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A longitudinal study of piece rate and health: evidence and implications for workers in the US gig economy



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ABSTRACT

Objectives: The objective of this study was to evaluate health outcomes for workers subject to piece rate historically to better understand the implications of pay type in the modern-day gig economy. While piece rate occurring in the 1980s and 1990s predates recent platform-based employment, it introduced and normalized patterns of economic precariousness that are instrumental in the current gig economy. Evidence suggests that such pay types may result in poor health outcomes; however, cross-sector evidence of its long-term effects on US workers is lacking. This article represents the first longitudinal cross-sector analysis relating health outcomes to this performance pay type in US workers.

Study design: This is a longitudinal cohort study.

Methods: Data from six survey waves of the 1979 National Longitudinal Survey of Youth collected between 1988 and 2000 are used in a random-effects logit model to predict self-reported health limitations related to piece rate, while controlling for worker, work environment, lifestyle, time, and location trends.

Results: Pay tied to piece rate in current or prior periods significantly increases the odds of self-reported health limitations compared with salaried work (odds ratio [OR]: 1.4–1.8). These effects are elevated for the subgroups of low-wage (OR: 1.5–1.8), female (OR: 1.8–1.9), and non-white (OR: 2.0–2.1) workers compared with their high-wage, male, and white peers.

Conclusions: The results suggest that piece rate pay designed to promote efficiency may have important negative implications for worker health, especially for the most vulnerable members of the US workforce such as women, minority, and low-income workers. Given the growing popularity of performance-based pay to the gig economy, more research is needed to determine if the practice is justified from a public health perspective.

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Introduction

Adam Smith surmised at the start of the industrial revolution in *Wealth of Nations* (1776) that ‘Workmen...when they are liberally paid by the piece, are very apt to overwork themselves, and to ruin their health and constitution in a few years’.¹ The practice of tying worker compensation directly to effort represents the dominant form of pay in the growing ‘gig economy.’ Gig work is best described as the division of paid effort into smaller components, offered to independent contractors with low barriers to entry via a Web-based platform.²

This article explores the historical form of pay type most closely aligned with modern-day gig work – piece rate – to understand the potential impact of recent transitions in performance-based pay on worker health. ‘Piece rate’ links pay directly to the quantity of goods or services a worker produces. Despite recent declines in US manufacturing where piece rate was particularly popular,³ it continues to be prevalent in certain sectors such as the booming logistics industry, where temporary workers and truck drivers are paid by the truckload. Piece rate pay in this industry has been associated with risky behavior, leading to increased accidents and fatalities for workers and bystanders and spurring demands for changes to the incentive structure for workers in this industry.⁴

While our analysis focuses on piece rate through the 1980s and 1990s, which predates recent platform-based gig employment, the expansion of contingent labor practices such as piece rate in these formative pre-gig years remains relevant to the current gig economy.⁵ With this historical perspective in mind, we evaluate health outcomes for workers subject to piece rate compensation in a longitudinal panel to provide context for understanding the implications of modern-day performance-based pay in the growing gig economy.

Methods

We test the relationship between exposure to piece rate and self-reported worker health outcomes using data from a cohort of US workers maintained by the Bureau of Labor Statistics – the National Longitudinal Survey of Youth 1979 (NLSY79). The NLSY79 is a large cohort study of US workers born between 1957 and 1964, with follow-up available initially on an annual basis from 1979 to 1994 and then biannually from 1994 through 2014. However, data on piece rate pay are limited to six of those survey waves (1988, 1989, 1990, 1996, 1998, and 2000). Although these data are more limited than the full NLSY panel, they provide a unique series of repeated observations on individual workers, which allows us to follow workers as they move in and out of piece rate jobs and identify cumulative health effects that may exacerbate over time.

Table 1 summarizes the data available during the six survey waves of the NLSY79 with pay type information. ‘Piece rate’ is a category of performance-based pay that is directly tied to the unit of production or service, which is analogous to how the gig economy typically compensates contract workers for direct effort. Exposure to piece rate pay represents on

average nearly 3% of the total jobs reported by workers over the sample period. However, roughly 10% of the surveyed workers reported at least one piece rate job during the entirety of the observed period, which is similar to previously cited estimates of the prevalence of piece rate pay in US workers over this time period⁶ as well as the number of US workers primarily doing independent work.⁷

The data describing worker health outcomes in the NLSY79 vary depending on the survey year, as the health section of the questionnaire was adapted over time to reflect respondents’ varying life cycle stages. The most complete match to the six survey waves of pay type data is represented by the variable ‘Health limitation.’ For this variable, workers self-report whether they have any health condition or circumstance that limits their activities, work, or otherwise. Similar to all variables in the NLSY data series, Health limitation is subject to self-reporting bias. Given the data available, there is no way to determine the extent to which this may be impacting the associations reported in this article. However, unless workers reporting piece rate are differentially biased than their salaried peers in how they report health limitations, any self-reporting bias should not impact that primary covariate of interest.

Other important control variables identified in Table 1 include key worker demographics such as income, race, education, sex, age, and health insurance status. The low-wage cutoff is based on the definition of the US Department of Health and Human Services as a nominal hourly wage below 145% of the federal minimum poverty wage. Additional work-related covariates are noted for workers in the manufacturing sector where piece rate is more common, self-employed, tenure at job, and hours worked per week, as evidence suggests that workers paid through incentive-based systems tend to work more hours per week than salaried workers.⁸

Finally, important personal health behaviors such as diet, exercise, and smoking are only available for a single survey wave but included in the model as time-invariant controls. These individual worker habits provide important information on health status and risk preferences, which impact the unobserved sorting of workers into various workplaces. Smoking status has been used in previous research as an indicator of risk preference based on evidence that US workers who smoke take substantially more risky jobs in terms of occupational safety, earnings, and employment.⁶ Given the limitations of the time-invariant data series, there is no way to determine the extent to which changing health behaviors and attitudes toward health are impacting the associations observed in this study. However, any changes in health behaviors are unlikely to impact the primary variable of interest, piece rate, unless these behaviors and attitudes change differentially over time for workers receiving piece rate vs salary.

A total of 8,985 individuals initially reported data on piece rate (yes/no) during the first survey wave (1988), which represents the overall potential base sample of workers in this study. However, some workers stopped reporting data as time progressed, starting with 0.5% of the sample in the first follow-up period (1989) and progressing to 11.3% of the initial sample by the last survey wave (2000). Intermittently missing values for the other variables also contributed to a reduction

Table 1 – Summary statistics for NLSY79 survey waves 1998, 1989, 1990, 1996, 1998, and 2000.

Variables	Definition	Categories	N	Mean	S.D.	Min	Max	% missing (n = 53,910)
Primary dependent variable								
Health limitation	Worker reports health limitation(s)	0 = No, 1 = Yes	48,775	0.07	0.25	0	1	9.5%
Primary independent variables								
Annual piece rate	Primary job reported as piece rate in the current survey wave	0 = No, 1 = Yes	38,702	0.03	0.17	0	1	28.2%
Ever piece rate	Any job (not just primary) reported as piece rate in the current or previous survey wave	0 = No, 1 = Yes	39,902	0.10	0.30	0	1	26.0%
Additional covariates								
Hours worked per week	Hours per week in primary job	Continuous	44,501	40.17	11.93	0	168	17.5%
Male	Worker is male	0 = No, 1 = Yes	53,910	0.50	0.50	0	1	0%
Manufacturing	Has any job in the manufacturing industry	0 = No, 1 = Yes	44,453	0.20	0.40	0	1	17.5%
Low-wage worker	Wage <145% of fed. minimum	0 = No, 1 = Yes	43,273	0.63	0.48	0	1	19.7%
Education	Highest grade completed	Count	49,142	12.93	2.41	0	20	8.8%
Non-white	Individual is black or Hispanic	0 = No, 1 = Yes	53,910	0.49	0.50	0	1	0%
Tenure at primary job	Years of tenure at primary job	Continuous	42,738	4.20	4.62	0	31	20.7%
Health insurance	Covered by health insurance plan	0 = No, 1 = Yes	40,789	0.81	0.39	0	1	24.3%
Age (years)	Age at interview	Continuous	53,910	32.20	5.12	23	44	0%
Self-employed	Self-employed in any job	0 = No, 1 = Yes	44,435	0.10	0.30	0	1	17.6%
Cross-sectional variables^a								
Diet	Trying to lose weight (self-reported 2002)	0 = No, 1 = Yes	43,866	0.44	0.50	0	1	18.6%
Exercise	Engages in exercise at least three days per week (self-reported 2002)	0 = No, 1 = Yes	41,448	0.64	0.47	0	1	23.1%
Smoker	Currently smokes at least one cigarette per day (self-reported 1998)	0 = No, 1 = Yes	45,234	0.32	0.47	0	1	16.1%

NLSY79, National Longitudinal Survey of Youth 1979; S.D., standard deviation.

^a Variables only available as cross sections reported in a single survey wave; observations repeated through the longitudinal panel to identify time-invariant impact of important health-related behaviors.

in the overall sample size available for analysis as noted in [Table 1](#).

Sensitivity analyses compared the health of workers missing piece rate information with those reporting it, conducted separately by survey wave to control for the deleterious effect of increasing age on health. Workers missing piece rate data report comparatively poorer health than workers who respond (yes/no) with this information. These results indicate that a healthy worker effect might be prompting selection (sorting) bias in the cohort. However, this healthy worker effect, if present, is likely to bias the analytical results on piece rate toward the null, attenuating the estimated odds ratios (ORs) in favor of no significant effect.

A final note on missing data in the sample is that health insurance is not reported at all in one of the six survey waves and including it as a covariate would limit the time points observed to five survey waves. However, health insurance may have a significant impact on worker health outcomes and represent a confounder if workers paid by piece rate experience differential rates of coverage compared with their salaried peers. For this reason, results from the more complete panel of data are presented in the body of this article, while the analyses that include health insurance as an explanatory variable are reported for comparison purposes as an [Appendix](#).

Statistical model

A random-effects logit model was used to predict the presence of self-reported worker health limitations using the `xlogit` command in STATA, version 15, (College Station, TX) based on the following Equation (1):

$$I_{it} = \alpha_0 + \beta X_{it} + \delta W_{it} + \phi \text{PayType} + \sigma_i + \pi_k + \kappa_t + \varepsilon_{it} \quad (1)$$

Where *i* and *t* indicate index workers and survey waves, respectively, and *I* is the presence of a health limitation (0 = No, 1 = Yes). Descriptive statistics of the variables used to identify Equation (1) are provided in [Table 1](#). *X* and *W* control for heterogeneity across workers and work environments, respectively. σ , π , and κ control for worker, region (determined by Census division), and survey wave effects, respectively. Worker-level random-effects control for unobserved characteristics such as risk preferences that might impact the sorting of workers into piece rate jobs, and errors are clustered by worker to control for repeated observations within the panel series. An advantage of the random-effects model in this case is that it allows us to control for time-invariant demographic characteristics directly, providing an estimate of their effects on the dependent variable.

Pay type is defined in two ways: as an annual value of piece rate reported in a worker's primary job (0 = No, 1 = Yes) and as a cumulative piece rate specification that takes on a value of 1 if a worker has reported piece rate at any point before or during the observed survey wave. While the annual piece rate is intended to capture the immediate health consequences of this pay type, the cumulative piece rate variable may capture the ongoing and exacerbating impact of piece rate pay over time. Alternative specifications of cumulative and lagged piece rate linking one period directly to the period before and

after were not appropriate because of the time discontinuity of the six survey waves. The final data set does not contain survey weights, which are inappropriate for longitudinal analyses of the NLSY79 cohort.⁹

The logit model described previously was adapted and run separately for specific subgroups of vulnerable workers, focusing on low-income (vs high-income), female (vs male), and non-white (vs white) workers, to explicitly identify whether the modeled relationships were significantly different for susceptible subgroups of workers. Alternative specifications using interaction terms to explore differential effects across subgroups were also tested. Only the results of the separate subgroup analyses are reported here, as this approach allowed us test for both differential and individual effects of piece rate on health across the various subgroups of workers.

Results

[Tables 2 and 3](#) provide estimates of the effect of piece rate on worker health limitations for this cohort. [Table 2](#) relates annual piece rate to health limitations in a specific survey wave, while [Table 3](#) presents similar results, specifying the piece rate impact as cumulative over time. All coefficients are represented as ORs to facilitate interpretation and comparisons of the effects. Being paid piece rate compared with salaried work has a statistically significant negative effect on worker health both in the annual (OR = 1.75) and cumulative (OR = 1.42) specifications, suggesting both immediate and longer term impacts on worker health. When broken down by subgroup, the odds of reporting health limitations fall away for high-income, male, and white workers but are amplified and remain statistically significant for the subgroups of low-wage (OR = 1.53–1.77), female (OR = 1.80–1.94), and non-white (OR = 1.95–2.05) workers. Additional covariates statistically and significantly related to health limitations include age, tenure at job, hours worked, self-employment, and education, as well as the time-invariant health behaviors including exercise, dieting, and smoking. Although the size of the effects varied across specifications, the odds that a worker reported health limitations generally increased with age, smoking status, and dieting, while tenure on the job, hours worked, education, and exercise were all associated with reduced worker health limitations.

Health insurance as an independent variable reduces the sample size available for the analysis by one survey wave, limiting the number of follow-up periods and the power of the study to detect statistically significant differences; however, because health insurance plays a potentially important role in a worker's health, separate specifications including this variable are presented as an [Appendix \(Tables A-1 and A-2\)](#). Similar to the primary specifications that include data from all available survey waves, currently receiving piece rate pay is associated with a significantly increased odds of reporting a health limitation, overall and specifically for the subpopulations of low-wage, female, and non-whites workers (OR = 1.8–2.1). The coefficient is similar for workers ever receiving piece rate (OR = 1.4) but is no longer statistically

Table 2 – Effect of piece rate on the odds of worker health limitations.

Variable	Full model	Not low wage	Low wage	Male	Female	White	Non-white
Piece rate (annual)	1.75** (1.16–2.62)	2.05 (0.74–5.66)	1.77* (1.14–2.74)	1.58 (0.82–3.05)	1.94* (1.15–3.26)	1.50 (0.87–2.59)	1.95* (1.09–3.50)
Age	1.06** (1.01–1.11)	1.05 (0.94–1.16)	1.08** (1.03–1.14)	1.11** (1.03–1.20)	1.03 (0.98–1.09)	1.10** (1.03–1.18)	1.03 (0.97–1.09)
Manufacturing job	0.90 (0.72–1.14)	0.69 (0.40–1.20)	1.00 (0.78–1.28)	0.84 (0.60–1.18)	0.93 (0.69–1.27)	0.91 (0.66–1.25)	0.92 (0.67–1.27)
Tenure at primary job	0.96** (0.94–0.98)	0.99 (0.95–1.03)	0.96** (0.93–0.98)	0.98 (0.95–1.01)	0.95** (0.92–0.98)	0.94** (0.91–0.96)	1.00 (0.97–1.03)
Hours worked per week	0.99** (0.98–0.99)	0.97** (0.95–0.98)	0.99 (0.98–1.00)	0.98** (0.96–0.99)	0.99 (0.98–1.01)	0.99** (0.97–0.99)	0.99 (0.97–1.00)
Self-employed	1.33 (0.98–1.80)	1.25 (0.64–2.41)	1.36 (0.96–1.92)	1.20 (0.76–1.89)	1.46 (0.97–2.19)	1.42 (0.96–2.11)	1.26 (0.78–2.03)
Education	0.89** (0.85–0.94)	0.98 (0.88–1.08)	0.89** (0.84–0.94)	0.90** (0.84–0.97)	0.89** (0.83–0.95)	0.88** (0.82–0.95)	0.90** (0.84–0.96)
Non-white	0.85 (0.68–1.05)	0.96 (0.59–1.56)	0.81 (0.64–1.03)	0.81 (0.57–1.16)	0.86 (0.65–1.12)	N/A	N/A
Male	0.72** (0.57–0.91)	0.63 (0.37–1.08)	0.77* (0.60–0.99)	N/A	N/A	0.75 (0.53–1.07)	0.70* (0.51–0.97)
Low wage	1.59** (1.27–1.98)	N/A	N/A	2.00** (1.45–2.76)	1.30 (0.96–1.75)	1.51** (1.12–2.04)	1.69** (1.22–2.34)
Exercise (2002)	0.54** (0.44–0.67)	0.52* (0.31–0.86)	0.55** (0.44–0.69)	0.36** (0.26–0.52)	0.72* (0.55–0.94)	0.47** (0.34–0.64)	0.64** (0.48–0.86)
Diet (2002)	1.40** (1.13–1.73)	1.34 (0.84–2.16)	1.40** (1.11–1.77)	1.31 (0.92–1.88)	1.42* (1.08–1.85)	1.60** (1.17–2.18)	1.20 (0.89–1.61)
Smoker (1998)	1.65** (1.32–2.07)	2.41** (1.39–4.19)	1.55** (1.23–1.97)	1.55* (1.09–2.22)	1.69** (1.27–2.25)	1.95** (1.40–2.70)	1.34 (0.99–1.82)
N (observations)	26,655	9,647	17,008	13,064	13,591	14,036	12,619
N (individuals)	6,145	3,229	5,036	2,912	3,233	3,205	2,940

Odds ratios reported, 95% confidence interval in parentheses; model controls for survey year and census division (results not reported); ** $P < 0.01$, * $P < 0.05$.

significant, while it remains statistically significant for the vulnerable subsets of workers (OR = 1.5–2.1).

Discussion

The evidence presented in this study suggests that piece rate pay, which is increasingly popular as a compensation mechanism for contract workers in the gig economy, increases the odds of health limitations compared with salaried work. Interestingly, the deleterious effects of this type of performance-based pay are not borne uniformly across workers and instead appear to disproportionately impact low-wage, female, and non-white workers compared with higher wage, male, and white peers. This study is the first one to attempt a large-scale longitudinal and cross-sector analysis of US workers, linking health outcomes to piece rate. It builds on previous efforts to use the NLSY1979 cohort to identify a statistically significant impact of pay type on worker accident and injury risk.⁶ Similar international studies identified a statistically significant relationship between piece rate and worker health across sectors in the UK;^{8,22} however, these results may have limited applicability in the US context because of differences in underlying worker protection and labor laws. The present study corroborates the UK findings for US workers, with poorer health outcomes reported for piece rate workers than for salaried workers, especially for the low-wage, female, and minority workforce.

The elevated risk to vulnerable worker groups is not surprising, as previous literature linked piece rate pay to increased risk of occupational accidents and injuries for blue-collar workers⁶ and women.¹⁰ There is also mounting evidence that racial and gender bias in performance reviews reinforces gender and racial pay gaps.¹¹ If women and racial minorities must work harder than their male and white peers to attain the same level of pay, then they could be reasonably expected to face a greater physical and emotional toll within the context of piece rate and gig pay. Recent evidence specific to the gig economy finds growing inequality among the bottom 80% of the distribution of workers in these jobs,² as well as a gender gap in earnings favoring men.⁷ More research is needed to understand these differential effects, which could be the result of many factors beyond wage incentives, including but not limited to current and historical discrimination practices in hiring and employment.

Key evidence has surfaced since Adam Smith's early conjecture to support his theory of the negative health impacts of tying worker compensation directly to their productivity output. Studies have linked incentivized pay schemes to increased accident and injury risk,^{6,8,10,12,13} as well as poor health outcomes in specific populations or industries. For example, negative effects of pay by the piece have been observed on the body mass index in Filipino farmers,¹⁴ absenteeism in German steel plant workers,¹⁵ depression and somatic complaints in Israeli garment workers,¹⁶ elevated heart rates in Canadian loggers,¹⁷ and medication usage in

Table 3 – Cumulative effect of piece rate on the odds of worker health limitations.

Variable	Full model	Not low wage	Low wage	Male	Female	White	Non-white
Piece rate (ever)	1.42* (1.03–1.96)	0.83 (0.36–1.90)	1.53* (1.09–2.15)	1.14 (0.70–1.87)	1.80** (1.16–2.78)	0.88 (0.53–1.47)	2.05** (1.36–3.11)
Age	1.06** (1.02–1.11)	1.05 (0.95–1.17)	1.08** (1.03–1.13)	1.11** (1.03–1.19)	1.03 (0.98–1.09)	1.10** (1.03–1.18)	1.03 (0.96–1.09)
Manufacturing job	0.91 (0.73–1.14)	0.69 (0.39–1.20)	1.01 (0.79–1.29)	0.81 (0.58–1.14)	0.96 (0.71–1.31)	0.93 (0.67–1.28)	0.92 (0.67–1.27)
Tenure at primary job	0.96** (0.94–0.98)	0.99 (0.95–1.03)	0.96** (0.93–0.98)	0.97 (0.94–1.01)	0.95** (0.92–0.98)	0.93** (0.90–0.96)	1.00 (0.96–1.03)
Hours worked per week	0.98** (0.98–0.99)	0.96** (0.95–0.98)	0.99* (0.98–0.99)	0.97** (0.96–0.98)	0.99 (0.98–1.00)	0.98** (0.97–0.99)	0.99 (0.97–1.00)
Self-employed	1.36* (1.03–1.80)	1.25 (0.66–2.36)	1.41* (1.03–1.93)	1.29 (0.86–1.96)	1.42 (0.98–2.08)	1.41 (0.98–2.05)	1.32 (0.86–2.04)
Education	0.89** (0.85–0.94)	0.96 (0.87–1.06)	0.89** (0.84–0.94)	0.90** (0.83–0.96)	0.89** (0.83–0.94)	0.87** (0.81–0.94)	0.90** (0.84–0.96)
Non-white	0.83 (0.67–1.03)	0.98 (0.60–1.59)	0.78* (0.62–0.99)	0.79 (0.56–1.13)	0.84 (0.64–1.10)	N/A	N/A
Male	0.72** (0.57–0.91)	0.67 (0.39–1.14)	0.76* (0.59–0.99)	N/A	N/A	0.78 (0.55–1.10)	0.67* (0.49–0.93)
Low wage	1.61** (1.29–2.00)	N/A	N/A	1.96** (1.44–2.69)	1.35 (1.00–1.82)	1.61** (1.19–2.17)	1.62** (1.18–2.24)
Exercise (2002)	0.54** (0.44–0.68)	0.49** (0.30–0.82)	0.54** (0.44–0.70)	0.37** (0.26–0.52)	0.72* (0.55–0.94)	0.47** (0.34–0.64)	0.64** (0.48–0.86)
Diet (2002)	1.39** (1.12–1.72)	1.33 (0.83–2.14)	1.39** (1.10–1.75)	1.36 (0.96–1.93)	1.39* (1.07–1.82)	1.62** (1.19–2.21)	1.16 (0.78–1.56)
Smoker (1998)	1.64** (1.32–2.05)	2.29** (1.32–3.97)	1.54** (1.22–1.95)	1.59** (1.12–2.25)	1.64** (1.23–2.18)	1.84** (1.33–2.55)	1.41* (1.04–1.91)
N (observations)	27,158	9,818	17,340	13,392	13,766	14,343	12,815
N (individuals)	6,156	3,257	5,077	2,915	3,241	3,212	2,944

Odds ratios reported, 95% confidence interval in parentheses; model controls for survey year and census division (results not reported); **P < 0.01, *P < 0.05.

Canadian garment workers.¹⁸ Pay for performance has also been linked to increased worker compensation costs in a US shoe-manufacturing firm,¹⁹ negative physical and emotional health outcomes in Vietnamese garment workers,²⁰ and negative self-reported health outcomes, back problems, and repetitive stress injuries in cross-industry analyses of British workers.^{21,22} Additional evidence linking poor health and well-being outcomes specifically to modern-day gig work is limited but growing.²

Although incentivized pay systems are generally understood to increase worker productivity,^{23–26} the impact on overall profits for business operations that pay workers in this way remains a topic of debate.^{19,27} Evidence suggests that gains in productivity may be offset by maladaptive worker behaviors, including those detrimental to health that ultimately increase operating costs and lower business profits.^{6,19,28} This unintended consequence makes intuitive sense, as worker behaviors and activities that are financially rewarded, such as increased output, take precedence over those that are not rewarded, in this case worker health and safety. This study extends the argument one step further to suggest that poor health outcomes linked to performance and piece rate might further erode a company's bottom line, as health limitations are likely to result in increased health-related absenteeism, lower performance, and higher healthcare costs. Indeed, higher health costs related to performance-based pay might explain why labor platform companies such as Uber are so strongly resisting having legal status as employers. The externalization of health and other traditional fringe expenses onto their gig

workforce may be a pivotal pillar of their business model. The negative effect of piece rate pay may be particularly harmful to the profits of companies staffed with the vulnerable worker groups highlighted in the current analysis.

Limitations

While the NLSY79 provides a large and representative sample of US workers over time, the data available on piece rate are limited to six years of follow-up and are missing for some surveyed workers. In addition, key health behavior variables are available only in a single survey wave, and the NLSY data are subject to self-report error. However, as noted previously, these sources of bias are most likely to attenuate the relationship between piece rate and health in the direction of the null hypothesis.

The longitudinal study design with random effects as well as the inclusion of worker risk preferences such as smoking status are intended to control for unobserved characteristics that might impact the sorting of workers into workplaces; however, failure to fully account for non-random sorting will bias the estimated effects. This bias would again be trended toward the null, assuming more able-bodied workers sort into potentially higher paying piece rate work as noted in previous analyses.²⁹

Although these data were not sufficiently robust to identify causal effects of piece rate pay on health, the analyses highlighted statistically significant associations between piece rate pay and worker health limitations, most notably among the susceptible subgroup categories.

Conclusion

This study is the first to explore the effects of piece rate on worker health outcomes in a large and representative longitudinal panel of US workers across sectors. The results suggest that a worker's health suffers as a result of piece rate compared with salaried work, especially for vulnerable subgroups of the US workforce. In fact, the results show little to no impact of piece rate for the non-susceptible segments of the working population, with the entirety of the effect borne by low-income, female, and non-white workers. Further research is needed to understand why these workers suffer worse health outcomes than their more advantaged peers and to identify the underlying reasons why piece rate increases health problems in already vulnerable worker groups.

The results of this research provide suggestive evidence of increased healthcare costs for workers subject to piece rate by way of declining health. Although performance pay schemes are generally understood to be revenue promoting, the impact on profits that include costs related to worker health, declining performance, and absenteeism deserve further review. Incentive-based pay schemes such as piece rate should be evaluated in terms of their health-limiting effects on the workforce and not just by increased efficiency measures. Further research is needed to determine best practices around piece rate and profits, as this type of performance pay may represent a lose-lose scenario for both workers and businesses.

Future research efforts should also be guided toward directly testing the pay-health relationships observed in this historical analysis of long-term trends on modern-day gig and contract workers. Analysis of data on modern-day gig and piece rate contract workers would reveal differences in trends critical to understanding the impact of piece rate pay in the transitioning US service economy. One potential difference worthy of further review is whether the types of workers who self-select piece rate work has changed over time; for example, if more disabled workers opt into the modern-day gig economy because of the flexibility and other amenable characteristics of the contract work setting, this will alter the observed relationship between performance pay and worker health. In this case, it would be important to look at variables such as disability status among other critical differences to properly control for worker self-selection and sorting to identify the relationship of pay type on health.

In summary, this research provides historical evidence to suggest that piece rate work has negative implications for US workers, particularly women, minorities, and the working poor. This article provides an underlying rationale for how these results might be extended to the gig economy; however, more work in this area is needed to understand and relate these results to modern-day work practices.

Author statements

Ethical approval

This study protocol and protection of subject confidentiality was approved by the Tufts Institutional Review Board and the Bureau of Labor Statistics.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

M.D. was responsible for the study design, data analysis, writing, and revision of the manuscript. E.H. contributed to data collection, data analysis, and manuscript revision. All authors have read and approved the final version of this manuscript.

Data statement

Although the NLSY79 data set is publicly available, location characteristics used to assign region to workers in this study are confidential.

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Appendix

Table A-1 – Effect of piece rate on the odds of worker health limitations including health insurance.

Variable	Full model	Not low wage	Low wage	Male	Female	White	Non-white
Piece rate	1.80* (1.15–2.79)	1.66 (0.52–5.36)	1.78* (1.10–2.88)	1.82 (0.91–3.64)	1.80* (1.01–3.23)	1.47 (0.78–2.75)	2.13* (1.15–3.94)
Health insurance	0.97 (0.77–1.22)	0.51 (0.23–1.14)	1.02 (0.80–1.30)	1.06 (0.74–1.53)	0.92 (0.67–1.25)	0.89 (0.63–1.27)	1.06 (0.77–1.45)
Age	1.07** (1.02–1.12)	1.07 (0.96–1.19)	1.08** (1.03–1.14)	1.10* (1.02–1.20)	1.04 (0.98–1.11)	1.10** (1.03–1.18)	1.04 (0.97–1.11)
Manufacturing job	0.92 (0.71–1.17)	0.68 (0.37–1.25)	0.98 (0.75–1.27)	0.84 (0.58–1.21)	0.96 (0.68–1.35)	0.88 (0.62–1.25)	0.97 (0.68–1.03)
Tenure at primary job	0.96** (0.94–0.98)	0.99 (0.95–1.04)	0.96** (0.93–0.98)	0.98 (0.94–1.01)	0.95** (0.92–0.98)	0.93** (0.90–0.96)	1.00 (0.97–1.03)
Hours worked per week	0.99* (0.98–1.00)	0.97** (0.95–0.98)	0.99 (0.98–1.00)	0.97** (0.96–0.99)	0.99 (0.98–1.01)	0.99* (0.97–1.00)	0.99 (0.97–1.00)
Self-employed	1.44* (1.02–2.02)	1.20 (0.55–2.62)	1.48 (1.01–2.16)	1.32 (0.79–2.19)	1.55 (0.98–2.45)	1.61* (1.03–2.52)	1.28 (0.76–2.17)
Education	0.90** (0.85–0.95)	1.01 (0.91–1.12)	0.89** (0.84–0.94)	0.91* (0.84–0.98)	0.89** (0.84–0.96)	0.88** (0.82–0.95)	0.91** (0.85–0.97)
Non-white	0.78* (0.62–0.99)	0.74 (0.44–1.25)	0.78 (0.61–1.00)	0.70 (0.48–1.02)	0.82 (0.62–1.10)	N/A N/A	N/A N/A
Male	0.70** (0.54–0.90)	0.65 (0.37–1.13)	0.75 (0.57–0.98)	N/A N/A	N/A N/A	0.75 (0.52–1.09)	0.67* (0.47–0.94)
Low wage	1.72** (1.35–2.19)	N/A	N/A	2.31** (1.61–3.32)	1.33 (0.96–1.85)	1.53* (1.10–2.11)	2.02** (1.38–2.95)
Exercise (2002)	0.51** (0.41–0.65)	0.40** (0.23–0.70)	0.55** (0.44–0.71)	0.36** (0.24–0.52)	0.67** (0.50–0.88)	0.44** (0.31–0.61)	0.61** (0.45–0.84)
Diet (2002)	1.40** (1.11–1.76)	1.50 (0.91–2.49)	1.39** (1.08–1.77)	1.35 (0.93–1.97)	1.39* (1.05–1.86)	1.57** (1.13–2.18)	1.21 (0.89–1.66)
Smoker (1998)	1.65** (1.31–2.10)	2.24** (1.25–4.01)	1.55 (1.21–1.99)	1.63* (1.12–2.38)	1.64** (1.21–2.22)	2.02** (1.43–2.87)	1.29 (0.92–1.79)
N (observations)	22,653	7,880	14,773	11,088	11,565	11,912	10,741
N (individuals)	6,086	2,989	4,922	2,892	3,194	3,179	2,907

Odds ratios reported, 95% confidence interval in parentheses; model controls for survey year and census division (results not reported); **P < 0.01, *P < 0.05.

Table A-2 – Cumulative effect of piece rate on the odds of worker health limitations including health insurance.

Variable	Full model	Not low wage	Low wage	Male	Female	White	Non-white
Piece rate (ever any)	1.38 (0.98–1.93)	0.71 (0.30–1.68)	1.48* (1.04–2.11)	1.10 (0.66–1.84)	1.73* (1.10–2.71)	0.81 (0.48–1.39)	2.08** (1.35–3.20)
Health insurance	0.96 (0.76–1.21)	0.51 (0.24–1.10)	1.01 (0.80–1.29)	1.04 (0.73–1.49)	0.91 (0.67–1.23)	0.84 (0.60–1.19)	1.10 (0.80–1.49)
Age	1.06* (1.01–1.12)	1.08 (0.97–1.20)	1.08** (1.02–1.13)	1.10* (1.02–1.19)	1.04 (0.98–1.10)	1.10** (1.02–1.18)	1.04 (0.97–1.11)
Manufacturing job	0.93 (0.72–1.19)	0.67 (0.37–1.23)	1.00 (0.77–1.30)	0.81 (0.56–1.16)	0.99 (0.71–1.38)	0.91 (0.64–1.29)	0.97 (0.69–1.38)
Tenure at primary job	0.96** (0.94–0.98)	0.99 (0.95–1.03)	0.95** (0.93–0.98)	0.97 (0.94–1.01)	0.95** (0.92–0.98)	0.93** (0.90–0.96)	0.99 (0.96–1.03)
Hours worked per week	0.98** (0.97–0.99)	0.96** (0.94–0.98)	0.99* (0.98–1.00)	0.97** (0.96–0.98)	0.99 (0.98–1.01)	0.98** (0.97–1.00)	0.99 (0.97–1.00)
Self-employed	1.45* (1.06–1.97)	1.18 (0.57–2.46)	1.50* (1.07–2.12)	1.38 (0.87–2.19)	1.48 (0.97–2.26)	1.55* (1.03–2.35)	1.35 (0.84–2.17)
Education	0.90** (0.85–0.94)	0.99 (0.89–1.10)	0.89** (0.84–0.94)	0.90** (0.83–0.97)	0.89** (0.83–0.95)	0.88** (0.81–0.94)	0.91** (0.84–0.97)
Non-white	0.76* (0.61–0.96)	0.76 (0.45–1.28)	0.75* (0.59–0.96)	0.68* (0.47–0.98)	0.80 (0.60–1.08)	N/A N/A	N/A N/A
Male	0.70** (0.54–0.90)	0.69 (0.39–1.20)	0.74* (0.57–0.97)	N/A N/A	N/A N/A	0.79 (0.54–1.14)	0.64* (0.45–0.90)
Low wage	1.75** (1.37–2.22)	N/A	N/A	2.25** (1.59–3.19)	1.40* (1.00–1.96)	1.65** (1.20–2.28)	1.92** (1.32–2.80)
Exercise (2002)	0.52** (0.41–0.65)	0.39** (0.22–0.68)	0.56** (0.44–0.71)	0.36** (0.25–0.52)	0.67** (0.50–0.89)	0.44** (0.32–0.61)	0.61** (0.45–0.84)
Diet (2002)	1.39** (1.11–1.75)	1.49 (0.91–2.46)	1.37* (1.07–1.75)	1.40 (0.97–2.03)	1.37* (1.03–1.82)	1.59** (1.15–2.21)	1.18 (0.86–1.61)
Smoker (1998)	1.63** (1.29–2.07)	2.09* (1.17–3.73)	1.54** (1.20–1.97)	1.65** (1.14–2.38)	1.58** (1.17–2.15)	1.87** (1.32–2.63)	1.37 (0.98–1.90)
N (observations)	23,156	8,051	15,105	11,416	11,740	12,219	10,937
N (individuals)	6,102	3,023	4,972	2,900	3,202	3,188	2,914

Odds ratios reported, 95% confidence interval in parentheses; model controls for survey year and census division (results not reported); **P < 0.01, *P < 0.05.