131	0.096
Archivists, curators, and museum technicians 25-4010	0.096
Hosts and hostesses, restaurant, lounge, and coffee shop 35-9031	0.094
Industrial production managers 11-3051	0.092
Advertising and promotions managers 11-2011	0.091
Combined food prep and serving workers, including fast food 35-3021	0.089
Construction managers 11-9021	0.089
Property, real estate, and community association managers 11-9141	0.088
Chief executives 11-1011	0.088
1st-line supervisors/managers food prep and serving workers 35-1012	0.085
Computer hardware engineers 17-2061	0.083
Management analysts 13-1111	0.082
Food service managers 11-9051	0.079
First-line supervisors/managers of retail sales workers 41-1011	0.079

Occupation	Freq.
Environmental engineers 17-2081	0.079
Farm, ranch, and other agricultural managers 11-9013	0.078
Database administrators 15-1041	0.075
Mathematicians, Statisticians, and Misc mathematical science occ 15-20XX	0.074
Logisticians 13-1081	0.073
Compliance officers 13-1041	0.071
Training and development specialists 13-1151	0.070
Misc community and social service specialists, incl heal educators and comm health workers 21-109X	0.070
Computer and information systems managers 11-3021	0.069
Loan counselors and officers 13-2070	0.069
Other education, training, and library workers 25-90XX	0.067
Transportation inspectors 53-6051	0.066
Natural sciences managers 11-9121	0.066
1st-line supervisors/managers of correctional officers 33-1011	0.065
Financial examiners 13-2061	0.065
Producers and directors 27-2012	0.065
Petroleum engineers 17-2171	0.064
Software developers, applications, and systems software 15-113X	0.062
Supervisors, transportation and material moving workers 53-1000	0.062
Editors 27-3041	0.060
First-line supervisors/managers of gaming workers 39-1010	0.060
Sheet metal workers 47-2211	0.060
Morticians, undertakers, and funeral directors 39-4031	0.059
Surveying and mapping technicians 17-3031	0.059
Directors, religious activities and education 21-2021	0.059
Appraisers and assessors of real estate 13-2021	0.059
Claims adjusters, appraisers, examiners, and investigators 13-1030	0.058
Material moving workers, incl mine shuttle operators and tank car, truck, and ship loaders 53-71XX	0.056
Highway maintenance workers 47-4051	0.056
Licensed practical and licensed vocational nurses 29-2061	0.056
Economists 19-3011	0.054
Aircraft pilots and flight engineers 53-2010	0.054
Mining & geological engineers, including mining safety engineers 17-2151	0.054
Engineering managers 11-9041	0.053
Aircraft mechanics and service technicians 49-3011	0.052
Wholesale and retail buyers, except farm products 13-1022	0.050
Mining machine operators 47-5040	0.050
Purchasing agents and buyers, farm products 13-1021	0.050
Counter attendants, cafeteria, food concession, and coffee shop 35-3022	0.049
Cooks 35-2010	0.049
Waiters and waitresses 35-3031	0.049
Drafters 17-3010	0.048
Computer programmers 15-1031	0.047
Fishers and related fishing workers 45-3011	0.047
Physical therapists 29-1123	0.047
Geological and petroleum technicians 19-4041	0.047
Automotive body and related repairers 49-3021	0.047
Environmental scientists and geoscientists 19-2040	0.046
Receptionists and information clerks 43-4171	0.046
Training and development managers 11-3131	0.046
Construction and building inspectors 47-4011	0.045
Miscellaneous entertainment attendants and related workers 39-3090	0.045
Computer network architects 15-1143	0.044
Social workers 21-1020	0.044
Managers, all other 11-9199	0.043

Occupation	Freq.
Agricultural inspectors 45-2011	0.042
Cement masons, concrete finishers, and terrazzo workers 47-2050	0.041
Miscellaneous life, physical, and social science technicians 19-4090	0.041
Real estate brokers and sales agents 41-9020	0.041
Gaming services workers 39-3010	0.041
Information security analysts 15-1122	0.040
Engineers, all other 17-2199	0.040
Bartenders 35-3011	0.039
Physicians and surgeons 29-1060	0.039
Financial specialists, all other 13-2099	0.038
Clinical laboratory technologists and technicians 29-2010	0.037
Dancers and choreographers 27-2030	0.036
Television, video, & motion picture camera operators & editors 27-4030	0.035
Heavy vehicle & mobile equipment service techs & mechanics 49-3040	0.035
Security guards and gaming surveillance officers 33-9030	0.035
Computer occupation, all other 15-1199	0.034
Registred Nurses 29-1141	0.033
Locomotive engineers and operators 53-4010	0.033
Veterinarians 29-1131	0.033
Purchasing agents, except wholesale, retail, and farm products 13-1023	0.032
Meeting, convention, and event planners 13-1121	0.031
Parking enforcement workers 33-3041	0.031
Special education teachers 25-2050	0.031
Production, planning, and expediting clerks 43-5061	0.031
Precision instrument and equipment repairers 49-9060	0.031
Recreation and fitness workers 39-9030	0.031
Logging workers 45-4020	0.031
Accountants and auditors 13-2011	0.030
Marine engineers and naval architects 17-2121	0.030
Driver/sales workers and truck drivers 53-3030	0.030
Agricultural and food science technicians 19-4011	0.029
Dentists 29-1020	0.029
Procurement clerks 43-3061	0.028
Gen and operations managers 11-1021	0.028
Postsecondary teachers 25-1000	0.028
Speech-language pathologists 29-1127	0.028
Agricultural and Biomedical engineers 17-20XX	0.028
Nurse midwives and Nurse Practitioners 29-11XX	0.028
Air traffic controllers and airfield operations specialists 53-2020	0.027
1st-line supervisors/managers fire fighting & prevention workers 33-1021	0.027
Hotel, motel, and resort desk clerks 43-4081	0.027
Physician assistants 29-1071	0.026
Miscellaneous social scientists, including survey researchers and sociologists 19-30XX	0.026
Market research analysts and marketing specialists 13-1161	0.026
Office clerks, general 43-9061	0.025
Secretaries and administrative assistants 43-6010	0.025
Audiologists 29-1181	0.024
Septic tank servicers and sewer pipe cleaners 47-4071	0.024
Librarians 25-4021	0.023
Industrial engineers, including health and safety 17-2110	0.022
Interviewers, except eligibility and loan 43-4111	0.021
Psychologists 19-3030	0.021
Radiation therapists 29-1124	0.021
Hairdressers, hairstylists, and cosmetologists 39-5012	0.021

Occupation	Freq.
Parking lot attendants 53-6021	0.020
Broadcast and sound engineering technicians and radio operators 27-4010	0.020
Maintenance and repair workers, general 49-9071	0.020
Heating, air conditioning, refrigeration mechanics, installers 49-9021	0.019
Fire inspectors 33-2020	0.018
Counselors 21-1010	0.018
Barbers 39-5011	0.017
Other extraction workers, incl roof bolters and helpers 47-50XX	0.017
Library technicians 25-4031	0.017
Computer and information reserach scientists 15-1111	0.017
Miscellaneous health technologists and technicians 29-2090	0.016
Cargo and freight agents 43-5011	0.016
Mechanical engineers 17-2141	0.015
Electrical and electronics repairers, industrial and utility 49-209X	0.015
Chemical technicians 19-4031	0.015
Securities, commodities, and financial services sales agents 41-3031	0.015
Computer operators 43-9011	0.015
Architects, except naval 17-1010	0.014
Computer support specialists 15-1150	0.013
Diagnostic related technologists and technicians 29-2030	0.013
Elementary and middle school teachers 25-2020	0.012
Preschool and kindergarten teachers 25-2010	0.012
Conservation scientists and foresters 19-1030	0.012
Computer systems analysts 15-1121	0.012
Recreational therapists 29-1125	0.012
Carpet, floor, and tile installers and finishers 47-2040	0.011
Court, municipal, and license clerks 43-4031	0.011
Cashiers 41-2010	0.011
Respiratory therapists 29-1126	0.011
Judicial Law Clerks 23-1012	0.011
Library assistants, clerical 43-4121	0.010
Photographers 27-4021	0.010
Ship and boat captains and operators 53-5020	0.010
Electrical and electronic engineers 17-2070	0.010
Engineering technicians, except drafters 17-3020	0.009
Occupational therapists 29-1122	0.008
Business operations specialists, all other 13-1199	0.007
Other teachers and instructors 25-3000	0.007
Misc vehicle & mobile equipment mechanics, installers, repairers 49-3090	0.006
Other healthcare practitioners and technical occupations, including podiatrists 29-XXXX	0.005
Health practitioner support technologists and technicians 29-2050	0.005
Funeral service workers 39-40XX	0.004
Private detectives and investigators 33-9021	0.004
Radio and telecommunications equipment installers and repairers 49-2020	0.003
Helpers, construction trades 47-3010	0.003
Miscellaneous construction and related workers,incl photovoltaic installers	0.002
Grounds maintenance workers 37-3010	0.002
Other installation, maintenance, and repair workers 49-909X	0.001
Painters, construction and maintenance and paperhangers 47-214X	0.001