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Abstract
We estimate the labor supply curve for long-haul truck drivers in the United States, applying ordinary least squares regression to a survey of truck drivers in the United States. We start with the standard model of the labor supply curve and then develop two novel extensions of the standard model, incorporating pay level and pay method, testing the target earnings hypothesis. We distinguish between long-haul and short-haul jobs driving commercial motor vehicles. Truck and bus drivers choose between long-distance jobs requiring very long hours of work away from home and short-distance jobs generally requiring fewer hours. The labor supply curve exhibits a classic backward bending shape reflecting drivers' preference to work until they reach target earnings. Above target earnings, at a "safe rate" for truck drivers, they trade labor for leisure; they work fewer hours, leading to greater highway safety. While other research has shown that higher paid truck and bus drivers are safer, this is the first study showing why higher paid drivers are safer. Drivers work fewer hours at a higher pay rate and likely have less fatigue. Pay rates also have implications for driver health because worker health deteriorates as working time exceeds 40 hours.

Keywords:
labor supply curve, long distance truck drivers, working hours, pay rates, pay methods, piece rates, compensation, truck driver safety, labor/leisure tradeoff, labor markets

Introduction

More than a decade and a half after the creation of the Federal Motor Carrier Safety Administration (FMCSA) within the U.S. Department of Transportation (USDOT), trucking safety remains important public policy. While fatalities in truck crashes declined from 0.363 per 100 million vehicle miles traveled (VMT) to 0.138 fatalities per 100 million VMT between 1975 and 2014, on average 11.4 people die every day in truck crashes (Large Truck and Bus Crash Facts [LTCBF] 2014, Table 1).[1] The truck fatality trend follows the passenger vehicle trend closely: automobile fatalities declined from 3.25 to 1.05 per 100 million VMT (LTBCF 2014, Table 5). Because of the difference in mass, truck-car crashes are more likely to involve high negative consequence for automobile passengers. While fatal truck crashes declined 28% from 2001 through 2010 and fatal truck crashes declined 48% per million VMT, fatal crashes have risen 8% per million VMT since then (LTBCF 2014, Figures 1 and 2).

Larger and heavier trucks, increased congestion, and just-in-time (JIT) delivery have all been considered as possible explanations for the number of crashes and deaths related to trucking (Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health et al., 2016: 34). Research also has focused on nighttime driving, driver fatigue, and increases longer truck trips. Little effort, however, has focused on the effects of competition on freight rates, and compensation on truck driver working hours. This study explains how compensation influences work hours in the trucking industry, influencing safety outcomes.

[1] https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2014#A3.

Previous research on commercial safety has focused on the immediate mechanisms influencing certain driver behaviors, taking an engineering or behavioral approach. The engineering approach examines road configuration, vehicle dynamics, and safety technologies. Behavioral studies focus on speeding, driving long hours, and fatigue rather than on economic motivations, as if truck drivers speed and drive long (and often illegal) hours just because they are greedy or because they have a preference for speeding and other reckless behavior. This research shows how driver compensation influences long work hours and tests the target earnings hypothesis theoretically and empirically, providing a rational explanation for why they work long hours.

Literature

Yellen hypothesizes that an employer paying higher than average wages will discourage workers from shirking, since losing their job imposes a cost on workers. She argues that if the cost of monitoring workers is higher than the cost of higher wages, the "efficiency" wage can help employers elicit greater effort from workers (Yellen, 1984).

In addition to compensation level, the type of payment can also influence behavior. "Piecework" rates in trucking provide an incentive for workers to increase their effort (Prendergast, 1999). While the efficiency wage argument appeals to the worker's long run interest to maintain employment, the piecework system creates a short run incentive to increase production by paying the most productive workers higher earnings, leading to longer hours than other similarly situated workers.

Piecework pay has been the norm in long-haul trucking for decades (Levinson, 1980) and in road transport more generally for hundreds of years (for example, see Gerhold, 1993). Most intercity drivers in both truckload (TL) and less-than-truckload

(LTL) trucking are paid by the mile or by the load, rather than hourly (Burks et al., 2010). In North American trucking, length-of-haul (mileage) often is the sole determinant of compensation. Drivers frequently wait long periods for their loads, and in many cases must load or unload their own freight. This non-driving time generally goes underpaid or unpaid, relative to driving time; the tension between piecework pay and speed limits encourage drivers to work unusually long hours in order to reach earnings targets (Belzer, 2000).

While these compensation practices may elicit more work effort from drivers, such practices may create incentives encouraging behaviors negatively influencing safety-related outcomes and attract workers with few labor-market alternatives. Such behaviors may include speeding, taking safety shortcuts, neglecting safety inspections, working illegally long hours, and neglecting repairs; TL drivers regularly work between 90 and 100 hours per week, even though the legal limit is around 60. Drivers may work these long hours simply by recording unpaid non-driving labor off duty, and electronic logs may be set to record driving only when a truck exceeds 5 miles per hour, thus allowing the driver to work (and drive) while remaining logged off duty (Viscelli, 2016). In addition, FMCSA regulations changed in 2004, reducing the effectiveness of the seventy-hour-per-eight-day-week working time limit (designed to give over-the-road truck drivers a longer weekly break) by allowing truck drivers who reach their seventy-hour limit to re-set their weekly hours to zero after taking a 34-hour break (the "34-hour restart"). This allows drivers to log as many as 84 hours in a seven-day week (Saltzman and Belzer, 2007), though drivers usually just log non-driving labor off duty. While long hours may provide short-run economic benefit to individual drivers or carriers, in the long run drivers to supply excessive labor to the marketplace for a fixed number of workers, reducing wages and encouraging illegal and dangerous hours of work.

In 1990, the National Transportation Safety Board called for a review of trucking industry structure, operations, and conditions that may create incentives for drivers to violate hours of service (HOS) regulations and use drugs (National Transportation Safety Board - U.S. Department of Transportation, 1990). In 1995, a study raised questions about the influence of pay policies on truck driver fatigue and suggested a possible link between compensation method and fatigue-related crashes (National Transportation Safety Board - U.S. Department of Transportation, 1995).

Research has shown that pay levels may motivate long driving hours and illegal substance use, contributing to fatigue (Hensher et al., 1991; General Accounting Office - U.S. Congress, 1991; Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health et al., 2016: 34-36). Forty-five percent of respondents to a New York State survey thought hourly pay would reduce driver drowsiness (McCartt et al., 1997). Focus groups believe per-mile compensation limits income and encourages cheating (Cadotte et al., 1997; Mason Jr. et al., 1991). Piece rate systems, when coupled with enforceable HOS regulations, limit the income opportunities of drivers (Chatterjee et al., 1994).

Monaco and Williams found that occupational characteristics, not demographics or education, predict truck crash rates. A probit analysis of the University of Michigan Trucking Industry Program (UMTIP) driver survey data determined that higher driver pay rates and hourly pay predicted that drivers had a lower probability of having been involved in a crash during the previous year or a having had a logbook violation over the previous 30 days. Those paid percentage of revenue—a combination of revenue miles hauled plus the market value per mile of that freight movement—had the highest rate of HOS violations and crashes (Monaco and Williams, 2000).

While scholars have documented the safety consequences of long work hours in many industries and particularly in trucking, theoretically grounded, empirically validated studies have been lacking. Similar problems have beset research on health consequences of long hours. Dembe and colleagues conducted a number of studies using the National Longitudinal Survey of Youth in the United States and found a strong association between long and irregular work hours and occupational injury and illness, as well as negative employment consequences (Dembe *et al*., 2005, Dembe *et al*., 2006; Dembe *et al*., 2007). A study of medical interns showed that exceptionally long hours were associated with fewer "attentional errors" (Lockley et al., 2004). Several Australian studies have shown the association between long work hours and safety and health problems in long-distance trucking (Mayhew and Quinlan, 2006) as well as in short-haul trucking (Williamson et al., 2009) and the same has been shown in the U.S. (Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health et al., 2016). However, research has not shown clearly why long haul drivers work such extremely long hours. Are they actually greedy for as many hours of work—and miles—as they can get, or do they have a target earnings level they need to reach to pay their bills, and turn down work once they reach that target? We suggest here that truck drivers who choose long-haul work do so to achieve earnings targets they probably could not reach any other way.

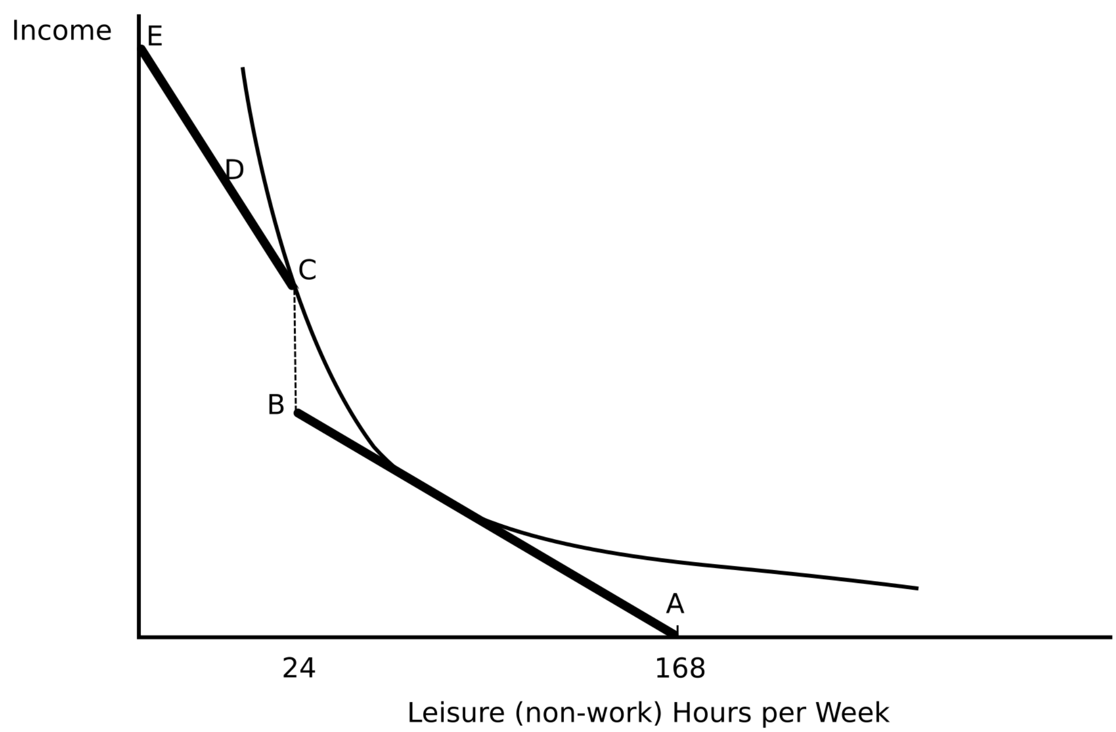
Theory

We divide our theoretical discussion into three parts. First, we discuss a standard model of labor supply, modified to account for the particular constraints faced by a long-haul driver paid by distance. This model allows us to specify the economic incentive effects of piece rates compared with time rates. Second, we consider a series of models stylizing the employment relationship somewhat differently than our basic model. These models capture different aspects of the complex causal structure of jobs than our standard model. These models differ from our standard one because they represent situations in which the employee receives a higher net wage than that offered by the next best alternative. Third, we consider a model that describes how unpaid time can create an incentive for drivers to work in excess of the hours of service regulations.

The standard model of the labor supply curve

The standard model implicitly assumes that we observe an equilibrium in which straightforward economic factors such as differences in the productivity of employees, or in the positive or negative non-pecuniary rewards of the particular job, explain pay differences. Given the high turnover in trucking, we start with a model that assumes workers are indifferent between the current job and the next best alternative. HOS regulations allow drivers fourteen hours between the start and end of a shift. After fourteen hours, drivers must take at least ten hours off before resuming driving. Since the individual consumes both leisure time and income, we measure leisure time on the horizontal axis and income on the vertical. An hourly worker can choose a point anywhere on the budget constraint represented by the line segment A-B. However, those willing to work at least six days per week, away from home for weeks, may earn higher income. The segment C-D-E represents this constraint. To earn the higher annual income offered by long-haul trucking, drivers must work the long hours the job requires. Drivers can choose jobs with more time off (such as short-haul) but lower income. The indifference curve that passes through point C shows those workers who are indifferent to taking the lower income of hourly employment and the higher pay and longer hours of long-haul trucking. In this case, no rents are earned, since workers are indifferent between working in the trucking industry and working as hourly production workers in another industry. However, those workers who wish to work even more hours can choose to do so, and will choose a point such as D in trucking—a point that exceeds the legal limit.

Figure 1



Extensions of the standard model: Pay level

While this model explains why some workers choose employment in long-distance trucking, it does not address the relationship between the level of pay and driver behavior. Why might higher mileage rates induce workers to become more safety conscious? The efficiency wage gives workers the incentive to work more safely when behavior is difficult to monitor directly. For example, a firm concerned about the number of crashes and violations might pay above market wages to its drivers to encourage safety for at least two reasons. First, drivers failing to meet the firm's safety requirements lose these above market wages, causing the drivers to focus on safety. Second, efficiency wages would attract safer drivers to the firm since these drivers would be rewarded for safety, while reducing turnover. Efficiency wages thus reduce crashes and violations. As long as the value of reduced crashes and greater productivity is greater than the cost of paying the efficiency wage, the rational firm will pay efficiency wages.

Another example involves regulation. The forty-hour standard workweek (and time-and-one-half for overtime) prescribed by the Fair Labor Standards Act (FLSA) in the United States does not apply to safety-related employees of interstate trucking companies (Belzer, 2000). While the FLSA's minimum wage requirements do apply, because truck drivers self-report non-driving labor and because low pay rates in trucking give truck drivers an incentive to work unusually long hours, a regulatory requirement to pay drivers for all of their work time might create an incentive to work fewer hours. Even with electronic logbooks, drivers systematically violate the HOS maximum labor time regulation because non-driving labor time requires self-reporting and drivers' economic incentives run counter to long-term safety and health policy (Viscelli, 2016).

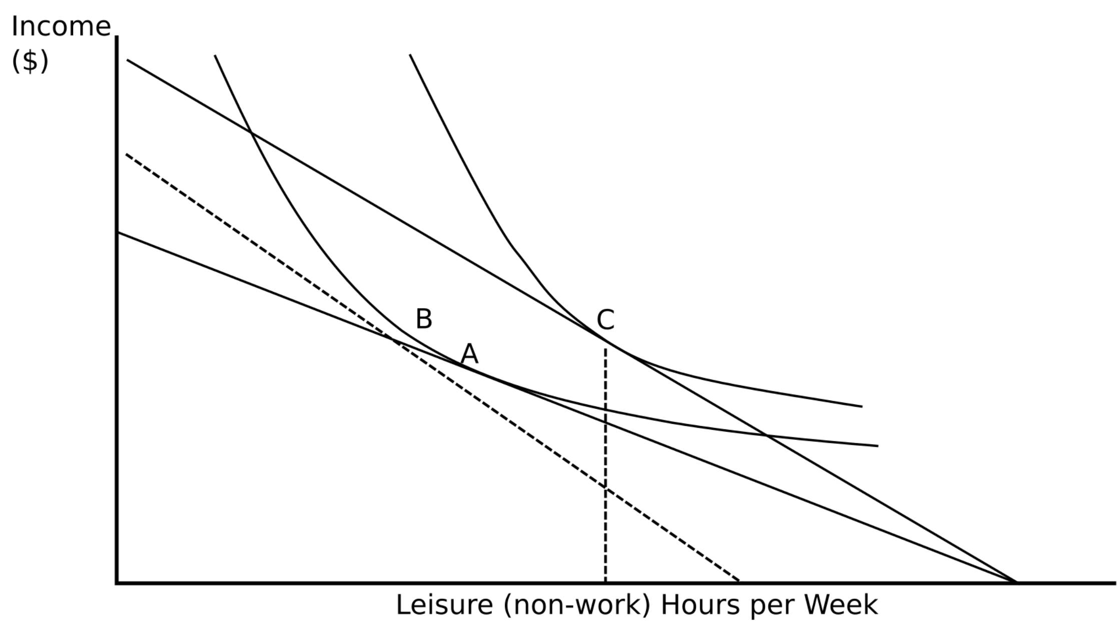
Workers also might have a ‘target’ income and higher compensation might induce them to be more safety conscious than they would be otherwise (Camerer et al., 1997). Drivers who cannot reach this target income without violating HOS regulations have an incentive to exceed them. A higher mileage rate would allow these drivers to reach their target income after fewer hours of work.

This incentive can exist even if the target income hypothesis is not true, since higher incomes mean a higher level of utility. As long as the additional utility from income is greater than the disutility of working, offset by the threat of detection and the expected cost of paying the fine for violation or losing their job, drivers have an incentive to work additional hours. On the other hand, higher pay rates can reduce this incentive, regardless of whether the target income hypothesis is applicable, if their current job is better than the alternative. If drivers have a target income, higher pay rates will allow them to satisfy these targets without increasing their hours to dangerous levels.

Extensions of the standard model: Method of pay

For those drivers without target earnings, higher pay also reduces the incentive to work additional hours as long as the income effect of this increase is larger than the substitution effect. However, if the substitution effect is larger, a higher pay rate would lead to greater hours worked. This ambiguous theoretical prediction provides the basis for a testable hypothesis regarding the actual response of drivers to changes in pay rates. Figure 2, Extension of the Standard Model, shows the case where a higher pay rate leads to fewer hours worked. In this instance, the substitution effect of greater compensation rates causes the driver to increase hours worked from A to B, while the income effect reduces these hours from B to C. Since the reduction in hours worked due to the income effect is larger than the increase due to the substitution effect, the net effect is to reduce hours worked. In this case, however, workers may make more money for fewer hours of work. Therefore, a higher driver pay rate can reduce the incentive to work beyond the HOS regulations, regardless of whether the target income hypothesis holds true, leading to greater safety performance.

Figure 2

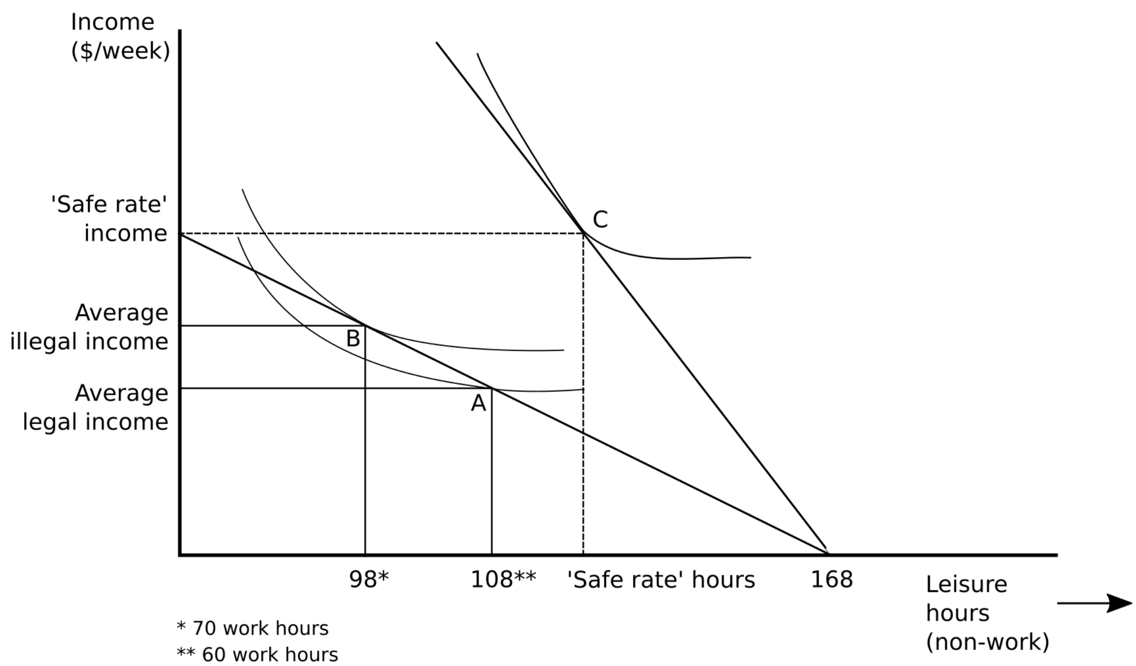


A-B Increase Work (Substitution Effect)
B-C Decrease Work (Income Effect)
A-C Total Effect — Decrease work since income effect is greater than the substitution effect

The common practice to either underpay or pay nothing for non-driving time also influences driver behavior. Unpaid time spent loading, unloading, and waiting represents a significant proportion of working time, according to results from the UMTIP Drivers Survey as well results from a National Institute for Occupational Safety and Health (NIOSH) survey (CHEN Guang X. et al., 2015). Drivers who are unpaid or underpaid for non-driving labor have an incentive to underreport this unpaid time to conserve driving hours.

Figure 3 shows hours of leisure, measured from left to right, and working hours, measured from right to left on the horizontal axis; compensation appears on the vertical. Assuming legal logging, for a given amount of unpaid time (U*), drivers have a certain limited amount of legal driving and working time, indicated by the vertical line through point A. This determines a driver's maximum level of income. If at this point the compensation for an additional hour of driving is higher than the marginal rate of substitution of money for time, then drivers would prefer to work more hours. They can do this by not reporting some of the time spent unloading, which allows drivers to spend more time on the road. This incentive exists even if there is some compensation for non-driving labor time, as long as it is less than the amount paid for driving.

Figure 3



The fact that most drivers either are paid by the mile or earn a percentage of revenue creates an incentive for drivers to violate the HOS regulations. Drivers earn the same amount for a given load, regardless of hours worked. If traffic, weather, or other delays cause the trip to take extra time, drivers have a strong incentive to work additional hours to reach target earnings.

Payment by "percentage of revenue" compounds the piecework earnings problem. If the supply of trucks and drivers is loose, competition for freight also drives down rates. Since it is hard to verify non-driving delays, drivers may work extra hours without fear of detection. The ease with which drivers hide non-driving hours by logging off duty heightens the competition and squeezes drivers to work more for lower effective rates.

This problem remains significant even when carriers adopt electronic logbooks. While the electronic logbook reliably records when the truck is moving, it does not show what the driver is doing when the truck is stopped; this requires driver self-report.

While point B shows fewer hours worked than point A', it represents more total hours, since the total reported hours, offset by those not reported, are at point B. Point A' indicates the utility maximizing point for 'desired' hours worked. Since these delays are difficult to verify, drivers may work extra hours without fear of detection. With FMCSA's permissive regulations regarding logging non-work labor time, incentives for truthfulness remain weak even when drivers use electronic logbooks.

The tradeoff between pay rate and work hours

Why are hours of work important for truck and bus drivers? Many studies have found a relationship between fatigue and crash rates. Lin *et al*. use 1984 data from an LTL firm to show that accident rates increase with the number of continuous hours driven (LIN Tsuoo-Ding et al., 1993), while McCartt *et al*. provide similar results from a survey of truck drivers in New York State (McCartt et al. 1997). Beilock used a survey of drivers at Florida inspection stations to show that tight schedules induced drivers to either violate speed limits or violate the HOS regulations (Beilock, 1994). In a similar study, Hertz estimated that 51% of observed drivers violated these regulations (Hertz, 1991). A 2010 NIOSH survey showed violations continue at a high rate even after HOS regulations were relaxed substantially (CHEN Guang X. et al., 2015). Since HOS regulations were created to reduce driver fatigue, it is important to determine the factors that create an incentive for drivers to violate these regulations (Panel on Research Methodologies and Statistical

Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health et al., 2016).

Methods

We establish the applicability of the labor/leisure tradeoff in trucking by estimating a labor supply curve. The truck driver labor/leisure tradeoff establishes a foundation for understanding the extent to which industrial work-process organization and driver compensation contribute to truck drivers' propensity to work much longer hours every week than typical non-driving production workers, and by extension, the tendency to accumulate fatigue resulting from chronic long hours. Previous research has established the link between long hours and fatigue, as well as extent to which safety and health problems arise from these long hours (Dembe et al., 2005; Dembe et al., 2006; Dembe et al., 2007; Dembe et al., 2004; Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health et al., 2016).

Labor Supply Curve Estimation

We estimate the determinants of the number of driver weekly work hours—particularly, the relationship between mileage rates and work hours. Since it is reasonable to assume that hours might be determined in part by some of the same random components that influence mileage rates, we cannot estimate this relationship directly. We use a two-step procedure, first estimating the mileage rate for each driver, and then using the fitted values of the mileage rate to estimate the weekly hours equation.

We estimate each equation using ordinary least squares (OLS). The general form of the model can be written as:

$$Rate_i = \beta_1 + \beta_2 X_{i2} + \beta_3 X_{i3} + \ . \ . \ . \ \beta_K X_{iK} + \varepsilon_i$$

where $Rate_i$ is the mileage rate for the i^{th} driver, the X's represent characteristics of the driver and job that are relevant to determining the mileage rate, and the β's are the parameters to estimate. The term ε summarizes the random components and unobserved characteristics of the individual driver and job.

We divide the variables used to estimate the mileage rate equation into two groups. The first group of variables summarizes the human capital characteristics of the individual driver: experience, tenure, education, union status, race, age and marital status. We use other family income to measure the importance of driving income relative to overall household income. We include the squares of experience and tenure to allow for a non-linear relationship between these variables and the mileage rate. We also allow for an interaction between race and union status, which allows the union premium to differ by race. Finally, we use drivers' previous violation record as a proxy for individual skill and performance levels.

We expect mileage rate to correlate positively with experience and tenure; a negative second order term would indicate that this premium decreases as mileage rates increase. While in most occupations we would expect a high school degree to raise the wage rate, this may not hold for truck drivers because of the low formal education requirement of truck driving. Prior research suggests that unionized and white workers would also earn more than other drivers. We hypothesize that unions would raise the mileage rate of non-white drivers by more than that of white drivers, as the earnings discrimination literature suggests unions often have an equalizing effect on the wages of non-white workers. Finally, we expect those drivers with a previous moving violation would earn a lower mileage rate.

The second group of variables captures characteristics of the firm and job. Prior research has documented that larger firms pay higher wages, *ceteris paribus*. Private carriage firms (versus for-hire firms) and firms that haul primarily dry boxes (versus temperature-controlled trailers, flat beds, and tankers, for example), might be expected to pay different mileage rates, but we cannot predict the direction of these differences in advance. Drivers with longer trips probably earn lower mileage rates since they spend a greater percentage of their time driving (and hence waste less time performing unpaid non-driving labor). Finally, we also include the amount of unpaid time and paid time off, although we cannot determine the direction of these influences in advance. Firms requiring a substantial amount of unpaid time for loading, waiting or other activities may or may not be compelled to compensate by paying a higher mileage rate, depending on the labor market pressure for drivers. Similarly, more paid holidays and longer vacations might compensate for a lower mileage rate, or they could be complementary aspects of 'good' jobs that offer better compensation generally.

Data

Data used to estimate the labor supply curve was obtained from a survey of drivers collected in 1997-1998 by UMTIP (see Belman et al., 2004). The sample includes all full-time employee drivers paid by the mile. The estimation is based on a sample of 233 employee-drivers for whom complete information was available. These drivers reported working an average of 64.49 hours per week with a minimum of 25 and a maximum of 126. Drivers earned an average of $0.286 per mile with a range from $0.13

to $0.485; on average they had 13.66 years of experience and average company tenure of 3.46 years. While the data are twenty years old, the work process and pay systems in trucking have not changed enough to make them obsolete and the economic motivations underlying truck drivers' work hours have not changed, so the econometric test of the foregoing theory remains valid. Because they were collected at the individual level, the data remain the most robust data available as of this writing. While not identical, the hours of work averages and distribution revealed in this survey in the late 1990s is consistent with more recent surveys, including one conducted by the Federal Motor Carrier Safety Administration in 2004-2005 (61.4 hours per week) and one conducted by the National Institute for Occupational Safety and health in 2010 (60 hours per week) (CHEN Guang X. et al., 2015; Federal Motor Carrier Safety Administration - U.S. Department of Transportation, 2005). Indeed, the 2010 NIOSH truck driver survey, conducted using a similar truck-stop design, shows that more than 20 percent of all drivers worked more than 75 hours per week, which is entirely consistent with the 1997 UMTIP survey used here and far greater than the stated legal limit of 60 hours per seven-day week.

Table 1. Summary Statistics, UMTIP Driver Survey of Piece Work Drivers, n = 233

Variable	Variable Definition	Mean	S.D.	Min.	Max.
Weekly Hours	Hours Worked in the week preceding the survey	64.49	18.11	25	126
Mileage Rate	$/Mile	0.286	0.055	0.13	0.485
Experience	Years of experience as a driver	13.66	10.12	1	43
Tenure	Number of years worked with current firm	3.46	4.58	0.083	30
HS Education	1 if driver completed high school, 0 otherwise	0.83	0.37	0	1
Union	1 if driver is a union member, 0otherwise	0.08	0.27	0	1
White	1 if driver is white, 0 otherwise	0.86	0.35	0	1
Age	Age of driver	42.18	9.51	22	64
Married	1 if driver is married, 0 otherwise	0.69	0.46	0	1
Other Income ($1000)	Other family income	46.98	18.88	0	120
Moving Violation	1 if driver received a violation in the past year, 0 otherwise	0.25	0.43	0	1
Medium Firm Size	1 if firm has between 100 and 500 drivers, 0 otherwise	0.33	0.47	0	1
Large Firm Size	1 if firm has more than 500 drivers, 0 otherwise	0.34	0.48	0	1
Private Carriage	1 if firm is private carriage, 0 otherwise	0.14	0.34	0	1
Dry van	1 if driver pulls primarily dry vans, 0 otherwise	0.65	0.48	0	1
Miles per Dispatch	Number of miles in the average dispatch	858.01	619.75	144.14	3500
Unpaid Time Per Mile	Average amount of unpaid time per mile driven, in minutes	0.23	0.4	0	3
Paid Days Off	Number of paid holidays, sick and vacation days per year	13.7	8.4	0	35
% Night Driving	Percent of driving hours between 11:00 PM and 7:00 AM	0.22	0.21	0	0.75
% Non-Driving	Percentage of time spent in activities other than driving	0.19	0.17	0	0.89
Last Home	Number of days since the driver was at home	8.46	12.74	0	90

Pay rates in current U.S. dollars, 1997-1998.
$1.00 in 1997 was the equivalent of $1.50 in 2016.

Several variables are categorical. Union members account for 8% of the sample, 86% are white, 25% have had a moving violation in the past year, while 33% work in a ‘medium’ sized firm (between 100-500 workers) and 34% work in ‘large’ firms with more than 500 workers. Fourteen percent of drivers work in the private carriage segment of the market and 65% haul dry boxes. This sample may be biased toward larger for-hire firms because these drivers more likely are employees and because private carriage represents roughly half of all trucking, but the implications for this study are unknown.

The average miles per dispatch is 858 with a standard deviation of 619.75; we attribute the extent of variation to the wide variety of operations in the trucking industry. On average, drivers spend about 0.23 minutes in uncompensated activities per mile driven. Given the average of 858 miles per dispatch, this means that the median trip includes about 197 minutes of uncompensated labor time. At the other end of the spectrum, the median driver receives 13.7 paid holiday, vacation and sick days per year, with a minimum of zero and a maximum of 35.

Drivers average 42.18 years old and 69% of them are married. The variable 'other income' is the measure of total family income less the income earned from driving. This can include income earned by other family members or by the driver in other occupations. The mean value is $46,980 with a standard deviation of $18,880. Finally, 22% of driving occurs at night (between the hours of midnight and 6:00 a.m.) and 19% of the typical driver’s time is spent in non-driving activities. The typical driver last slept at home 8.46 days prior to the interview.

Results

Mileage Rate Estimation

Table 2 reports the results of the mileage rate equation. Returns to tenure and experience are statistically significant at the 5% level, as is the squared value of tenure. This means that an additional year of tenure at the mean (3.46 years) adds one percent to the average mileage rate. However, an additional year of experience (holding tenure constant) has a negligible effect. Union members can expect to earn almost $0.10 per mile more than non-union drivers, and this estimate is also significant at the 5% level. The returns to education are insignificant. White workers can expect to earn $.016 per mile (5.7%) more than others. In addition, the interaction of race and union status is not significant, indicating that the union premium is similar for all drivers, regardless of race.

Table 2. Mileage Rate Equation

Variable	Estimate	Standard Error	t-value
Constant	0.241***	0.016	14.918
Experience	0.002**	0.001	2.133
Experience^2	-4.1E-05	0.000029	-1.437
Tenure	0.004**	0.0017	2.049
Tenure^2	-0.00011**	0.000054	-1.972
HS Degree	0.000574	0.008	0.076
Union	0.097**	0.057	1.726
White	0.016**	0.008	1.858
Union by White	-0.04	0.058	-0.695
Previous Moving Violation	0.007	0.007	1.051
Medium Firm	0.013**	0.006	2.065
Large Firm	0.026***	0.009	3.164
Private Carriage	-0.020	0.010	-1.900
Dry van	-0.008	0.007	-1.221
Miles per Dispatch	-0.00002***	0.000006	-3.276
Unpaid Time	-0.010	0.008	-1.192
Paid Days Off	0.001**	0.0004	2.071

Sample Size	233	Dependent variable:	Mileage Rate
R-squared:	0.385	Rbar-squared:	0.340
Residual SS:	0.431	Std error of est:	0.045
F(16,216):	8.457	Probability of F:	0.000

Firm-level characteristics offer a great deal of insight into differences in driver compensation. Drivers working for large firms earn significantly more than those in smaller firms, similar to what research on firm size has shown generally (Bayard and Troske, 1999; Brown and Medoff, 1989). In addition, workers with more paid time off also earn higher mileage rates, indicating that 'good jobs' reward workers not just by paying higher wages, but with other forms of compensation as well. Drivers with longer dispatches earn less per mile than those with shorter dispatches. However, neither of these raises mileage rates substantially.

Weekly Hours Estimation

The weekly hours equation can be written as:

$$Hours_i = \gamma_1 + \gamma_2 * W_i + \gamma_3 W_i^2 + \gamma_4 Z_{i4} + \ldots \; \gamma_K Z_{iK} + \varepsilon_i$$

where $Hours_i$ are the weekly hours of the i^{th} driver, and W_i is the fitted wage of the i^{th} driver from the regression estimates described above. The Z's represent characteristics of the driver and job that influence the number of hours worked, while ε_i captures the random components of the hours worked not included in the explanatory variables.

To estimate the weekly hours equation, we must provide instruments that include variables in the mileage rate equation but do not determine hours of work. We hypothesize that experience, education, and race will influence wages, but not hours. Finally, we do not include the size of the firm and the type of trailer in the hours equation.

We include both the fitted wage and its square in the regression. This allows the influence of the wage rate to decrease, and even allows for the possibility of a 'backward bending' supply curve where higher wages can cause a decrease in hours worked. Other variables included in the regression are age (and its square), marital status and other income. We also consider characteristics of the firm and job that might influence hours worked. These include the percentage of night driving, the percentage of time spent in non-driving activities, the amount of unpaid time, and paid days off, as well as union status, length of dispatch, private carriage and tenure. Finally, the variable 'last home' is a measure of how long it has been since the driver has slept at home.

We report the results of the hours equation in Table 3. First, weekly hours are not estimated as precisely as the mileage rate in part because the reported hours may be measured with error, relative to the explanatory variables. Weekly hours are reported for the most recent week, but it is possible that weekly reported hours worked may over or under estimate the hours worked in a typical week. As long as these differences are not systematic, they do not bias the parameter estimates, but do make them less precise, as reflected in the results.

Weekly hours tend to increase with age, *ceteris paribus*, until the driver is about 44.6 years old, at which point they decline. Married drivers tend to work almost five fewer hours per week, suggesting that married drivers may be more willing than non-married drivers to trade personal time for labor once they have met their earnings targets, but this is significant only at the 10% level. Finally, we need to interpret the results on non-driving time. The variable 'unpaid time' measures the amount of unpaid time per mile driven. The estimate suggests that drivers who are not paid for their non-driving time tend to compensate by working longer hours, as hypothesized. The non-driving time variable measures the percentage of time that a driver spends in activities other than driving. While the negative coefficient may seem surprising, in conjunction with unpaid time, we interpret this variable to measure the effect of at least partly compensated non-driving time. We therefore are not surprised that drivers with more paid non-driving time may work fewer hours, while those who have more unpaid non-driving time may work more.

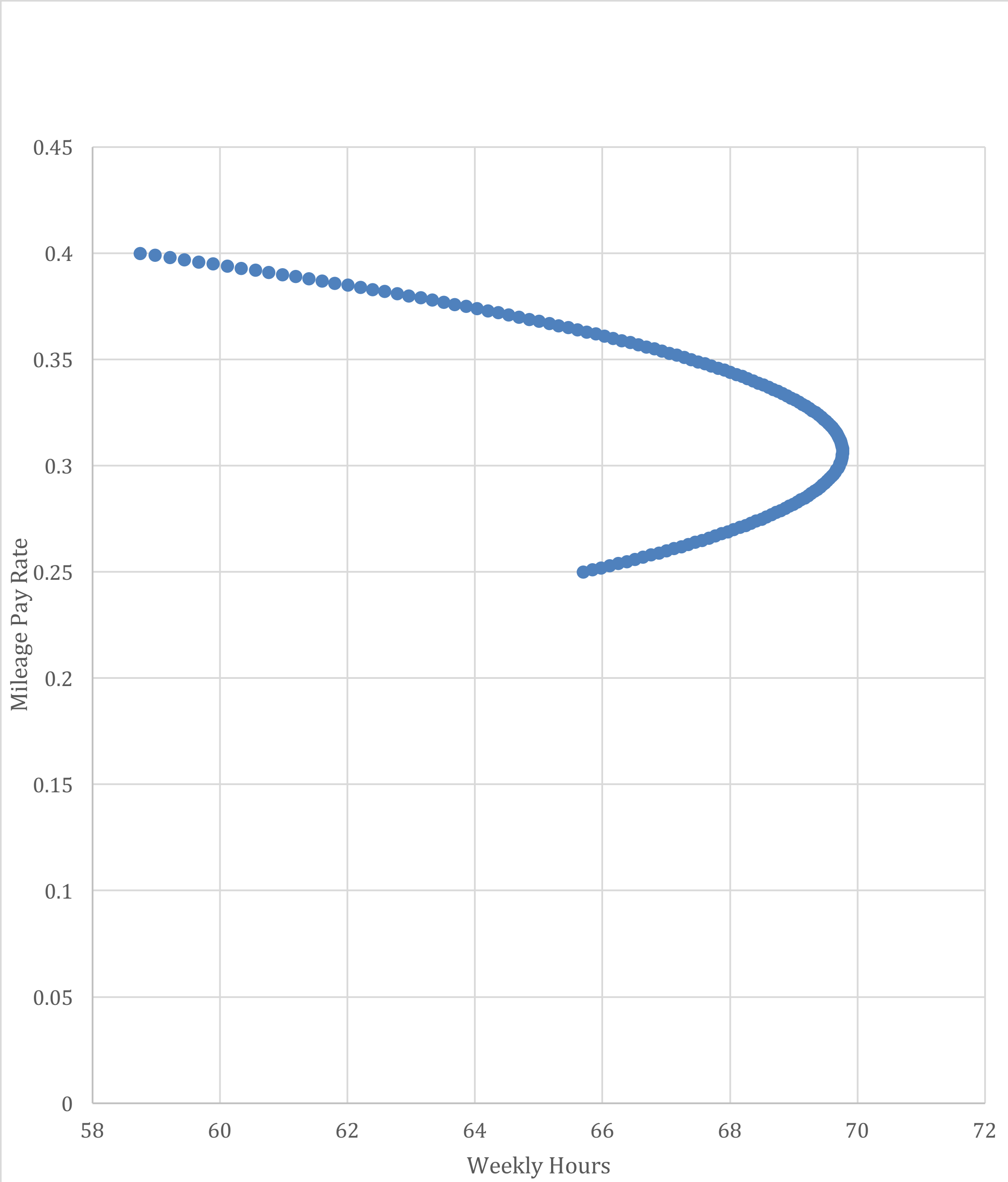
Table 3. Weekly Hours of Work Equation

Variable	Estimate	Standard Error	t-value
Constant	-116.29**	52.88	-2.199
Fitted Rate	776.75**	370.8	2.095
Fitted Rate^2	-1266.30**	637.3	-1.987
Age	3.119***	0.849	3.674
Age^2	-0.035***	0.001	-3.578
Married	-4.853*	2.548	-1.905
Other Income ($1,000)	0.021	0.067	0.348
% Night Driving	9.241	5.598	1.651
% Non-Driving Time	-21.820**	9.788	-2.229
Unpaid Time	11.066***	3.441	3.216
Union	10.842	9.372	1.157
Miles per Dispatch	0.0007	0.002	0.313
Private Carriage	-4.082	3.464	-1.178
Tenure	-0.365*	0.201	-1.820
Last Home	-0.006	0.125	-0.045

Sample Size:	233	Dependent variable:	Hours per Week
R-squared:	0.164	Rbar-squared:	0.111
Residual SS:	63611.8	Std error of est:	17.082
F (14,218):	3.061	Probability of F:	0.000

We interpret the mileage rate results as follows. The fitted value of the mileage rate and its square are significant at the 5% level, showing an overall positive influence of wages on hours, for most drivers. The positive relationship between mileage rates and hours continues until the mileage rate reaches about $0.307 per mile, at which point we estimate that further increases in the mileage rate begin to reduce weekly hours. This relationship is described in Figure 4. Note particularly the predictions of hours worked relative to the HOS regulations current at the time of the survey. For low mileage rates, increasing the mileage rate leads to an increase in hours worked. The mean rate of $0.286 provides an estimate of about 69.2 hours worked per week, with a slight increase to almost 69.8 hours for rates above the mean, up to $0.307 per mile. However, after this point, further increases in the mileage rate lead to fewer work hours, supporting the target-earnings hypothesis. Once drivers earn a high enough rate and are already working long hours, they use further mileage rate increases to 'buy' more time off rather than purchase more goods and services. It is insightful to observe that the point at which the estimated pay-rate curve crosses the 60-hour legal limit is $0.395 per mile in 1997 dollars. In 1997 J.B. Hunt Trucking, one of North America's largest TL carriers, raised truck driver compensation to an average of $0.37 per mile in a successful effort to reduce turnover and driver crash rates (Rodriguez et al., 2006). In recruiting efforts at the time, Hunt described itself as offering union-level pay rates without the union. Our estimates predict that for $0.37 per mile, drivers would reduce their weekly hours from 69.2 (at the average mileage rate of $.286 per hour) to 64.7 hours per week, and further reduce hours to 60 at the $0.395 per mile rate—very close to the top rate set by Hunt at that time.

Figure 4: Labor Supply Curve for Long-Distance Truck Drivers



Interpretations:

Rate	Hours	
$0.286	69.2245482	Sample Mean
$0.307	69.7670643	Max Hours at .3075
$0.308	69.7650398	Tipping point for reduced work hours
$0.370	64.693353	Rate set by J.B. Hunt to reduce turnover & crashes
$0.394	60.1164762	60 hours of work
$0.395	59.8941155	Rate required to reduce hours of work below legal limit

Joint decisions of drivers and firms at higher or lower rates of pay may also explain the shape of the labor supply curve. Firms paying a high rate may have a systematic preference that their drivers obey the hours-of-service regulations, while firms that pay a low rate of pay may recognize that their drivers cannot make a living without working more hours than the regulations allow, and may allow (look the other way), encourage, or coerce them to work more hours and drive more miles; this understanding may be consistent with low-rate firms' need to extract additional productivity from each truck and driver to support their businesses. The point estimates suggest that if the mileage rate were to increase to $0.395 per mile, drivers would reduce their weekly hours to the 60-hour legal limit. At this rate, drivers' compensation is sufficient for them to satisfy their income requirements without having an incentive to work more than mandated by law.

Discussion and Policy Implications

This study’s findings suggest that truck drivers work long hours because they have target earnings; that is, they need to earn a certain amount of money each week to pay their bills. For the growing number of lease-purchase drivers, who lease their trucks from motor carriers from which they obtain their freight, this pressure is especially intense (Viscelli, 2016). While truck drivers made a substantial living during the era of economic regulation and strong union bargaining power, the liberalization of trucking economic regulation and resultant de-unionization have reduced compensation by more than half; union density has declined from about 60 percent in 1977 to below 10 percent in 2017 (Hirsch and Macpherson, 2017).

This low union density and intense competition, along with changing industry structure since 1980 that intensified competition, has substantial implications for supply chains and their governance. Replacement of institutional with market regulation in the U.S., starting in 1977 administratively and institutionalized by the Motor Carrier Act of 1980 and the subsequent dissolution of the Interstate Commerce Commission and Congressional mandate of intrastate deregulation prompted intense competition (Belzer, 2000). Neoliberalism allowed cargo owners to gain substantial economic power, creating economic welfare, the economic rents from which they have captured, bringing customers lower prices while creating sweatshop conditions for commercial motor vehicle drivers (for a global analysis of unequal distribution of rents, see Milanovic, 2016). Global supply chains, driven by the power of the customer, left the transportation providers to compete with few limitations.

Various institutional actors have tried to regulate this competition. The Transport Workers Union of Australia has conducted a decades-long “comprehensive campaign” for “safe rates” and the extension of employment regulation to cover unionizeable owner-drivers, at the state and national level, dovetailing with the unique Australian industrial relations system featuring expert industrial tribunals that mandate minimum industrial practices and compensation. The TWU also incorporated a “chain of responsibility” strategy to try to match legal responsibility with the sophisticated supply chains that developed after deregulation (Kaine and Rawling, 2010). This strategy included a mechanism with which to incorporate the interests of subcontractors and precarious workers (Rawling and Kaine, 2012), since deregulation has intensified this phenomenon around the world, and particularly in the U.S. and Australia.

In response to an interest expressed by the International Trade Union Confederation, the International Transport Workers Union, the International Organisation of Employers, and the International Road Transport Union, the International Labour Office hosted a tripartite sectoral council meeting on road transport safety and health, producing a report (Sectoral Policies Department and Cruz-Ross, 2015) and the negotiations produced a resolution inferring the need for safe rates to level the playing field for motor carriers and drivers.[2] The ILO continues to grapple with these supply chain workplace regulations questions going forward and consensus on a policy response remains in development.

Perhaps the most important policy implication resulting from this research is that long-haul drivers will not have an economic incentive to reduce their working hours unless they are paid for all their work time. Truck drivers paid on a piecework basis (by the mile, by the load, or a percentage of revenue) will continue to have an incentive to record non-driving labor as off duty, which pushes them to work up to one hundred or more hours per week, depending on the number of unpaid non-driving hours embedded in their work. Although a hard cutoff is arbitrary, because evidence suggests that working more than approximately 60 hours per week substantially increases negative consequences for truck driver and public highway safety, as well as truck driver health, this research supports the safe-rates public policy advocated by employers, worker representatives, and governments as negotiated within the ILO framework.

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[2] http://www.ilo.org/sector/activities/sectoral-meetings/WCMS_337096/lang--en/index.htm; http://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/meetingdocument/wcms_458146.pdf http://www.ilo.org/sector/activities/sectoral-meetings/WCMS_337096/lang--en/index.htm

Conclusions

We derived a labor supply curve from the UMTIP Driver Survey Data. While this study is limited by the cross-sectional nature of the data, it uses the most precise sample of drivers known to exist. This curve represents a joint employer-employee decision to trade pay rates against the number of hours worked. We estimate the bundle of attributes associated with the job—the combination of pay rate and working time—and the trade-off that truck drivers make between compensation and job attributes.

Our estimates support the hypothesis that drivers have target earnings. Drivers first choose between local jobs, which more likely allow truck drivers to have more regular daily schedules and fewer work hours as well as lower total weekly earnings, and long-distance jobs that require drivers to be away from home for extended periods and work much longer hours. Once drivers are away from home for extended periods, they more likely prefer to keep working and earning as much as they can because almost all of their pay is determined by mileage (Viscelli, 2016); see the extension of the standard model in Figure 2.

Long-distance drivers paid lower than average earnings seek to earn about $750 per week ($1,138 per week in 2017 dollars) by increasing their hours, accepting more trips and more miles, confirming the "target earnings" hypothesis. Figure 4 depicts the labor supply curve for long-distance employee truck drivers paid by the mile. Long-haul drivers prefer jobs that make more work hours available as pay increases, up to an average of 30.75 cents per mile (46 cents per mile in 2017 dollars) and 69.767 hours per week (well beyond the legal limit). As pay rates increase above this level, drivers work fewer hours and, at the margin, trade labor for leisure. That is, at higher pay rates drivers will "pay" for more non-work time, which they would prefer to take at home, or at least resting. At approximately 39.5 cents per mile (60 cents per mile in 2017 dollars) drivers prefer to work 60 hours (approximately the legal limit before the FMCSA effectively increased hours in 2004), and a higher pay rate is associated with the preference for fewer hours; this may be a "safety pay rate" since it is associated with the choice to limit hours to 60 per week, on average. Notably, in this survey, on average truck drivers at the lowest mileage pay rate already work more than 60 hours per week. As their rate increases, they work even more hours before topping out at almost 70 hours per week before beginning to limit their hours.

While previous research has shown the relationship between compensation and safety, research has not explained why higher pay leads to greater safety. This research, supporting the target earnings hypothesis, has shown that as pay increases above target earnings, drivers prefer a job package associated with fewer work hours. As driver hours decrease, at the margin, trucking becomes safer. In other words, truckers drive fewer miles and work fewer hours, are less likely to change jobs, and are less likely to have a crash. As turnover declines and firms attract and retain more experienced truck drivers, trucking operations become safer and the occupation regains the attractiveness it needs for workforce stability and skill development.

How do truck drivers actually work this many hours, on average, when regulations allow them to work 60 hours in a seven-day week? Viscelli claims during his recent time as a truck driver, he worked between 90 and 100 hours per week by logging his non-driving work time off duty, and that most other long-haul truckers did the same. Ouellet reported similar experiences in the non-union sector dating back some 35 years, suggesting nothing has really changed (Ouellet, 1994). How could drivers do this if the regulation prohibits it? Regulations are hard to enforce and include a maze of loopholes. As discussed above, not only can truck drivers take a 34-hour restart after they reach their 70-hour limit for an eight-day week, which they can easily reach in five busy days, they can take a 34-hour "restart" and continue to work as many as 84 hours during a seven-day week. In addition, regulations formerly had a permissive rule allowing drivers to log off duty whenever they were not "responsible" for the truck or the freight (the rule required the carrier to specify the off-duty period in advance, with a beginning and end). However, FMCSA it loosened the rule further in 2013, removing most constraints on this off-duty provision (Ferro, 2013).

This research shows the underlying economic force inducing long-haul commercial motor vehicle drivers to work extremely long hours, compared with similarly situated workers, and how their choice to become long-distance drivers leads directly to a choice to work exceedingly long hours within the existing regulatory regime, with deleterious safety and health consequences. Cargo owners remain the underlying force driving the market, as they compete for the customer dollar.

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