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Although the effect of technology on productivity, employment and conditions of work has been a topic of research in the social science community, the IT revolution of the last two decades has spurred new interest in this issue. Current research has been particularly concerned with the effect of technological change on income distribution and the employment opportunity for less skilled workers. This research takes advantage of a unique and richly detailed survey of truck drivers to investigate the relationship between IT and the productivity, hours of work and wages of truck drivers. The occupational focus of this research is unique in this literature but it may be needed to understand the causal linkages between technology and outcomes such as productivity, earnings and work effort. The implementation of communications and monitoring technologies for truck drivers is very different from those implemented in other settings such as retail trade and manufacturing. Differences in the employment relationship among occupations may also result in technologies with similar purposes to operate through different causal mechanisms and to affect outcomes differently. Occupational studies potentially provide deeper insights into the operation of technology, at the cost of applying to a narrower range of employees. This said, truck drivers are among the largest occupations in the United States with the 2,840,900 employees and self-employed workers in truck driving in 1995 comprising 2.4% of the employed labor force. Truck driving is also among the fastest growing major occupations with employment rising by 75% between 1973 and 1995.

This paper is divided into three parts. The first provides an overview of the work and work life of truck drivers. The second examines which types of drivers have access to and use technology. The balance of the paper is given over to a cross sectional study of the effects of technology on earnings, productivity, and working conditions. The cross sectional study builds on a unique data set of 573 structured interviews with truck drivers to investigate how technology has affected drivers' earnings, productivity, and working conditions. We find that, although most truck board technologies have little systematic influence on driver earnings or work, satellite communication systems, a recently implemented communications and location technology, increase drivers' annual earnings through improved efficiency and work intensification.

The Work Life of an Over-the-Road Driver:

Long Haul truck drivers' work life, represented in word, song and film as that of a cowboy with an eighteen wheel horse, is distinct from that of most employees. Drivers work longer hours than the typical full-time employee, spend extended periods away from home, are often not directly compensated for time spent working, receive few benefits relative to their age and work experience, and suffer high levels of turnover. Their work life reflects the particular needs and competitive pressures of the motor freight industry as well as the regulatory framework which controls drivers' work. Truck drivers are exempt from the Fair Labor Standards Act requirements for overtime pay and pay for time worked. Instead, they are subject to the hours of service (HOS) regulations of the Department of Transportation. These rules limit drivers to sixty hours of work time in seven days, and require an eight-hour break after ten hours of driving and fifteen hours of total work time.[1] Drivers, rather than employers, are liable for violations of the HOS regulations. The working conditions for truck drivers, particularly the long hours of work and accompanying problems with chronic sleep deprivation and drowsiness, have been a source of concern as they are perceived to affect public safety. These concerns are motivating research on truck drivers' sleep patterns (Lyznicki, Doege, et al., 1998; Atkinson, 1999) as well as the first substantial revision of the hours of service rules since 1937 (Federal Motor Carrier Safety Administration, 2000).[2]

Our description draws extensively on a survey of full-time over-the-road and local drivers in the motor freight industry conducted by the Sloan Foundation Trucking Industry Program (UMTIP) and the Institute for Social Research in the summer and fall of 1997.[3] The survey, which includes data from 573 drivers, collected a range of data including respondents' work history; the characteristics of their current work; the structure of compensation; time spent working, waiting, and resting; and use of technology. As it was focused on over-the-road (OTR) drivers and conducted in truck stops, the survey under-sampled metropolitan area drivers, who are less likely use truck stops than OTR drivers, and it may have under-sampled organized drivers.[45] It has advantages over the more commonly used Current Population Survey (CPS) in collecting a richer body of information, eliciting more accurate responses about compensation and hours of work, collecting economic data on owner-operators as well as employees, and avoiding some matters of representativeness.[6] A description of the survey methodology and summary of results may be found in Belman, Monaco, and Brooks (BMB, forthcoming).[7]

What does this survey tell us about the work life of truck drivers? Drivers are, in many respects, typical blue-collar workers. They are somewhat older than a national sample of blue-collar workers, a result of the twenty-one year legal minimum age for obtaining a Commercial Drivers License (Table Ia). Consistent with their greater age, drivers are also more likely to be married and have children than other blue-collar males. Although few women are employed as drivers, the racial and ethnic composition of the driver labor force is comparable to that of

- - - - Table Ia about here - - - -

other blue-collar workers. The educational attainment of drivers is also similar to that of other blue-collar workers: 43.6% of drivers have a high school degree, 21.8% have some college courses, 4.5% have a college degree. Judged by their annual income, motor freight drivers are solidly middle class (Table Ib). The median annual income of drivers in 1996 was $35,000, slightly above the $34,522 median family income for families with a wife who is not in the paid labor force (Mishel, Bernstein and Schmitt, 1999, Table 1.5).[8]

- - - - Table Ib about here - - - - -

Drivers appear less middle-class when hours of work, rates of pay, benefits, and working conditions are considered. Ninety percent of drivers work under compensation schemes that link pay to mileage (BMB, pp 44). To earn a middle-class income, the median respondent needed to drive 110,000 miles a year and work approximately 3,000 hours (BMB, pp 40,44 & 50).

Respondents averaged 11.4 hours of work in the prior 24 hours; 8.5 hours were spent driving while 3.1 hours were spent on other duties and waiting (Table Ic). Although most drivers worked five or fewer days in the last seven, 20% reported working six days and an additional 19% reported working all seven (BMB, pp 95). Using data on the last seven calendar days, the median driver reported working exactly sixty hours, but 25% reported working at least seventy hours and 10% reported working at least ninety hours (BMB, pp 95). Based on data on the last pay period, we found the median respondent worked sixty-two hours in seven days; mean work time was 65.7 hours (BMB, pp 99). Drivers also take little time off work. The median driver took five days of vacation, four holiday days, and no sick leave in 1996 (BMB, pp 66). Assembling these elements, the typical driver works approximately 3,000 hours annually, earning their way into the middle-class income by working 1.5 full time jobs.[9] The median driver would earn only a modest $23,340 for a standard 2,000 hour year.

- - - - Table Ic about here - - - - -

How much do drivers earn per hour? While only 10% of drivers are paid by the hour, an hourly rate, inclusive of all earnings including bonuses, can be constructed as the ratio of reported annual income to estimated annual hours of work. The average hourly wage of drivers was $11.67, 76% of the $15.45 average hourly earnings of the employed force (Mishel, Bernstein and Schmitt, 1999, pp 123). Union drivers earned the top rate of $14.68 per hour, while non-union drivers averaged $10.75 and non-union owner-operators earned $12.03. Benefit coverage and levels are also relatively low. Conventional pension plans are rare; only 26.6% of drivers participated in such plans and most of these were union members. Deferred compensation plans such as a 401(K) are more common; 46.6% participated in such plans, but the median driver had less than $5,000 in his or her account (BMB, pp 59). Medical insurance is more common among employees; 100% of union members and 87.4% of non-union employees reported some form of medical insurance, but only 66% of owner-operators carried such plans. Over half of these plans were contributory. Only 27.4% were fully funded by the employer, most of these were found in the organized sector (BMB, pp. 59).

The dynamics of the occupation, in which drivers compensate for low rates through long hours of work, leads to frequent violations of the hours of service rules, inadequate rest, and drowsiness while driving. Responses to questions on working time over the last seven days and the last pay period suggest that working up to and beyond the legal hours of work is ubiquitous. Consistent with anecdotal evidence of drivers' gaming of the hours of service rules (DiSalvatore, 1988), only 16.1% of respondents to the UMTIP survey believed that logbooks accurately reflected drivers' hours of work. Fifty-six percent reported that they had worked more than they had logged in the last thirty days, and fifty-five percent reported that they had driven more than ten hours without an eight hour break in the last thirty days. Problems of dozing and lack of sleep while driving are common; 35% of drivers reported dozing while driving at least once in the last thirty days, and 15% reported dozing at least three times over that period (BMB, pp 161). While most drivers reported at least six hours of sleep in the last twenty-four hours, 5.4% reported two or fewer hours of sleep and 15% of drivers reported not sleeping in the twenty-four hours before returning home (BMB pp 86).

Turnover and quit rates are high. Although the median driver had worked in his or her occupation for twelve years, median service with the current employer was eighteen months (BMB, pp 107). Only 21% of non-union employees had been with their employer for four years or more. One quarter of non-union employees reported quitting a driving job in the last year, and the same proportion of non-union owner-operators reported terminating a lease or otherwise breaking a long-term relationship with an employing firm (BMB, pp 107). High turnover results from drivers seeking better employment, but respondents suggested that some companies force out drivers who would otherwise qualify for the higher rates that come with longer service.

There is considerable inequality among drivers with regard to wages, hours of work, and working conditions. The most obvious division is between organized employees, non-union employees, and owner-operators.[10] The median union member earned $44,000 annually, 26% more than non-member employees' median earnings of $35,000 and 33% more than non-union owner operators. The median non-union owner-operator's earnings after truck expenses were 6% less than those of non-union employees. The pattern of inequality for hours is different. Owner-operators worked the shortest hours: 56 hours per week with 11 days off annually for an annual work year of 2824 hours at the median. Union employees worked 60 hours per week, took 15 days off for an annual work year of 2940 hours (BMB, pp. 74). Non-union employees worked the longest hours: 65 hours per week, 8 days off and an annual work year of 3306 hours. These differences in annual hours result in a pattern of hourly rates that diverges from that of annual earnings. Union employees had the highest hourly rates, earning 37% more than non-union employees, while owner-operators earned 12% more per hour than non-union employees (BMB, pp 74).

Non-wage benefits were also unequally distributed. Union members were more likely to participate in pension plans (77%) and medical insurance plans (100%) than were non-union employees (21.4% and 87.4%) or owner-operators (15.4% and 66.2%) and were only slightly less likely to participate in deferred compensation plans and IRAs (44.0% and 29.4%) than were non-union employees (59.8% and 12.8%) or owner-operators (15.3% and 33.3%) (BMB, pp 59). Organized drivers' ability to maintain considerably better wages and benefits may rest, in part, on the union's retreat into segments of the industry which have barriers to entry (such as less than truckload freight), which are more concerned with the quality of work than the price (such as new auto haul), or local markets which are highly organized.

There were also considerable differences in earnings within each of these groups. Among non-union employees, the driver at the 25th percentile earned 23% less than the median driver, while the driver at the 75th percentile earned 28% more than the median driver. The dispersion of earnings is more marked at the 10th and 90th percentile, with the former earning 52% less than the median, and the latter earning 48% more. The dispersion of earnings is smaller among organized drivers, but substantially larger among owner-operators. The narrower spread in earnings of union employees is consistent with the literature that finds that unions reduce wage variance through rate standardization; the larger dispersion of owner-operators' earnings may be due to the greater risk assumed by owner-operators.

Who Uses Technology?

The most recent technologies adopted by the industry, communications and location technologies, routing technologies, and computing technologies, are used directly by drivers. The Driver Survey indicates that faxes are the most commonly used technology (32.3% report using a fax), but satellite-based communication and location systems (29.5%) are almost as common as are beepers (28.5%) and cell phones (31.1%) (Table II). In contrast, relatively few drivers use e-mail (2.3%), and a modest number use two-way radios (6.8%). The most common routing technology is CB radio (64.7%); the second is use of a dispatcher (32.6%). Computer mapping technologies, such as on-board computer maps (8.1%) and laptops with maps (3.9%), are relatively uncommon. Despite news stories about the use of laptop computers by drivers (Kopytoff, 1999), only 5.1% of drivers have such equipment in their trucks. With certain exceptions, notably fax machines, few drivers report using multiple technologies.

- - - - Table II about here - - - - -

Although influenced by customers and employees, firms control the adoption of technology. Given the cost of technology to firms, there must be a profit incentive for firms to implement new technologies such as Satellite Based Systems (SBS). Bresnahan and Bryjulfsson (2002) propose that technology will be adopted if it improves firm performance by improving service to customers or aligning the incentives of firms and workers. This finding is echoed by Hubbard (2000). Acemoglu (2000) echoes this importance of workers in successful implementation of technology; firms will receive no returns to technology if the technology is not "complementary" to worker skills.

Using firm data collected by the American Trucking Association and the Department of Transportation, Chakraborty and Kazarosian (1999) assess technology's impact on trucking firms. They find that the adoption depends upon the segment of the market served by the firm. Heavier loads, longer trips, and time sensitivity increase the likelihood that the firm will adopt technologies such as SBS (including Automatic Vehicle Location – AVL) and on-board computers.

As a survey of drivers rather than firms, the UMTIP Driver Survey provides a different perspective on the adoption of technology. In addition to the extensive information collected about drivers, the survey included questions on presence and use of technology (gadgets in the parlance of the survey) as well as on the characteristics of the employing firm. This allows further testing of the hypotheses about forces driving the adoption of technology.
We begin with some descriptive statistics, dividing workers by the operating characteristics of their firm and examine the prevalence of the most common technologies within these subgroups.

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Not surprisingly, over-the-road drivers are more likely than local drivers to use SBS (32.1% vs. 15.6%) and less likely to use two-way radios (5.2% vs. 17.8%) or cell phones (28.5% vs. 48.9%) in their work. SBS is also more common among for-hire drivers than private carriage (34.6% vs. 5.3%). Drivers in private carriage are more likely to use cell phones (44.6% vs. 28.3%). The usage of SBS between owner operators and employee drivers is close (25.9% vs. 30.4%), however owner operators are more likely to use beepers (52% vs. 20.6%) and cell phones (38.6% vs. 28.6%).

There is a marked difference in SBS adoption between union and nonunion drivers (11.1% vs. 32.7%). Union drivers are more likely to use cell phones (44.9% vs. 29.3%) and less likely to use beepers (16.8% vs. 30%) than nonunion drivers. While the lower utilization of SBS may be associated with unionism *per se*, it is more likely explained by the concentration of union drivers in the LTL and local delivery sectors of the industry.[11] As LTL firms tend to run regular routes with little discretion in driver's scheduling, the gains from accurate tracking and real time communications would be small. Similarly, local cartage is not characterized by the communications problems of companies with large OTR divisions. Finally, comparing drivers by type of trailer hauled, drivers with dryboxes are more likely to have SBS in their trucks than those hauling other trailer types (42.3% vs. 18.1%).

To examine the use of technology in more detail, we focus on one technology, Satellite Based Systems. It is becoming the dominant truck specific technology and that with the most potential to align the incentives of firms and drivers. We estimate a probit model of the use of this technology. The dependent variable takes a value of one if the driver has SBS in his/her truck, zero otherwise. As the focus is on the types of firms that are more likely to adopt this technology, the first model includes only firm characteristics as explanatory variables. These controls include dummy variables for local, private carriage, union, owner operator, drybox, pay method, and firm size. Dummy variables are included for pay as percent of revenue or by the hour. The omitted pay system is pay by the mile, the base group for pay. Satellite systems are characterized by substantial returns to scale as firms have to purchase equipment and man a central operation that can handle a large number of trucks. We control for scale effects with dummy variables for firm size. Firms with less than 25 drivers are the base group and dummies are includes for 25-99 drivers (F25), 100-249 drivers (F249), 250-499 drivers (F250), 500-999 drivers (F500), 1000-4999 drivers (F1000), and 5000 or more drivers (F5000). Results of this estimation are presented in column 1 of Table IV.

- - - - Table IV about here - - - - -

We present the partial derivatives of the probit evaluated at the means, the counterpart of the coefficients obtained from linear models. This allows us to interpret the coefficients presented as "marginal effects." The results reinforce the descriptive statistics. Drivers in private carriage are 21% less likely than for-hire drivers to have SBS in their trucks. Union drivers are 20.4% less likely to use SBS in their work than nonunion drivers. Pay method matters as well.

Drivers paid percent of revenue or by the hour are 16.3% and 14.6% less likely to use SBS than driver paid by the mile. There is strong evidence that satellite-based systems are characterized by scale effects and that these systems are not economically useful to firms with fewer than 250 drivers. The coefficients on the largest firm sizes are positive and significant. Firms with more than 250 drivers are between 44% and 62% more likely to use SBS than firms with less than 25 drivers.

We next extend the model to incorporate personal characteristics. The decision by firms to adopt technology may be influenced by the types of drivers in their labor force, not just by the segment of the market they serve. For example, firms may adopt SBS in order to enable them to hire and easily monitor less experienced (and thus less costly) drivers. A probit model is estimated with the same controls as the first model, plus controls for education, age, experience, race/ethnicity, veteran status, gender, and marital status. The results are presented in column 2 of Table IV.

The inclusion of individual characteristics does not significantly affect the prior results. No firm characteristics gain or lose statistical significance and the magnitudes of the coefficients do not change appreciably. The statistically significant personal characteristics include age, experience, gender and race. Age has a non-linear relationship to use of SBS technologies. Younger drivers are more likely to use these technologies but, because of the negative quadratic term, older drivers are indicated to be less likely to be in SBS-equipped trucks. The coefficient on occupational experience (years as a driver) is negative and significant, suggesting technology may be used as a substitute for experience. Education is unrelated to use of SBS systems. This is not entirely surprising since, although the base units require considerable technical knowledge to operate, the truck borne units require only basic literacy to read and type responses. Finally, the coefficients on Black and Female are positive and significant. Women typically have considerably less experience in truck driving than men and this may explain the positive relationship to use of SBS systems. The racial effect is not as readily explained.

Technology and Driver Worklife

We next use data from the TIP Driver Survey to examine the relationship between technology and annual earnings and rates of pay. We further examine the causal mechanisms underlying earnings outcomes by considering the effects of technology on driver output, as measured by annual mileage, on work intensity as measured by hours of work, and on HOS violations.

Though fundamental aspects of drivers' work have proven immune to technological change–the driver still moves the truck from the shipper to the receiver–the industry has undergone a technological transformation. Logistics software has taken over the work of the dispatcher, providing better coordination of trips and higher load factors. Improved drive train technologies have extended the life of equipment, reducing capital costs. Changes in regulations have permitted longer, heavier trailers, increasing drivers' productivity.

Communications technologies, such as satellite systems, beepers, cell phones, and two-way radios, locate trucks in real time and permit communication between the firm and driver without requiring the driver to stop. These systems offer firms the capacity to reroute as information becomes available while reducing time spent on pay phones. E-mail may be more helpful to owner-operators who use it to find loads and as a rapid, dependable communication. Such technologies should make drivers more productive by better coordinating their activities and reducing non-productive, non-remunerative time. To the degree that communications technologies allow drivers to use their time more efficiently, it would be expected that they would be associated with improved mileage and earnings but would not affect other dimensions of drivers' work.[12] If, in addition, firms use these technologies to monitor drivers and keep them from taking unauthorized breaks, income and mileage would increase but time spent working might also rise.

The gains from new routing technologies, such as maps on PCs and on-board computers, are less obvious. These technologies can provide information on current conditions, but the information is unlikely to be more current than that from road atlases supplemented by CB radio. Computing technologies, such as laptop PCs, should help drivers, particularly owner-operators, to run their businesses in an efficient manner and facilitate the use of communication technologies such as e-mail. If computing and routing technologies affect drivers' work, they might reduce work time, as they reduce unproductive time. Driver earnings should increase as paid work time would rise as a proportion of all work time and as owner-operators use their computing facilities to chose loads that pay more or are better coordinated with other loads on the trip.

There is limited evidence that technology has improved driver productivity. Data on trucks from the TIUS, suggests that driver monitors, such as vehicle locators, are associated with incentive gains to firms (Hubbard, 2000). Both incentive and efficiency gains are captured by firms through communications technology such as electronic vehicle management systems (Hubbard, 2000). Schneider National, an early adopter of satellite based systems, which is also among the nation's largest TL firms, reported that these systems reduced their total driver hours by nearly one million annually (Davis, 1999). Giant Foods estimated that truck borne communications technologies resulted in 1,200 fewer phone calls between drivers and dispatchers per day (Schulman, 1999). Contrary evidence tends to be more anecdotal, with some trucking firms indicating that satellite technologies do not benefit their operations but are adopted because customers believe that they are important.

In the remainder of this paper, we consider the effects of technology on rates of pay and annual income. We take advantage of the depth of information in the driver survey to further examine whether these effects are underlain by an effect on annual mileage, productivity, and the intensity of work (hours worked in the last seven days and the number of violations of the ten-hour limit in the last thirty days). In combination, these results provide a comprehensive view of the consequences of these factors for drivers' work lives. The models include controls for respondents' race, ethnicity, gender, and marital status; human capital; union status; for the industry segment; the region of domicile; whether the respondent is an owner-operator, a local driver, or employed in private carriage; the method of pay; and the number of drivers working for the employing firm.[13] We employ a parallel specification across the models. The model for violations of the ten-hour limit includes controls for 1996 annual miles and income.[14] With the exception of the equation for violations of the ten-hour rule, we estimate the equations allowing for simultaneity in the error terms between matched observations, a SUR estimate, to improve the efficiency of the estimates. Results are in Table V.

- - - - Table V about here - - - - -

Annual Earnings

The dependent variable in the annual earnings equation is the log of annual earnings from driving for employee drivers. Owner-operators reported net earnings after truck expenses but before taxes. Mean earnings were $33,300.

Most communications, routing, or computing technologies do not affect drivers' annual earnings. Satellite systems have a strong positive effect, raising earnings by 17.6%. The effect of satellite systems on drivers' earnings is notable both in magnitude and in the number of drivers (28.6%) who receive this advantage. Drivers with beepers earn 10.3% more annually, while drivers who use a two-way radio or route using pc maps earn 18% and 21% less annually, respectively.

Given that some technologies have a favorable effect on annual earnings, what might be the source of this favorable effect? Firms may have to pay higher *rates* to obtain the more skilled and committed workers needed to operate the technology. Technology may also improve earnings by reducing unproductive time and so increasing mileage or by intensifying work through closer monitoring of driver activities. Technology need not have a singular effect; it may increase rates and mileage and the intensity of work. We investigate these possibilities by examining the relationship between these factors and effective mileage rates, annual miles, and apropos of work intensification, hours worked per week and violations of the hours of service regulations.

Mileage Rates

We turn first to the mileage rate equation. We use "effective" mileage rates, the ratio of annual earnings to annual miles, so that drivers who are paid under other systems are included in the estimates and so that bonuses, payments for on-duty, non-driving time, and other forms of monetary compensation are incorporated. The mean rate for the sample is 38.9¢ per mile.

The relationship of technology to mileage rates is more varied than the relationship to annual earnings. Drivers using satellite systems are paid 5.9¢ per mile *less* than drivers without satellite systems, but the relationship is only significant in an 18% test. In contrast, two-way radios, beepers, and cell phones, communications technologies typically used within a local area, are associated with rates that are between 6¢ and 12.2¢ more per mile. The negative effect of satellite systems would be consistent with firms engaging in productivity-sharing with their labor force, with the lower rates compensating the firm for the expense of the system. Alternatively, the close communication between drivers and firms afforded by satellite systems may substitute for over-the-road experience and allow firms to employ less experienced drivers at lower wages. This is consistent with the coincident use of satellites and extensive recruitment of new drivers by Schneider and Hunt, the largest non-union TL firms. Driver survey data indicates that, while 28% drivers with at least four years in the occupation are in satellite-equipped trucks, 35% of drivers with less than four years of experience are in such vehicles. The higher mileage rates found for short-range communications systems may result from lower annual mileage, because of lower speeds and additional time spent loading by pick up and delivery drivers.

Mileage

Mileage is an essential element of driver productivity and is central to driver earnings. Mileage varies with the type of work. Local pick up and delivery workers drive fewer miles annually than over-the-road drivers. Allowing for differences in types of work, employees with higher mileage provide additional deliveries, earn more revenue for their firm, and increase their earnings. Drivers in the sample averaged 124,865 miles in 1996.

Mileage is influenced by some technologies. Drivers with satellites on their trucks drove an additional 21,717 miles, 17.4% more miles than the mean. The use of CB radio for routing was associated with an additional 7912 miles. In contrast, the use of a two-way radio for communication was associated 23,972 fewer miles driven in 1996. The longer mileage associated with use of CB radios likely reflects both the effects of obtaining up-to-date information as well as the type of driver who uses CBs. Two-way radios have limited range, and their use suggests a driver who makes short trips with more frequent pick-ups and deliveries.

Hours Worked and Violations of Hours of Service Violations

We discuss the final outcome measures, hours of work in the last seven days and the number of times a driver has driven more than ten hours without a break, together. The hours of service equation includes two additional explanatory variables, 1996 mileage and 1996 income, to control for factors related to excessive hours (Monaco and Williams, 2000). Our data indicate that the typical driver worked 65.4 hours in the previous week and violated the ten-hour rule six times.

Most technologies are unrelated to hours of work or violations of the ten-hour rule. Use of satellite systems increases both the hours of work and the probability of driving beyond the ten-hour limit. Drivers with such systems are estimated to work an additional 6.6 hours of work per week, 14% more hours than the base group. Satellite systems do not directly increase the number of violations of the ten-hour rule, but the increase in mileage associated with such systems would lead to one additional violation each thirty days.[15] Use of a CB radio is associated with an additional 2.8 violations in the last thirty days. The effect of CB radios on violations of the ten-hour rule may be attributable to drivers' ability to track and avoid police and DOT inspectors. The result for hours of work is consistent with the effect of CB radios found in the mileage equation.

Conclusion:

We investigate the relationship between technology and drivers' worklives using data from the UMTIP Driver Survey. Focusing first on which types of drivers are more likely to use satellite technology, we find that drivers in private carriage, union drivers, and those paid by the hour or as percent of revenue are least likely to drive trucks equipped with SBS. The largest firms are most likely to equip their trucks with SBS, providing some evidence of scale effects of this technology. There is also evidence that SBS technology is used as a substitute for experience.

Research on the effects of technology on labor markets finds that current technologies are most useful to better-educated workers, are skill-biased, and that they act to reduce the earnings of less educated workers. Examining the impact of satellite technology on worker outcomes, we find that SBS does more than simply lower drivers' pay. Consistent with the skill-bias hypothesis, drivers who use satellite systems may be paid less per mile. This effect is, however, statistically weak and would account for a modest reduction in earnings throughout trucking. In contrast, drivers on satellite-equipped trucks realize 17.6% higher annual earnings. The higher earnings are due to the increased mileage of such drivers, about 22,000 additional miles per year. Part of this mileage gain is explained by efficiencies provided by these systems, but drivers with satellites also work 14% more hours weekly. The increased hours would account for approximately 60 percent of the increase in mileage, the remaining 40 percent is associated with improved productivity and is captured entirely by firm. The overall finding, that technology improves productivity and earnings but intensifies and lengthens the work day, is consistent with sociological studies of technology (Graham, 1995).

Given the apparent benefits of satellite technology to both firms and workers, it is interesting to gauge the feelings of drivers towards technology. The UMTIP Driver Survey questioned the drivers on their likes and dislikes of the technology they used.[16] We focus on these responses for those drivers who used SBS. Ten percent of drivers stated that there was nothing they liked about SBS. The vast majority indicated that they liked the increased efficiency and convenience provided by the SBS. Thirty-two percent liked that they did not need to stop to contact their dispatcher, 39% liked that they did not have to use a truckstop pay phone, 17% liked that they could get information directly from the company without stopping the truck, and 18% indicated that they felt SBS allowed them to save time and improve their efficiency.

Not surprising, the biggest complaint about SBS was that drivers felt monitored (24%). Other dislikes include being bothered or too easy to reach (11%) and technical problems with the systems (9%). It is notable, however, that 37% of the drivers reported that there was nothing they disliked about the satellite systems.

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Table Ia: Characteristics of Driver Survey and National Blue Collar Samples

Characteristic		UMTIP Driver Survey	National Blue Collar Sample
Age			
Gender	Male	97.2%	60.2%
Race	White	85.3%	83.1%
	African-American	8.9%	12.8%
	Other	4.1%	3.3%
Ethnicity	Hispanic	2%	8.5%
Marital Status	Never Married	12.8%	26.4%
	Married	63.6%	54.5%
	Widowed	2.6%	3.2%
	Divorced/Separated	11.1%	15.9%
Education	Less than High School	2.3%	6.8%
	Some High School	18.3%	14.0%
	High School Diploma	43.6%	48.9%
	Vocational Degree	4.4%	4.8%
	Some College	22.7%	18.6%
	Associate Degree	3.9%	4.8%
	College Degree or More	4.8%	5.2%

Data on truck drivers from the UMTIP driver survey. National blue collar sample taken from 1997 CPS. Except for data on gender, CPS data is limited to male blue collar workers age 18 and older.

Table Ib: 1996 Annual Incomes of Truck Drivers and the National Male Labor Force		
Truck Drivers		
		1996 Income
	mean	$35,985
	10th percentile	$15,000
	25th percentile	$26,000
	median	$35,000
	75th percentile	$45,000
	90th percentile	$53,000
National Labor Force		
Family Income, wife not in labor force	median	$34,522
Earnings of Year-Round Full-Time Male Workers with High School Diploma	mean	$32,521
Family Income and Earnings of Year Round Full-Time Male Workers from State of Working America: 1998-1999		

Table Ic: Mileage and Hours of Work of Truck Drivers					
Miles Driven				Hours Worked	
	Last 24 Hours	Last 7 Days	Last Year	Last 24 Hours	Last 7 Days
mean	439.7	2126	109,965	11.4	63.2
10th percentile	130	700	50,000	5.8	38
25th percentile	268	1500	82,000	8.2	50
median	400	2186	110,000	11.0	60
75th percentile	583	2800	130,000	14.0	75
90th percentile	750	3500	160,000	18.0	90
Data from UMTIP Driver Survey					

Table II: The UMTIP Driver Survey Sample: Descriptive Statistics

Communications Technologies	fax	32.3%
	beeper	28.5%
	two way radio	6.8%
	cellular phone	31.1%
	e-mail	2.3%
	satellite based system	29.5%
Computing Technologies	laptop computer	5.1%
Routing Technologies	Dispatcher	32.6%
	cb radio	64.7%
	on-board computer with maps	8.1%
	laptop with maps	3.9%
Collective Bargaining	union member	12.3%
Human Capital	Age	42.0 years
	occupational experience	15.0 years
	less than high school education	20.2%
	high school diploma	43.8%
	vocational or technical degree	4.5%
	some college	21.8%
	associate of arts	4.4%
	college degree or higher	4.5%
Other Characteristics	local driver	12.5%
	owner operator	24.8%
	private carriage	17.4%
	paid by the hour	15.5%
	paid percent of revenue	36.0%

Table III: Technology Adoption: Descriptive Statistics

	Local	Over-The Road	Private Carriage	For Hire	Drybox	Other Trailer
Pay phone	79.8%	92.3%	90.1%	90.8%	88.3%	93.0%
SBS	15.6%	32.1%	5.2%	35.3%	42.3%	18.1%
Fax	12.3%	35.3%	24.2%	34.1%	33.7%	31.1%
Beeper	37.0%	27.2%	26.8%	28.8%	20.4%	36.4%
Radio	17.8%	5.2%	1.0%	6.2%	6.1%	7.6%
Cell Phone	48.9%	28.5%	44.6%	28.3%	30.8%	31.5%
N	50	422	88	385	234	238

Table III (continued)

	Owner Operator	Employee Driver	Union	Nonunion
Pay phone	90.0%	91.0%	91.3%	90.6%
SBS	25.9%	31.4%	11.1%	32.7%
Fax	43.3%	28.7%	22.7%	33.6%
Beeper	52.0%	20.6%	16.8%	30.0%
Radio	5.4%	7.3%	2.3%	07.4%
Cell Phone	38.6%	28.6%	44.9%	29.3%
n	126	346	46	426

Table IV: Adoption of Satellite Based Systems: Probit Estimation

	DF/dx	DF/dx
Local	-0.0681 (-0.82)	-0.0348 (-0.40)
Private carriage	-0.2107 *** (-3.33)	-0.2171 *** (-3.45)
Owner operator	0.0642 (1.13)	0.0626 (1.06)
Union	-0.2042 *** (-3.62)	-0.1968 *** (-3.39)
Drybox	0.1586 *** (3.45)	0.1428 *** (2.97)
Percent	-0.1634 *** (-3.36)	-0.1582 *** (-3.17)
Hourly	-0.146 ** (-2.13)	-0.1425 ** (-2.11)
F25	-0.0173 (-0.24)	-0.0125 (-0.16)
F100	0.1189 (1.47)	0.1012 (1.20)
F250	0.4639 *** (4.79)	0.4838 *** (4.76)
F500	0.5218 *** (5.19)	0.4989 *** (4.65)
F1000	0.4471 *** (5.01)	0.4472 *** (4.73)
F5000	0.6180 *** (4.17)	0.6143 *** (3.93)
Less than high school		-0.0430 (-0.72)
Vocational/technical		-0.0982 (-0.99)
Some college		-0.0335 (-0.58)
Associate		-0.0353 (-0.34)
College graduate		0.7570 (0.65)
Age		0.0440 ** (2.09)
Age-squared		-0.0005 ** (-1.96)
Occupational experience		-0.0193 ** (-2.10)

Occ exp-squared		0.0003 (1.34)
Black		0.1688 ** (2.04)
Hispanic		0.0736 (0.41)
Native American		0.0821 (0.55)
Veteran		-0.0130 (-0.27)
Female		0.1569 * (1.65)
Married		0.0190 (0.24)
Separated, divorced, widowed		0.0246 (0.29)
n	440	439
Likelihood Ratio	172.07	193.72
Pseudo R-squared	0.3229	0.3641

Table V: Effects of Technology on Truck Drivers: Regression Estimation					
Variable	Annual Earnings	Mileage Rates	Annual Mileage (1996)	Hours Worked in Last 7 Days	Violations of 10 Hour Rule
Communications Technology					
fax	0.0079 (0.10)	-0.0614 (1.17)	3338.73 (0.50)	3.2892 (0.74)	0.4928 (0.35)
beeper	0.0980 * (1.65)	0.1055 ** (2.81)	74.3651 (0.02)	3.7387 (1.17)	0.1586 (0.15)
radio	-0.2039 ** (2.10)	0.1224 ** (1.99)	-23972.35 ** (3.08)	-5.3188 (1.02)	-2.7071 (1.56)
cell phone	0.0557 (1.01)	0.0596 * (1.71)	-512.549 (0.12)	1.4139 (0.48)	-0.6850 (0.71)
e-mail	-0.0049 (0.05)	-0.0091 (0.15)	4764.044 (0.64)	-2.6177 (0.53)	-0.0812 (0.05)
satellite based system	0.1622 ** (2.41)	-0.0586 (1.37)	21716.98 ** (4.02)	6.5767 * (1.82)	-1.5072 (1.25)
Computing Technology					
Laptop computer	0.1025 (0.87)	-0.0150 (0.20)	11534.29 (1.22)	-1.9963 (0.32)	0.7529 (0.37)
Routing Technology					
Use dispatcher	-0.4951 (0.93)	0.0540 (1.60)	-5528.186 (1.29)	2.7855 (0.97)	1.2236 (1.29)
cb radio	-0.3532 (0.67)	-0.0404 (1.22)	7912.266 * (1.88)	-0.7006 (0.25)	2.7838 ** (3.00)
On-board computer w/maps	0.0022 (0.02)	-0.0212 (0.34)	-4985.488 (0.64)	-5.4687 (1.04)	0.1318 (0.08)
Laptop with maps	-0.2339 * (1.93)	-0.0963 (1.23)	7797.63 (0.78)	-7.7456 (1.16)	-1.0640 (0.48)
Collective Bargaining					
Union member	0.1350 * (1.66)	0.0385 (0.75)	-1504.706 (0.23)	-0.3571 (0.08)	0.4493 (0.31)

Human Capital					
Age	-0.0348 * (1.76)	-0.0343 ** (2.74)	-2464.61 (1.56)	-1.1087 (1.05)	-0.4755 (1.37)
Age^2	0.0004 * (1.70)	0.0004 ** (2.81)	22.72 (1.25)	0.0072 (0.59)	0.0035 (0.88)
Occup. Exp	0.0311 ** (3.42)	-0.0004 (0.07)	983.95 (1.35)	-0.4845 (0.99)	-0.0043 (0.03)
Occup. Exp^2	-0.0007 ** (3.23)	-0.00006 (0.42)	-19.649 (1.06)	0.0187 (1.51)	-0.0001 (0.31)
Less than HS	-0.0632 (0.97)	-0.0718 * (1.74)	7317.651 (1.40)	0.9887 (0.28)	-0.7058 (0.62)
Vocational Deg.	0.0021 (0.02)	0.2022 ** (2.61)	-3855.575 (0.39)	15.1960 ** (2.31)	6.1176 ** (2.85)
Some College	-0.0441 (0.55)	0.02984 (0.73)	-9125.581 * (1.77)	0.2071 (0.06)	1.0595 (0.93)
Associate of Arts	0.0729 (0.55)	-0.0123 (0.15)	315.4873 (0.03)	3.1040 (0.44)	-0.1132 (0.05)
College or More	-0.1937 * (1.65)	-0.0247 (0.333)	-9297.122 (0.99)	14.7174 ** (2.33)	4.2706 ** (2.08)
Characteristics of Work					
Owner-operator	-0.1051 (1.62)	0.0344 (0.83)	-11131.95 ** (2.13)	-12.9922 ** (3.72)	1.3799 (1.21)
Local driver	-0.0012 (0.02)	0.2543 ** (4.84)	-22796.93 ** (3.43)	2.5704 (0.58)	0.5150 (0.35)
Private carriage	0.1556 ** (2.37)	0.0410 (0.99)	7441.995 (1.42)	-0.3571 (0.08)	-1.7256 (1.48)
Paid by hour	-0.0421 (0.55)	0.0695 (1.42)	-14210.47 ** (2.30)	-4.2461 (1.02)	-0.3566 (0.26)
Paid % of revenue	0.0258 (0.45)	0.1530 (0.42)	3901.628 (0.84)	1.2789 (0.41)	1.3478 (1.32)
Additional Controls					
Annual miles	No	No	No	No	0.000047 ** (4.25)
Annual wage	No	No	No	No	-0.000017 (0.53)
Race/Ethnicity/Gender/ Marital Status	Yes	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes	Yes
Industry Segment	Yes	Yes	Yes	Yes	Yes
Firm Size	Yes	Yes	Yes	Yes	Yes
Diagnostics					
N	395	395	395	395	395
RMSE	0.4273	0.2709	34285.22	22.9965	7.6538
Chi-Squared	135.2546	191.7986	189.8318	151.4758	168.9935

* -significant at 10%   ** - significant at 5%

[1] These regulations have changed effective June 2003. Drivers are now required to take a 10-hour break after 11 hours driving and 15 hours of work.

[2] Historic concern about the risk to the public posed by overtired transportation workers is reflected in limits on the hours of railway operative employees in the 1890s (Commons, Leschoier, and Brandeis, 1935)

[3] The survey was funded by the Alfred P. Sloan foundation.

[4] Twelve percent of survey drivers reported union membership, about half the rate indicated by the Current Population Survey (Hirsch and MacPherson, pp 78). This reflects the under-sampling of drivers who work within metropolitan areas as well as the strength of unionism in segments of motor freight industry, such as parcel express, whose drivers drive short routes under tight deadlines and are less likely to use truck stops for fueling or breaks.

[5] The data in the UMTIP survey does compare favorably to the data found in other data sets of truck drivers. Annual mileage reported in the Driver Survey is similar to that of tractor-trailers used for trips of more than 200 miles as reported in the 1997 Vehicle Inventory and Use Survey. The age, gender, and education of Driver Survey respondents are similar to those of truck drivers in the Current Population Survey (Belzer, Burks, Fulton, Grimes, Swan and Sedo, 2001).

[6] The UMTIP driver survey is more accurate on issues of compensation and hours of work, the two central work related items collected by the CPS, because the UMTIP questions are structured for the compensation systems used in trucking and are not asked by government employees. As will be discussed, drivers often violate federal and state hours of service restrictions and deceive local, state, and federal employees about their hours of work. This appears to carry over to their attitudes to all government employees, including CPS surveyors. In contrast, the UMTIP survey was structured to reassure drivers about anonymity: the surveyors were not government employees, and they elicited information on actual rather than legally permissible time. Finally, CPS' use of proxy respondents and the failure to collect working hours information on drivers who report variable hours results in under-representation of OTR drivers for key economic data as well as adds inaccuracy to reported pay and hours.

[7] The survey utilized a two stage sampling design. In the first stage, truck stops were chosen randomly within state/size categories. In the second stage, interview approaches were randomized by time of day as well as by the individual entering the truck stop or fuel line. Only drivers holding a class C Commercial Drivers License who were currently employed as drivers and were driving a truck at the time of the interview were eligible for the survey. Surveys were conducted

on weekdays with the exception of follow up telephone interviews, which collected information on the last full day of work (potentially a weekend).

[8] Drivers' mean income, $35,985, was slightly above their median earnings.

[9] See Belman, Monaco, and Brooks (forthcoming) for details on the construction of annual hours of work.

[10] As there were only two union owner-operators in the sample, we do not provide separate descriptive statistics on this group.

[11] It is possible that union drivers are in a better position than nonunion drivers to prevent SBS adoption due to privacy concerns.

[12] There is little reason to believe that the new communications technologies would change rates of pay as they do not require substantial training to master. The reduction in unremunerated time would increase the effective wage rate of drivers, and this could affect their hours of work. The direction of the effect would depend on whether drivers had a dominant income or substitution effect and whether they were close to their hours of service limits.

[13] The driver survey estimates suffer the usual limitations of cross section estimates. We are only able to evaluate how technology, human capital, and union membership affect wages at a point in time, not across time. For example, we do not know how much wages fell because of de-unionization, only the current union premium.

[14] The models are estimated using survey weights and allowing for clustering of characteristics by truck stop. Most are estimated with 395 observations. Fifty-one employee drivers were excluded as they were not working as drivers in 1996 and did not report 1996 income, or because they reported a 1996 income from driving of less than $5000 or more than $100,000. Twenty-seven owner-operators were eliminated because their reported earnings net of truck expenses were extremely low, under $2,800, or extremely high, over $100,000. We excluded seventeen drivers because they did not report their industry segment. Eleven were excluded because of the lack of information on firm size.

[15] An additional 10,000 annual miles of driving is associated with .47 violations of the ten-hour rule every thirty days.

[16] Each respondent was allowed to give up to three responses to the questions, "What do you like about your gadget?" and "What do you dislike about your gadget?"