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IZA DP No. 16477

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ABSTRACT

When Is High Turnover Cheaper? A Simple Model of Cost Tradeoffs in a Long-Distance Truckload Motor Carrier, with Empirical Evidence and Policy Implications*

The U.S. trucking industry has been calling out a shortage of truck drivers for nearly forty years, since soon after its economic deregulation in 1980. Burks and Monaco (2019) provided evidence that the overall truck driver labor market works about as well as any blue collar labor market, and suggested persistently high driver turnover uniquely at long-distance truckload firms (central to long distance freight but employing only 20% of tractor-trailer truckers) drives the shortage perception. The American Trucking Associations (ATA) agreed with the location of the problem, but argued that a driver shortage and high turnover are distinct, and that a long-term shortage does exist. We review the evidence for a shortage and find it unconvincing. We also review empirical evidence that long-distance truckload has had persistently high-turnover since the mid-1980s. To explain this, we provide a simple model of long-distance truckload cost minimization in which there is a tradeoff between the costs of turnover and two other costs, higher pay to offset bad working conditions (compensating differentials), and running trucks out-of- route to get drivers home regularly (inefficient capital use). We show that high turnover is likely structural because it is part of the least-cost mixture. We then use our model to analyze the potential impacts of two technological changes (truck simulators and partially automated trucks), and a key policy championed by the ATA to "fix the shortage," interstate teenaged truckers. We show that these are likely to have results opposite to those the industry and policy makers expect.

JEL Classification: L1, J42, L9

Keywords: long-distance motor carrier, driver turnover, driver shortage, truckload, less-than-truckload, costs, teenaged truck drivers, partially automated trucks, truck transportation

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1. Introduction

The U.S. trucking industry has been reporting an ongoing truck driver shortage since a little after the 1980 economic deregulation of trucking, or *for most of the last forty years* (Casey 1987; Mele 1988; Cooke 1989; Christenson, Aames et al. 1997; Global Insight Inc. 2005; Costello 2012; Costello and Suarez 2015; Costello 2017; Costello and Karickhoff 2019b; Economics Department 2021). In one recent analysis, the American Trucking Associations (ATA), the principal industry trade organization,[1] predicted a shortage of 160,000 drivers by 2028 (Costello and Karickhoff 2019b). Industry spokespersons have pointed out demographic challenges facing the industry: the existing driver pool is aging and the number of young white blue collar males, from which the industry has traditionally drawn, is decreasing, and the industry has not attracted many drivers from other demographic groups (Short 2014; Costello and Karickhoff 2019b). However, these issues do not differentiate trucking from most other blue-collar occupations. A recent (pre-pandemic) analysis of nationally representative data did show that in the heavy and tractor-trailer truck driver occupation as a whole,[2] there is evidence of a relatively tight labor market since the turn of the century in that unemployment rates have been persistently less than in some other occupations requiring similar human capital. However, despite this, and contrary to the industry view, individuals enter and leave the occupation in response to variations in wages in the normal way (Burks and Monaco 2019). A related study by Phares and Balthrop (2022) found entry into truck driving was more responsive to wage variations than was entry into other blue collar occupations.

Why, then, has the industry maintained the opposite for nearly forty years? In a press release responding to Burks and Monaco (2019), the American Trucking Associations' Chief Economist, Bob Costello, said that the ATA has been "repeatedly emphasizing that the shortage is generally contained to one segment of our industry: the over-the-road or long-haul

[1] The American Trucking Associations is a federation of state-level trucking associations, plus a few associations based on industry segments (such as the Truckload Carriers Association).

[2] The standard occupational code for heavy and tractor-trailer truck drivers is SOC 53-3032. A history of wages and numbers for drivers in SOC 53-3032 who work in any part of Truck Transportation (NAICS 484), 2005 to 2022, is in Section 12: Appendix D.

for-hire truckload segment"(Costello 2019a).[3] Costello suggested that this fact reduced the importance of evidence that the truck driver labor market as a whole works, but the present authors agree with parts of his statement: for-hire long-distance truckload is unique among segments of the industry in having a persistent turnover problem, and this is distinct from a long-term shortage. We disagree that a long-term shortage exists in a form that ordinary market processes will not address, or that requires the kind of policy responses advocated by the ATA (e.g., teenaged truckers in interstate commerce). We also argue that the persistent turnover problem is the primary source of the perception by industry managers that there is a shortage.

In Section 2 we survey extant definitions of an occupational labor shortage, and the empirical methods of identifying one. We review some of the available data bearing upon whether a long-term shortage of long-distance truckload drivers exists, and find it to be unconvincing, although there are clear indications that there have been short-term shortages that were resolved by normal market processes.

In Section 3 we review what is known about the ATA's methodology in identifying a shortage. Although the methods used are not fully transparent, if we could peek under the hood, they might be reasonable. However, based on details revealed in an early ATA-sponsored study, we find that the methods used, by their nature, cannot address the likelihood that normal market processes will resolve the gap being projected between likely demand and likely supply. We conclude that the ATA's projections are not convincing in showing that the problem facing managers in long-distance truckload is correctly described as a long-term shortage.

In Section 4 we address the turnover issue. We review the ATA's data on driver turnover and show that firms reporting to the ATA about operations in this segment, long-distance truckload, have distinctively higher turnover for drivers than is observed in other types of long-

[3] Using the annual average total employment for 2022 of 543,300 in General Freight Long-distance Truckload, NAICS 484121, according to the Current Employment Statistics (Bureau of Labor Statistics Staff 2023a), and using the percentage of SOC 53-3032 in all of NAICS 484 Truck Transportation as of May 2022, or 57.62% (Bureau of Labor Statistics Staff 2023k), gives an estimate of 313,050 drivers in NAICS 484121, which is 15.7% of all non-farm-based employees in SOC 53-3032 (Bureau of Labor Statistics Staff 2023q). Including parts of Specialized Freight Long-Distance (NAICS 484230, which is primarily truckload in operational terms) would increase the percentage to around 20%. Details on the structure of for-hire trucking from the most recent quinquennial economic census appear in Section 10: Appendix A.

distance trucking. To explain why drivers quit so much this industry segment, we cite the relevant literature, the ATA's own explanation, and press reporting that highlights the stories behind the explanation. We conclude that the underlying reason managers in this segment call out a shortage is the continuing business problem of high driver turnover.

In Section 5 we address the underlying economic cause of the persistently higher driver turnover experienced by long-distance truckload firms, as compared to the turnover in other segments: the competitive structure of the industry, which makes a focus on cost minimization strategically central. In Section 6 we then introduce a model of cost-minimizing firm behavior for carriers in this specific setting in which turnover costs trade off against other costs. This model shows why high turnover is a predictable result of the collective effects of the competitive structure within the long-distance truckload segment: positive turnover costs are part of the least-cost mixture of all operational costs.[4] Section 7 reviews why the special circumstances of the period of pandemic recovery do not change our basic analysis.

In Section 8 we then apply our model to analyze two technological changes (the use of truck simulators in commercial driver training, and the introduction of partially autonomous trucks), and a policy intervention (permitting teenaged truck drivers to work in interstate commerce). Partially automated trucks and teenaged truckers are heralded by the industry as helping to address the perceived driver shortage. Using the model, we show that the likely results of these changes are not only not what the industry expects, but may actually worsen the persistently high turnover rate in long-distance truckload. In addition, the widespread use of teenaged truckers in interstate trucking is also likely to lower safety performance. Section 9 offers concluding remarks.[5]

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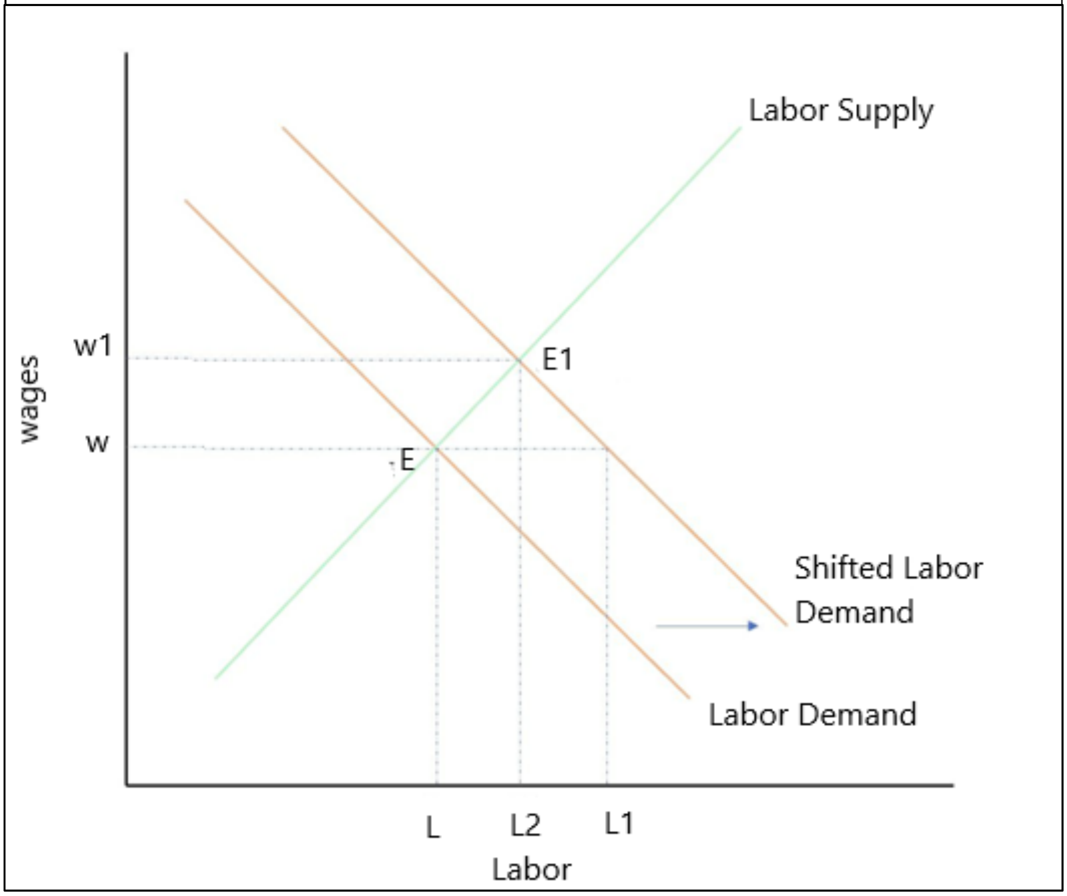
[4] While the model presented is not explicitly a model of "modern labor monopsony" (Manning 2021), its assumption that the wage level is a choice variable for motor carriers is consistent with the modern labor monopsony view that firms do not generally face perfectly elastic labor supply curves, because information about the occupation is costly. New-to-the-industry drivers have significantly less information about actual working conditions than do firms or incumbent drivers (Burks, Carpenter et al. 2009; Hoffman and Burks 2020)), and incumbent drivers face frictional costs of changing firms, once in the occupation (White 2016).

[5] Section 10: Appendix A provides details on the overall structure of for-hire trucking (NAICS 484, Truck Transportation). Section 11: Appendix B reviews data and graphical evidence discussed in Section 2. Section 12: Appendix C provides closed-form analytic solutions for the formal model of cost minimization. Section 12: Appendix D provides wage and count data on SOC 53-3032, Heavy and Tractor-trailer Truck Drivers. Section 13: Appendix E discusses limitations in the data and assumptions of the formal model. Finally, Section 14, Appendix F, displays graphs associated with the Section 7 discussion of the pandemic recovery period.

2. Is there empirical evidence of a long-term labor shortage in long-distance truckload?

From the standpoint of economics, it is straightforward to identify a labor shortage: it occurs when the going wage is lower than the wage that would bring quantity demanded and quantity supplied into balance, a balance which occurs at the point at which the supply curve

Figure 1: Demand and Supply Curves Illustrating How a Shortage May Occur When Demand Increases (the Demand Curve Shifts to the Right)



and demand curve cross, at point E, with wage w and labor supply L, as in Figure 1. Suppose that demand has increased, so that the labor demand curve shifted to the right. Labor employers (motor carriers) will want to hire amount of labor L1 at the original wage w, but sellers (drivers) will only be willing to supply the amount L. Buyers will perceive a shortage in the amount L1 – L, and this will persist until one of two things happens: a) price (the wage) rises from w to w1, at which point drivers will supply labor in the mount L2 (with a new equilibrium at point E1), or b) the labor demand curve shifts back to its original position, at which point both firms and drivers will be satisfied with wage w and labor in the quantity L. (Or, of course, both changes could occur in part, creating a new equilibrium, with a wage between w and w1 and a quantity between L and L2).

There are at least two reasons that a shortage could persist after an increase in demand. One is that some kind of governmental restriction or regulation holds the wage below the level that would balance quantity demanded and quantity supplied. However, this does not apply in the labor market for truck drivers in the U.S. Federal and state minimum wages arguably provide a type of floor below which driver wages may not drop (Jaillet 2018; Premack 2018; Premack 2019), but there are no regulatory price caps. A second might be that the supply response is very slow, such as may be the case with nurses or engineers, for whom the training pipeline may be several years long (Barnow, Trutko and Piatak 2013a; Barnow, Trutko and Piatak 2013b). However, while there is some variation by state, most training courses for the Class A Commercial Driver's License (CDL), the basic credential needed to work in long-distance truckload motor freight take around 6 to 7 weeks of full-time instruction and practice (Minnesota State Staff 2022a; Minnesota State Staff 2022b; The Schneider Guy 2023). In Minnesota the tuition cost in 2022 at a community college was $6,000 (Minnesota State Staff 2022b). Thus, while there may be a lag in driver supply response, along with lags in firm decisions to increase capacity (Miller, Schwieterman and Bolumole 2018), this should be on the order of several months, and it would be surprising if a driver labor shortage were to persist for the long-term for this reason.[6]

However, the demand and supply curves used in this explanation are theoretical entities: they specify counterfactual conditions about what all the buyers and sellers potentially in the market would do under circumstances not currently observed. It is possible under some circumstances to estimate the shape and position of segments of these curves (Greene 2008, Ch. 13) but this is not presently feasible for driver demand and supply using public data that is nationally representative. Since we can't directly observe changes in demand or supply curves, indirect methods have to be used.

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[6] Manufacturing firms appear to respond to demand shocks within about one year, which is consistent with the suggested timeline for motor carriers (Carlsson, Messina and Nordström Skans 2020).

An initial problem is that there is no clear dividing line between a tight labor market for truck drivers (as observed in Burks and Monaco (2019)), and an occupational labor shortage. If we had such a dividing line, the cleanest evidence of an occupational labor shortage arguably would be a significant increase in the number of job vacancies (Barnow, Trutko and Piatak 2013a; Barnow, Trutko and Piatak 2013b). However, the Bureau of Labor Statistics does not publish vacancy data by occupation, but by industrial groupings (Bureau of Labor Statistics Staff 2023h).[7] The nearest category to the type of jobs of interest in the present context is vacancies at all firms in the super sector of Trade, Transportation, and Utilities, which includes NAICS 22 (Utilities), NAICS 42 (Wholesale Trade), NAICS 44-45 (Retail Trade), and NAICS 48-49 (Transportation and Warehousing). This category is a bit too broad to tell us much about drivers in NAICS 484121. And, even if vacancies were available by occupations, the Standard Occupational Code is still too coarse to be a great deal of help (Barnow, Trutko and Piatak 2013a; Barnow, Trutko and Piatak 2013b). In particular, the category of heavy and tractor-trailer truck drivers (SOC 53-3032) is still too inclusive to help us much: out of a little less than 2 million non-farm-based employees in this category in 2022 (Bureau of Labor Statistics Staff 2023q), only 49% work in for-hire trucking, and assuming driver numbers are comparable to total employee numbers, only about 35% of those are in general freight long-distance truckload (NAICS 484121) and about 15% in the specialized freight segments (NAICS 484230) that are operationally similar.[8]

Indirect signals of a significant increase in vacancies would be measures like increased recruiting efforts or more directly economic measures, such as adding sign-on bonuses, increasing pay, improving working conditions, or the like (Barnow, Trutko and Piatak 2013a; Barnow, Trutko and Piatak 2013b). But systematic nationally representative data are not available for our target labor market for these indicators, either.

[7] Some additional breakouts are available by state and by employee-size class, but not for the industry sector of interest here.

[8] However, the history of numbers and mean pay for Heavy and Tractor-Trailer Truck Drivers who are employed in Truck Transportation (NAICS 48400) from 2005 to 2022 on an annual basis is available, and is displayed in Section 12: Appendix D. The breakout of employee numbers by segments of NAICS 48400 according to the 2017 quinquennial economic census is displayed in Section 10, Appendix A.

In a classic study of the supply of engineers in the 1950s, Blank and Stigler (1957) appeal to the fact of occupational choice, and argue that an observable signal of a shortage is a rise in the earnings of the target occupation relative to other occupations requiring the same human capital. Can we find evidence of such a relative wage increase for long-distance truckload drivers? There is no data series showing wages or earnings for precisely the drivers in long-distance truckload trucking, but there are a number of sources that aggregate data on the target subset together with other employees. There is data from the Occupational Employment and Wage Statistics (OEWS) on Heavy and Tractor Trailer Truck Drivers (Bureau of Labor Statistics Staff 2023q); as noted above, the limitation is that this covers all employee drivers in the occupation, including all parts of for-hire trucking, and also those in private carriage. There is data from the Quarterly Census of Employment and Wages (QCEW) for weekly earnings of all employees in General Freight Long-distance Truckload (NAICS 484121 (Bureau of Labor Statistics Staff 2023b)), and for hourly earnings of the same employee group from the Current Employment Statistics (CES) (Bureau of Labor Statistics Staff 2023c); while this is the right industry segment, and drivers will be at least 57% of these employees,[9] these data include clerical, managerial, and executive occupations. There is data from the CES covering Production and Non-supervisory Employees (Bureau of Labor Statistics Staff 2023e), which is closer to being data on drivers, as it is not increased by outlier executive salaries, but it includes non-driving non-managerial jobs, such as customer service workers, and it also includes two parts of general freight long-distance: both truckload and less-than-truckload (NAICS 484120 (Bureau of Labor Statistics Staff 2023d)).

In Section 11: Appendix B we examine two related but distinct proxies for the unavailable direct comparison of general freight long-distance truckload driver hourly earnings with the hourly earnings of workers with comparable human capital in residential construction (NAICS 2361). The first compares the nominal current hourly earnings of *production and non-supervisory employees* in residential construction (NAICS 23610) and those in general freight long-distance trucking (both TL and LTL), from January 1990 to June 2023. The second

[9] Based on the fraction of SOC 53-3032 in all of NAICS 484, for-hire truck transportation (Bureau of Labor Statistics Staff 2023k).

compares the current nominal hourly earnings of *all employees* in residential construction (NAICS 2361) to all employees in (only) general freight long-distance truckload (NAICS 484121), from March 2006 to June 2023. Both proxies tell the same qualitative story. We observe that the hourly earnings of employees in residential construction have been above those of workers in general freight long-distance since about 2000, except for one short period 2011-12 when the gap almost disappeared, before reappearing. These two (proxied) comparisons to the wages of occupational groups often considered to be an important alternative for truckers (Global Insight Inc. 2005) show the opposite of the pattern suggested in Blank and Stigler (1957).

A second indirect approach is that of Arrow and Capron (1959), who point out that when demand increases, the normal response is for price (wages) to rise, with the implication that in the absence of some friction that prevents the labor market from operating normally, higher wages should lead to a greater quantity of labor supplied. They then suggest that if there is a sufficient lag in the increase in the quantity of labor supplied in response higher wages, and at the same time, demand continues to increase (i.e., the demand curve continues to shift to the right), then there could be an ongoing shortage of labor that lasts as long as quantity supplied does not catch up with the increasing level of quantity demanded. Especially if there are lags in the driver supply response in the face of sustained demand increases, such a shortage could be more than a short-term phenomenon.

Can we find evidence for an Arrow-Capron-type shortage in long-distance truckload trucking, that is, are there indications of an ongoing steady increase in demand that shifts the demand curve to the right? Since we can't directly observe the relevant demand curve, we consider what would be appropriate evidence. We start by observing that demand for truckload freight services is derived from the underlying demand for goods being shipped. Changes in this demand are derived from changes in the consumption of goods, in capital investment, and in inventory levels, economic factors that are exogenous to trucking. This implies that the demand curve may shift in (a decrease) or out (an increase) because of a change in freight-consuming sectors of the economy. Each observed combination of average market price and quantity of freight movements supplied represents the joint effect of both the

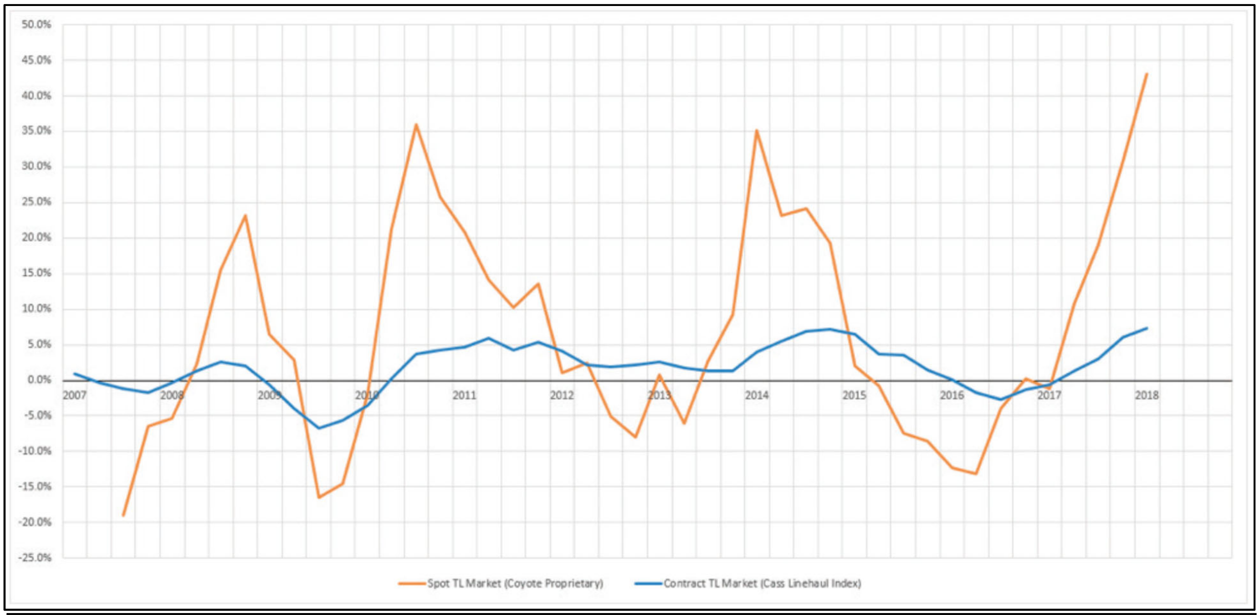


Figure 2: Cycles in the long-distance truckload spot and contract rate indices2007-2018, using proprietary indices of spot and contract market rates (Pickett 2018, page 69).

demand and supply curves, so it is not possible to directly infer changes in demand or supply from observing combinations of prices and the quantity of trucking capacity supplied alone.

However, in long-distance truckload there is a well-developed price mechanism that creates contract prices through regular reverse auctions by large freight users, and there is also a short-term market in which spot prices are established. These price mechanisms have been studied, and a cycle of demand-shifts and supply responses has been analyzed (Scott, Parker and Craighead 2017; Pickett 2018; Caplice 2021; Li, Bolumole and Miller 2022). These analyses together establish that when the spot price index rises sharply year-over-year it indicates a short-term increase in demand, and when that increase is sustained long enough, the contract rate index will rise, also, more slowly (Miller, Scott and Williams 2021). The opposite will occur when there is a reduction in demand, with first the spot price index falling and then the contract rate index following suit. Because change in demand can occur relatively quickly, while there is a lag (on the order of months, not years) in the response of long-distance truckload capacity suppliers, this creates a cycle that has a repeating pattern (Miller, Schwieterman and Bolumole 2018).[10] Figure 2 is a graph from Pickett (2018), illustrating these cycles.

[10] This pattern is reminiscent of cobweb cycles in agricultural production (Ezekiel 1938).

We can reasonably infer that a period of increasing demand for LD TL freight services, as indicated in periods of increasing spot market price indices in Figure 2, is associated with an increase in the demand for drivers in this segment, although the evidence reviewed earlier in this section suggests a modest lag in the decisions of firms to expand capacity (Li, Bolumole and Miller 2022), in the acquisition of new truck tractors to equip new drivers, and in the hiring and/or training of new drivers. When spot market prices drop below contract rates, we can infer the opposite (Pickett 2018; Scott 2018; Caplice 2021; Li, Bolumole and Miller 2022). There are two points to be made. First, as we will see in the next section, this pattern of recurring periods of increased demand for long-distance truckload freight followed by recurring periods of something nearer to a market equilibrium (or even a surplus of freight capacity) is exactly what we will find when examining the actual outcome of one of the ATA's specific shortage predictions. Second, Figure 2 displays a recurring cyclical pattern and does not suggest the Arrow-Capron condition of a sustained rise in demand that would substantiate the claim of a long-term driver shortage.

In summary, we cannot directly observe demand and supply curves in the labor market for drivers in long-distance truckload for-hire motor freight. The evidence does suggest that there are (relatively) short run market adjustments in long-distance truckload capacity and the associated supply of drivers for these trucks. But the available empirical evidence is not consistent with the existence of a long-term shortage in driver supply.[11]

3. Why does the ATA keep claiming there is a long-term labor shortage in long-distance truckload?

The ATA does not routinely explain the details of the methodology used to create its projections of a driver shortage. However, there are some helpful comments in their 2017 and 2019 reports (Costello 2017; Costello and Karickhoff 2019b), and a more complete description occurs in two consulting reports commissioned by the ATA in 1997 and 2005 (Christenson, Aames et al. 1997; Global Insight Inc. 2005). The 2019 report says:

[11] We note that the period of the pandemic shutdown and recovery involved unique circumstances, which will be discussed below in Section 7.

> "Calculating the driver shortage generally requires two steps: first, determining current demand for drivers of Class 8 tractors in order to project that demand in the future based on expected industry growth, and then calculating and forecasting the supply of truck drivers. Here, we utilize Census Bureau data on industry employment, civilian labor force numbers, and demographic data regarding age and gender. The Census Bureau projects growth in civilian labor force by age and gender" (Costello and Karickhoff 2019b).

The ATA's 2005 report, authored by Global Insight, provides significantly more detail. The authors describe a careful examination of Current Population Survey and 2000 Census data, which they use to define the size of the heavy and tractor-trailer trucking occupation, and the proportion of several relevant demographic groups that are in this occupation (Global Insight Inc. 2005, pages 6-18). An estimation of the future demand for truck drivers is made using their proprietary macroeconomic forecasting model of the US economy, and it is compared to the Bureau of Labor Statistics Employment Projections statistics (Bureau of Labor Statistics Staff 2023g), finding a reasonable agreement (Global Insight Inc. 2005, pages 18-22). The authors next project the potential future supply of truck drivers, using their earlier findings that "1) there are sharp, yet systematic, differences in the propensity of workers in different demographic groups to become truck drivers, and 2) there are widely divergent trends in expected population growth by age, race, and ethnicity (Global Insight Inc. 2005, page 25)." Two scenarios are projected, baseline and trend; for trend "we examined the trend since 1994 in the truck driver participation rate in each demographic cell and judgmentally extrapolated this trend to 2014 in a linear fashion" (Global Insight Inc. 2005, page 26). Using these analytic steps the authors conclude that there is a significant potential imbalance between the demand for drivers and the supply (Global Insight Inc. 2005, pages 30-34).

There is nothing wrong, in principle, with this type of exercise.[12] However, it has a significant limitation, because key elements project current patterns into the future. What this approach cannot fully address is how the freight and truck driver markets will respond in the

[12] As noted by Global Insight, the Bureau of Labor Statistics carries out a similar exercise every two years in which the numbers needed in each occupation a decade in the future are projected (Bureau of Labor Statistics Staff 2023g). This does not, of course, lead BLS to declare that occupations have a long-term shortage.

future if the demand for drivers is higher than the supply then available. Other things held equal, in a labor market that operates normally (as existing evidence suggests the driver labor market does (Burks and Monaco 2019; Phares and Balthrop 2022)), the response to an increase in demand for labor is an increase in wages, which in the short run increases the amount of labor supplied by simply moving up the supply curve (existing drivers work more, and individuals who can easily take up driving do so). In the longer run, if such a wage increase is sustained, and wages of relevant alternative occupations do not also rise, then the entire labor supply curve may shift to the right, as more individuals leave other pursuits to acquire the needed credentials and enter the occupation of truck driving, increasing the number of drivers available at all relevant wage levels.

The Global Insight authors realize this, and they point out that part of the problem in the time frame of their 2005 report is the drop in the average weekly earnings of truck drivers, as compared to, for instance, housing construction workers with similar human capital, during the early part of the new century. They observe that this change in relative wages needs to be reversed, and they go on to say "given the need to capture an even higher share of the labor force than truck drivers represented during the 1990s and the increasing constraints placed on the trucking industry by regulatory requirements discussed below, the size of the wage increase needed will be even larger" (Global Insight Inc. 2005, page 31-2).[13]

The Global Insight analysts made this projection in 2005: "In the absence of substantial market adjustments, this driver shortfall – projected demand less projected supply – would rise to 111,000 in 2014" (Global Insight Inc. 2005, page 2). This projection was made long enough ago to be measured against the evolution of the truck driver labor force. How did it work out? Industry stakeholders complained about a driver shortage in 2014 (Reiskin 2014), and spot market prices in long-distance truckload (to which we will return, below) signaled a short-run increase in the demand for freight services. However, stakeholders also saw the labor market adjusting as economic analysis suggests, with truckload driver pay rising (Watson 2014b; Watson 2015a). Truckload driver turnover also increased, as more new-to-the-industry drivers

[13] We reported on a comparison between the nominal hourly wages of employees in General Freight Long Distance and Residential Construction in the prior sections; details are in Section 14.

(who are more likely to exit when their expectations are not met (Burks 2009; Burks, Carpenter et al. 2009)), and incumbent drivers took the opportunity to switch jobs (Watson 2014a; Watson 2014e; Watson 2015b; Miller, Bolumole and Muir 2021). A greater inflow from demographic segments that had not historically provided many drivers was also called out (Watson 2014c). And despite the concerns expressed, firms did well financially (Watson 2015d). Further, in 2016, after market adjustments occurred, driver turnover fell, in a "sluggish market" which offered fewer opportunities to switch jobs (Watson 2016a; Watson 2016b; Miller, Bolumole and Muir 2021).[14] This accords nicely with the pattern suggested by Figure 1, illustrating a cyclical pattern of demand changes and market adjustments. Global Insight's wording was about a potential future shortage "in the absence of substantial market adjustments," and a substantial market adjustment is exactly what the evidence shows occurred. In other words, to project a driver shortage does not imply that the driver labor market is incapable of responding in the normal way.

4. Long-distance truckload does have structurally high driver turnover

The American Trucking Associations has surveyed member firms for some years as to their annualized driver turnover rates by industry segment, and the results are presented in a trade publication, the *Quarterly Employment Report*. Based on this publication, the authors calculated that average annualized turnover report over the entire period from Quarter 3 of 1996 through Quarter 1 of 2023 for large truckload firms (those with $30 million or more in annual revenue) was 92.7% (standard deviation of 18.6%[15]), and it was 77.6% (standard deviation of 16.8%) for small truckload firms. The ATA also surveyed less-than-truckload firms from Q4 of 2000 through Q1 of 2022.[16] The authors calculated that the reported annualized turnover rate for long-distance ("linehaul") drivers in these firms averaged only 11.8% (standard deviation of 3.8%), over the period of the published reports. An additional

[14] As we noted above, available data that is both nationally representative and public reveals important features of market outcomes, but generally cannot clearly distinguish the effects of an increase in truckload capacity (which implies an increase in the effective driver workforce) from a decrease in the demand for truckload services.
[15] Note that the standard deviation is of the mean value over multiple quarters, not of the mean in a given quarter.
[16] Data is missing for Q2, Q3, and Q4 of 2021, and data publication was halted after Q1 of 2022.

comparison may be found in the annual reports of the National Private Truck Council (NPTC Staff 2023). Private carriers are operated by firms in some other primary line of business as a part of that business, so they do not fall within the for-hire trucking industry (Truck Transportation, NAICS 484). But as they employ drivers who may operate over long-distances, they form a second relevant comparison group (Costello 2019a). NPTC reports annualized turnover rates from 2005 through 2022 that averaged 15.0%.[17] The differences between the high rates in long-distance truckload and the two other segments employing long-distance drivers are stark, and their persistence suggests that the distinctive turnover rates in long-distance truckload are structural, not a matter of happenstance.

Why might this be? Industry stakeholders and observers generally agree that the working conditions in long-distance truckload, combined with pay, are the primary reasons. Truckload motor carriers provide point-to-point service between shipper and consignee locations for full trailer-loads of freight. Demand is distributed geographically and temporally in a partially random manner, and if trucks are used efficiently, drivers are essentially treated like pinballs in an old-fashioned pinball machine—they are bounced around the countryside, either within a region, across regions, or as far as nationally, depending on the scope of their firm's work. Additionally, because the needs of shippers and consignees vary, as do conditions such as congestion and weather, driver work hours tend to be long and their work schedules tend to vary across daytime and nighttime (Powell, Sheffi et al. 1988; Belman, Monaco and Brooks 2004; Burks, Carpenter et al. 2008; Suzuki, Crum and Pautsch 2009; Monaco and Burks 2010; Chen, Sieber et al. 2015; Viscelli 2016; Li, Bolumole and Miller 2022). Of course, there is considerable individual variation, but "TL drivers tend to have irregular work schedules, long hours per week, and uncertain and limited time at home" (Monaco and Burks 2010). While LTL road drivers and long-haul private fleet drivers also have long work weeks, they face significantly less uncertainty, since LTL road drivers normally only run between the firm's own terminals, and long-haul private fleet drivers usually operate between freight docks controlled

[17] Because NPTC turnover data is available only annually, its standard deviation of 3.5% is not directly comparable to the ATAs' level of variation.

by their own firm and a limited set of supplier or customer locations. As ATA Chief Economist Bob Costello put it in his discussion of driver supply issues,

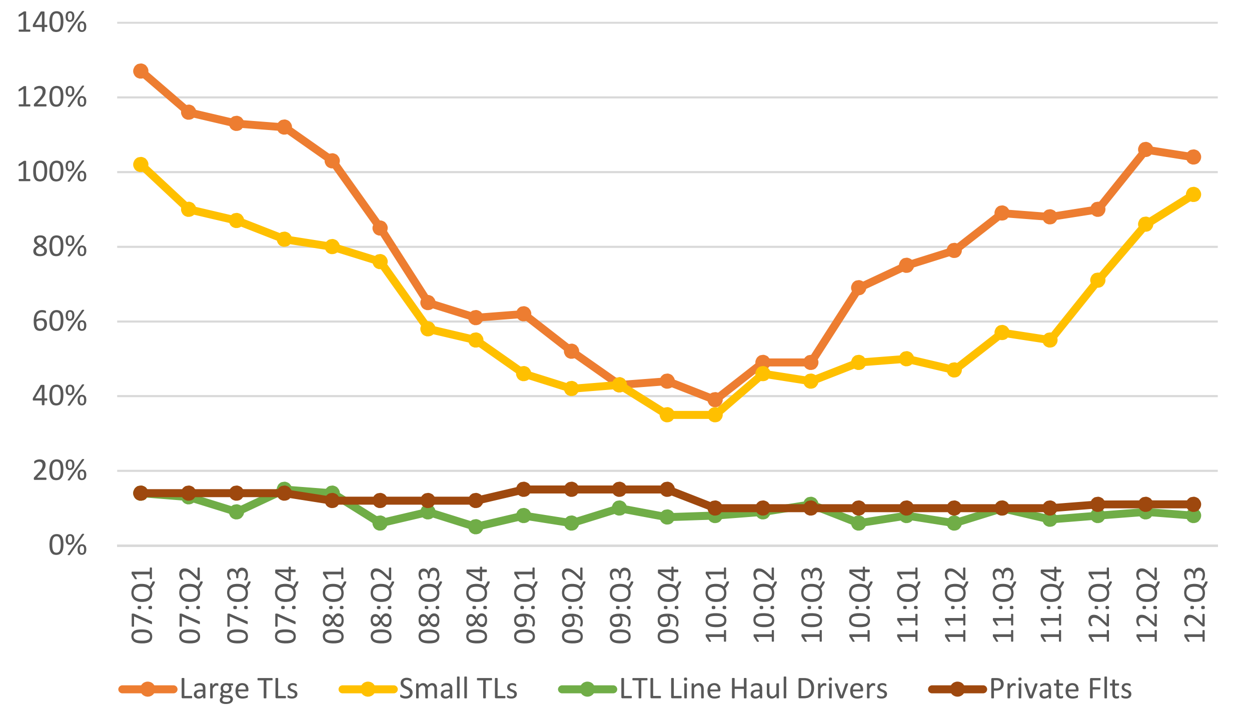
> "(W)e focus only on drivers of Class 8 tractor-trailers. This is where the bulk of the truck driver shortage prevails. Even within this category, the vast majority of the shortage is within the over-the-road, or non-local, for-hire truckload sector. The other main carrier types operating this type of equipment are for-hire less-than-truckload carriers (LTL) and private fleets (i.e., a retailer or manufacturer that operates a fleet of trucks to support their main business). LTL and private fleet drivers are generally paid more and are home more often" (Costello and Karickhoff 2019b).

Pay for long-distance truckload drivers (as with a majority of over-the-road drivers), is by the mile. This is not by miles on the odometer, but by a standard number of miles associated with each dispatch. This means that pay is also variable, since many partially random factors (weather, congestion due to accidents, changing hours at shippers and receivers, available fuel stops) can affect the completion of a dispatch (Monaco and Burks 2010). In fact, one study found that only 35% of new-to-the-industry drivers going through a carrier's training program completed the year of driving that would have made their training free. The authors found that drivers in the top quartile of IQ completed the year at a 50% rate, compared to only 25% for those in the bottom quartile, a result the authors attributed to the challenges of figuring out how to earn enough when new to the job (Burks 2009; Burks, Carpenter et al. 2009).

So, while the long-distance truckload turnover problem has multiple dimensions (including long work hours that can change irregularly), there are two that are primary: uncertain and limited time at home and pay. In fact, human resource firms serving the long-distance truckload industry segment generally say that many factors matter in driver retention, but most of the time, the top two reasons drivers at this type of firm quit are (1) pay, and (2) time at home (Ricks 2020; Coker 2022; Kuder 2022). Or, as New York Times reporter Peter Goodman put it after a long-distance truckload ride-along in 2022, "A 1,000-mile journey through the middle of America reveals the fundamental reason for truck driver shortages: It is a job full of stress, physical deprivation and loneliness" (Goodman 2022).

In fact, as may be observed in Figure 3 during the depths of the Great Recession, the nadir of which came in Q1 of 2010 for truckload turnover rates, when blue collar jobs were very scarce anywhere else in the economy, the annualized turnover rate for large TLs was still at

Figure 3. Annualized Long Distance Driver Turnover Rates by Carrier Type before, during, and after the Great Recession



Truckload and less-than-truckload turnover rates from the *Quarterly Employment Report*, American Trucking Associations; graph by the authors. Private carrier turnover (annual only) from National Private Truck Council summary report of their benchmarking survey (NPTC Staff 2023).

39%, while that for small TLs was 35% (Miller, Bolumole and Muir 2021).[18] We note that after the recession, the annualized turnover rates of large TL firms rose sharply to 106.0% in Q2 of 2012, and those of small TL firms rose to 94% in Q3 of 2012 and then held approximately steady for some time.

In other words, the recession muted but did not end the turnover situation in long-distance truckload, and when the recession was over, high turnover returned. During this

[18] Examination of a proxy for long-distance truckload drivers, the number of production and non-supervisory employees in long-distance general freight, shows that it reached its nadir in April of 2010, at 582,500. As recovery from the Great Recession proceeded in trucking, the real wages of these employees (in 2022 dollars) rose from $23.17 in September 2009 to $25.75 in February 2016 (a gain of 11%), while the number of these employees rose to 674,000 in the same month (a gain of 15.7 %, which is a significant labor supply response; figures calculated by authors from CES data (Bureau of Labor Statistics Staff 2023e)) .

period, line haul LTL drivers and private carrier drivers exhibited stable turnover rates that were much lower than any ever observed in truckload. This is clear evidence of a structural difference between the segments.

In summary, general freight long-distance truckload motor carriers face a structural problem: their labor market has consistently high turnover. However, while we agree with the ATA that this is not the same thing as a structural driver shortage (Costello 2019a), we disagree in finding no evidence of a sustained driver shortage. In fact, all the evidence about employment in general freight long-distance truckload is consistent with the view that this labor market works about as well as any other blue collar labor market in the U.S. We infer that the primary reason that managers in the long-distance truckload segment of for-hire trucking perceive a shortage of drivers is due to the turnover they experience, especially given the fact that fluctuations in turnover rates appear to be associated with cyclical movements in freight demand and freight market response (Miller, Bolumole and Muir 2021; Li, Bolumole and Miller 2022).

5. Competitive conditions in general freight long-distance truckload

The competitive conditions in NAICS 484121 provide the background to our explanation of the sources of high turnover in long-distance truckload. Three general characteristics define the setting: entry barriers, average costs, and brand names. First is the fact that entry barriers are quite low. To be a long-distance truckload carrier an operating authority obtained from the US DOT is needed, which consists of an MC number, from the FMCSA, and a USDOT number. A BOC-3 process agent, which provides an office location in each state that can respond to official inquiries (from a business support firm) is also required. In addition, various registrations at the state level (e.g., for vehicle identification and fuel taxes) and possibly at the local level, and an insurance policy with liability and cargo loss coverage are required (McGill 2023). However, DAT's David McGill estimates the total cost for someone who already has a truck to be $5,000 to $10,000, over the course of two to three months (McGill 2023).[19] The bottom line is that

[19] DAT Freight & Analytics, originally known as Dial-a-Truck, is a US-based freight exchange service ("load board") and provider of transportation information serving North America. Freight exchange services are used to match

starting a motor carrier may be as expensive, or even a bit less expensive, than starting a shop on main street in a small town. As a result, there is considerable churn among general freight long-distance truckload carriers, and entry is significant during strong freight markets. For example, the BLS's Business Employment Dynamics (BED) data for the number of opening truck transportation establishments (NAICS 484) shows a sharp increase in late 2018 into 2019 (Bureau of Labor Statistics Staff 2023l) and especially late 2020 and into 2021, which were periods following the start of bull market cycles in trucking (Caplice 2021).

Second is the fact that average costs for a given freight movement are quite similar across all scales of production, from one truck firms to the thousand truck giants. We know this is so because firms of all sizes have persisted as part of the general freight long-distance truckload market for several decades. This makes sense once one notices that while small firms cannot provide all of the logistics services that larger ones can, freight brokers and 3rd party logistics firms together with smaller firms can match what larger firms can provide.

Table 1. Distribution of General Freight Long-Distance Truckload Firms by Employment Size

Number of Employees	Firm Count
< 5	3,748
5-9	405
10-19	270
20-99	251
100-499	101
500+	73
Totals	
300,550	4,848

Source: Statistics of U.S. Businesses, 2019 Annual Data by 6-digit NAICS Industry and Establishment, U.S. Census Bureau[20]

Third is that the evidence suggests that brand names don't have as large an effect on prices in the sales of general freight long-distance truckload services as in some other parts of the economy. Large shippers or receivers normally accept bids only from large suppliers: carriers or brokers or third-party logistics firms. But as noted above, small carriers can choose to work with large intermediaries (brokers or third-party logistics firms), which provides the potential for market-based competition with large carriers. And in the online marketplaces

material ("loads") that needs to be shipped with over-the-road carriers, which can be hired to move those loads (Wikipedia Editors 2023).

[20] Table 1 is based on U.S. Census Bureau tabulations of actual establishments. It should not be confused with the Federal Motor Carrier Safety Administration (FMCSA) regulatory database, which lists hundreds of thousands of registered trucking operations, almost all very small, in general freight long-distance truckload.

serving the spot market link shippers with thousands of carriers of all sizes (Scott 2018). Industry analysts generally put managerial targets for operating ratios in long-distance truckload in the range of 88 to 92, implying gross margins of 8% to 12% (Lazarus 2013; Marsh 2021). By contrast, a design house (i.e., a "factoryless goods producer" (Fort 2023)) in a market with strong retail brands, such Apple in the market for personal electronic devices, might report a gross margin of 43% (Investor Relations 2023), while a consumer electronics designer and manufacturer such as Sony might be in the range of 33% to 43% (Macrotrends staff 2023).

It should be noted that, by contrast with general freight long-distance truckload, there are modest entry barriers in general freight long-distance less-than-truckload (LTL). Less-than-truckload firms require terminals in each local area served to aggregate shipments into and disaggregate shipments from full loads sent over the road between terminals.[21] This creates a potential entry barrier because every geographic market in the U.S. is already served by incumbent less-than-truckload firms. So, a new entrant will have to match the service times provided by incumbents when it adds terminals to its network. But building enough shipment density on new network links to match the revenue of incumbents generally takes time, and the operational costs accruing during this period of low density and hence low revenue are sunk (Monaco and Burks 2010). The only firm that ever tried to enter LTL on a large scale was Leaseway Express, which did so soon after deregulation in 1981. It failed within two years (Wong 2001). Most LTL firms expand by adding one or a few terminals on the periphery of their network, so that existing customers who ship to these additional areas form an initial customer base. The only *de novo* entrants that succeeded were two that entered in the same era as Leaseway Express, and they did so at small scale.[22] While LTL entry barriers have arguably not resulted in oligopoly pricing (Nebesky, McMullen and Lee 1995), the nature of competition in long-distance LTL is primarily among incumbents, as compared to the ongoing potential for entry in general freight long-distance truckload.

[21] An exception is found in some parts of refrigerated transport, in which a truckload of smaller shipments may be loaded on one trailer and delivered over longer distances in multiple stops by one driver (Correll 2021).

[22] These were Arkansas Freightways, which later became American Freightways and then part of FedEx Freight, and Con-Way Central Express, which later became part of XPO.

The net effect of these three segment characteristics is that firms enter and leave general freight long-distance truckload at substantial rates (Guntuka, Corsi et al. 2019; Miller, Phares and Burks 2023), and competition among firms is primarily based on price. This in turn implies that a central managerial strategy is cost containment. Since labor costs typically represent about 40% of average marginal costs across the industry (Leslie and Murray 2023), this makes controlling labor costs a key strategic goal.

6. A model of cost tradeoffs in general freight long-distance truckload

We construct a small, stylized model of the decision task facing the typical firm in the general freight long-distance truckload segment trucking industry. This model formalizes the tradeoffs such firms face between capital costs and the components of labor cost, given that minimizing the total costs of operation is a primary business goal.

We use a simple specification of the production technology that includes a feedback loop in which earnings limitations due to too little work, and driver "burnout" due to long times away from home due to too much work, both lead to higher quit rates. The out-of-pocket components of labor cost are the sum of the wages paid and the replacement driver training costs incurred. But there is a third, implicit cost. Both out-of-pocket components are affected by the dispatch rate, which one may think of as the intensity with which each driver/truck combination is utilized. Higher dispatch intensity moves more freight without increasing the number of trucks, and other things equal, gives drivers more pay and less home time. Drivers have a preferred amount of home time, relative to any given wage. So, if they are getting either less or more work than they prefer, their quit rate rises. More specifically, since other things equal the carrier would prefer higher dispatch intensity, up to full time utilization of each driver/truck combination, the value of revenue foregone on freight shipments not hauled because it would reduce home time too much is the implicit third component of the cost of obtaining effective TL labor.[23]

[23] Global Insight spelled this relationship out, "Although competitive wages are a major factor in attracting workers to the trucking occupation, quality of life issues are more frequently cited as the primary consideration for worker retention in the industry. The major irritants for drivers are extended periods on the road away from home and unpredictable schedules for getting home. Firms impacted the most are those with less flexibility to address this

We show that when there is this kind of trade-off between the intensity of truck use and the other two components of the cost of effective TL labor, the result is a that a rational, cost-minimizing firm will find its total costs are lowest when it has a positive level of turnover. The specific rate of turnover that is optimal will depend on the various sensitivity and technology parameters specified in the model, but qualitatively, this result provides a theoretical foundation that explains the fact that turnover has been persistently high for decades in long-distance TL.

The model can also be used to show how optimal wages and optimal turnover may change in response to changes in model parameters. A change might result from a new policy such as, for example, the widespread use of truck simulators in training new truck drivers, or the introduction of teenaged truck drivers (who are often argued to like the working conditions better than older drivers (Costello and Karickhoff 2019b)). Or such a change might result from the introduction of technology in the form of partial truck automation, which may have the potential to allow one driver to handle the human-driven parts of more dispatched. These issues will be addressed in Section 8.

The formal specification of the model is as follows, with an explanation below each equation.

(1) $\underset{\rho,\, W_S}{\text{MIN}}\ (P_K K + W_S S + P_T T)$, subject to constraints (2) through (7), as displayed below.

The firm's goal is to minimize total operational costs by choice of "dispatch intensity," ρ, and the wage paid per shipment, W_S, subject to several conditions. In the objective function 1), total costs are the sum of capital costs, wage costs, and training costs. Each of these is further specified: capital costs are the product of an imputed price of capital (P_K) and the quantity of capital (or "trucks," K); wage costs are the product of wages-per-shipment (W_S) and the number of shipments (S); and training costs are the product of the price to train one new driver (P_T) and the number of new trainees (T) required as a result of quits.

(2) $S = \rho K$

major negative aspect of the long-haul truck driver's job. *The marginal loss in productivity that may result from designing schedules to get drivers home more often must be weighed against the high cost of turnover*" (emphasis added) (Global Insight Inc. 2005, page 2).

Equation (2) specifies a simple technology—a relation between the number of trucks (the amount of "capital" (K)) and the number of shipments (S) that can be handled per time period, scaled by the dispatch intensity, ρ. It tells us how many shipments a single truck completes during a standard time period. Viewed from the other end of the telescope, this equation gives the demand for trucks (K) as a fixed proportion (1/ρ) of the number of shipments (S), given the current dispatch intensity ρ.

(3) $\lambda K = D$; $(0 \leq \lambda \leq 1)$

(4) $S_D = \lambda S$

Equation (3) imposes a fixed proportionality (λ) between the number of drivers (D) and the number of trucks (K). Equation (4) denotes the proportion of deliveries with drivers attending. While λ is by default equal to 1, we include it as a potentially changeable parameter in order to allow one route by which the partial automation of the driver's task, which might reduce it to a value less than 1, could enter the model.

We next create a small auxiliary analysis that allows us to capture the effects of both too low and too high shipments per driver. Drivers (D) are paid a constant wage (W_S) per shipment assigned to that driver, and an individual driver's income (I) is linear in the number of shipments (S_D/D) that the representative driver transports:

(a) $I = W_S \, {}^{S_D}/_{D}$

While increasing shipments per driver raises driver income, it also reduces the driver's leisure (home time) in an economically meaningful way. We model an individual driver's economic loss due to reduced leisure as a convex function of the number of shipments assigned to that driver. Specifically, we model the economic value of lost leisure (L) as the square of the number of shipments per driver per month:

(b) $L = \left({}^{S_D}/_{D}\right)^2$

This produces the following mathematical relationship: the net value to the driver of any given number of shipments becomes the following NetBenefit(·) function, which tells us that the driver's net benefit is the wage less the subjective cost in lost home time:

(c) $\text{NetBenefit}(S_D/D) = W_S(S_D/D) - (S_D/D)^2$

To maximize this, we set the first derivative (with respect to shipments per driver (S_D/D), equal to zero:

$$\text{(d) } d[\text{NetBenefit}]/d[S_D/D] = W_S - 2S_D/D = 0$$

Thus, the optimal level of shipments per month for an individual driver, when both too little pay and too little home time are disliked, is given by

$$\text{(e)} (S_D/D)^* = W_S/2.$$

We graph this relationship in *Figure 4*. The net economic gain from the driver's point of view is the difference in height between the two curves, which is optimized as indicated in the Figure. At shipments below the optimal point, the marginal value of income is higher than the marginal value of the leisure lost in acquiring it. At shipment levels beyond the optimal point, the marginal value of income is less than the marginal value of leisure lost in acquiring it. *Figure*

Figure 4. Income and the Value of Lost Leisure (here leisure is home time)

4 shows that the optimal balance for the driver is where the marginal value of income and the marginal cost of lost home time is equal, which is where the gap between the two values is the largest.

Having identified the optimal level of work intensity from the driver's point of view, in equation 5 we define a two-sided "misery index" (variable μ) as the square of the distance between actual work intensity and optimal work intensity.

$$(5)\ \mu = \left(\left({}^{S_D}/_{D}\right) - \left({}^{W_S}/_{2}\right)\right)^2$$

Equation 6 specifies the drivers' quit rate φ as a function of the misery index μ and a sensitivity ("sensitivity to misery") parameter β:

$$(6)\ \varphi = \beta\mu = \beta\left(\left({}^{S_D}/_{D}\right) - \left({}^{W_S}/_{2}\right)\right)^2$$

Figure 5. Shipments per Driver per Time Period versus Quit Rate

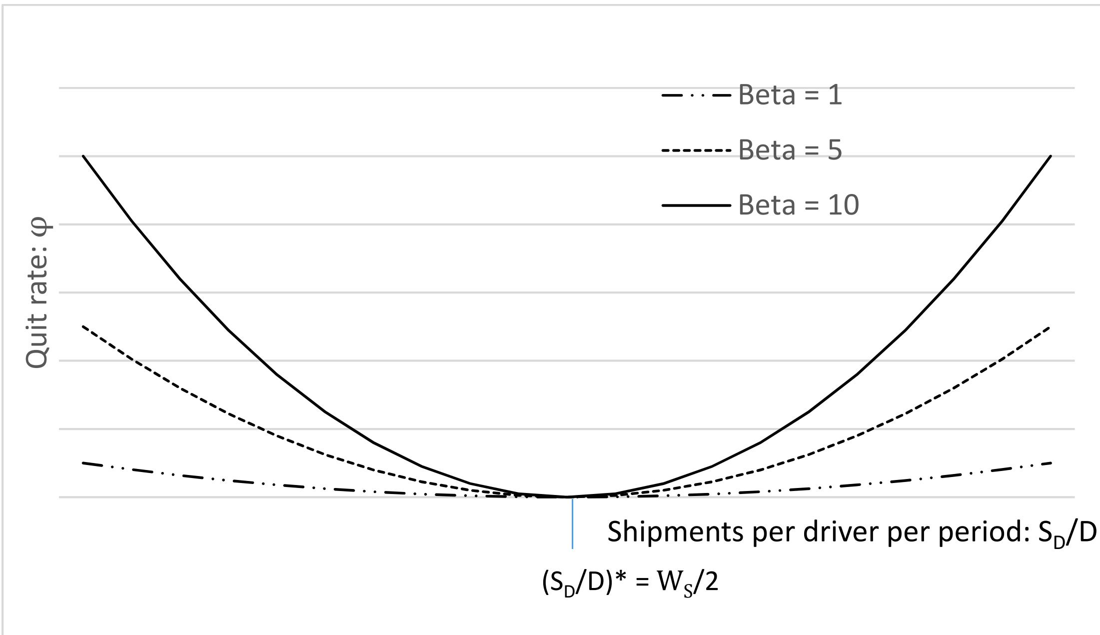


Figure 5 exhibits the relationship between shipments per month per driver, S_D/D, and the optimal quit rate, φ, graphically, for three different values of β. If the wage per shipment for deliveries rises, the curves shown shift rightward.

Finally, with a definition of the quit rate in hand, we can specify the level of turnover:

(7) $\quad T = \varphi D$

To summarize, the firm solves the following cost minimization problem, with constraints (5) and (6) capturing the driver's tradeoff between income and leisure, and the resulting tradeoff for the firm between dispatch intensity, wages, and quits.

(1) $\quad \underset{\rho,\, W_S}{\text{MIN}}\ (P_K K + W_S S + P_T T)$, subject to constraints (2) through (7)

(2) $\quad S = \rho K$

(3) $\quad \lambda K = D; \qquad\qquad (0 \le \lambda \le 1)$

(4) $\quad S_D = \lambda S$

(5) $\mu = \left(\frac{S_D}{D} - \frac{W_S}{2}\right)^2$

(6) $\varphi = \beta\mu$

(7) $T = \varphi D$

This model is simple enough that it can be solved analytically in closed form. We present only one key solution here; the others are presented in Section 12: Appendix C. Here is the resulting formula for the optimal value of φ, the quit/turnover rate:

Solution: $\varphi^* = \left[\frac{P_K}{(2\beta P_T - 1)\lambda P_T}\right]$

Notice that this expression is NOT zero, unless one of the following conditions hold:

a) $P_K = 0$, i.e., unit capital cost (price of a truck) is zero,

b) $P_T = \infty$, i.e., unit training costs are infinite,

c) $\lambda = \infty$, i.e., the number of required drivers per truck is infinite.

This makes explicit a fundamental insight from this model: high turnover rates can emerge not just due to mistaken human resource policies, but also as an optimal choice driven by the rational calculus of cost minimization, a situation which might then be generalized across the industry by competition among firms. We can observe that the actual optimal level of quits depends directly on the values of key parameters, including the ones listed immediately above, and also β, the sensitivity of the typical driver to misery in the form of a workload that is either too low (implying too little pay) or too high (implying insufficient time at home).

In order to use our model for policy analysis we need to review the comparative statics, which tell us how the optimizing behavior of the firm leads to effects on the values of the endogenous variables (those determined within the model) that result from changes in the model's parameters, or those factors determined outside the model which shape the firm's choices.

In Table 2 we restate the list of parameters, endogenous variables, and choice variables of the model, while Table 3 exhibits the comparative statics results. Each comparative statics result shows the effects of a change in one parameter on all the endogenous variables while keeping the other parameters constant.

To understand what Table 3 shows us, we consider the effects of key parameters on the endogenous variables, in order. The model has constant returns to scale technology, so it isn't surprising that changing the scale of operations (S: the total number of deliveries) affects the absolute volume in certain respects but does not affect relative prices or quantities. An increase

Table 2. Parameters, Endogenous Variables, and Choice Variables of the Model

Exogenous Parameters:

S:	Total Shipments (demand for the firm's services)
λ:	The required ratio of drivers-to-trucks
β:	Sensitivity of "quit rate" to driver misery, or the gap (whether above or below) between optimal home time and actual home time
$\mathbf{P_T}$:	Training cost per new driver
$\mathbf{P_K}$:	Cost/unit capital (i.e., of trucks); rental rate of capital

Endogenous Variables (values determined by firm's optimal choices of ρ and W_S)*:*

$\mathbf{S_D}$:	Shipments attended by drivers
D:	Stock (#) of drivers currently employed
K:	Amount of capital currently employed (# of Trucks)
T:	# of Trainees Required, in order to maintain stock (D) of Drivers
μ:	Misery index, deviation (+ or -) from the driver's optimal shipments
ϕ:	Quit rate

Choice Variables (varied by firm to achieve optimization, which here is cost minimization)

ρ:	The dispatch intensity, or shipments (S) per truck (K)
$\mathbf{W_S}$:	Driver compensation per shipment (S_D)

in shipments has no effect on the optimal wage or the optimal dispatch intensity. It raises the number of trucks and drivers, as well as the number of trainees, and total costs, but it has no effect on the driver dissatisfaction or the quit rate.

A decrease in the drivers-to-trucks ratio (λ) signifies a higher penetration of autonomous vehicles, which we will consider further in Section 8. Endogenous variables with a positive effect will also fall, while those with a negative effect will rise. This would lead the cost minimizing firm to increase dispatch intensity, and raise wages, but not enough to offset an increase in both the driver misery level and the optimal quit rate. Total costs can be expected to fall, since the number of drivers falls to meet the smaller truck fleet and the smaller effective percentage with actively attending drivers.

When average driver aversion to under- or over-work (β) rises, the optimal dispatch rate falls, and the optimal wage rises. To avoid higher quit rates and training expenses, firms strategically employ more trucks and drivers. Training costs also increase to some degree, since even with a constant quit *rate*, the higher stock of drivers yields more *quits*. Considering a change in the other direction, if teenaged drivers like being on the road more than older drivers, they may be less sensitive to under- and to over-work, relative to their desired number of shipments per month. So, the average value of β will fall. Thus, endogenous variables with a positive responses will also fall, and those with a negative response will rise. We will consider this further in Section 8.

Table 3. Comparative Statics Results from Model

	Choice Variables		**Endogenous Variables**					**Cost**
Parameters	**ρ**	**W_S**	**K**	**D**	**μ**	**ϕ**	**T**	**C(S)**
S	No Δ	No Δ	Pos	Pos	No Δ	No Δ	Pos	Pos
λ	Neg	Neg	Pos	Pos	Neg	Neg	Pos	Pos
β	Neg	Pos	Pos	Pos	Neg	Neg	Neg	Pos
P_T	Neg	Pos	Pos	Pos	Neg	Neg	Neg	Pos
P_K	Pos	Pos	Neg	Neg	Pos	Pos	Pos	Pos

"Pos" means that a change in a parameter moves the variable in that column in the same direction (increase -> increase and decrease -> decrease). "Neg" means a change in a parameter moves the variable in that column in the opposite direction (increase -> decrease and decrease -> increase). "No Δ" means a parameter change has no effect on the variable in that column.

When training costs (P_T) rise, the firm will lower its dispatch intensity and raise wages. Both have the effect of lowering driver dissatisfaction and the turnover level. A less aggressive dispatch means more trucks and more drivers are necessary to meet any given level of demand, but it is worth it for the firm to lower the number of trainees necessary as replacements for driver exits. If training costs fall, the opposite occurs; we will consider this further in Section 8.

An increase in the price of capital (P_K) leads the cost minimizing firm to raise the aggressiveness of its dispatch, and also to raise wages. As purchasing trucks becomes more expensive the firm will substitute towards driving the existing fleet harder, thus meeting existing demand with fewer trucks and fewer drivers. To ameliorate the increased misery of drivers, the firm raises wages somewhat, but not enough to prevent the quit rate from rising nor to prevent training numbers and training costs from also rising. Effectively, the firm substitutes training new drivers for the suddenly more expensive trucks.

Note that the model makes a number of simplifying assumptions, as is typical of all such models. The key point is that we have retained the variables that are of central causal importance in the cost structure of a typical long-distance truckload motor carrier, so that we have captured the central features of the cost minimization problem faced by truckload firm managers.

7. Did the Pandemic Recovery Change the Analysis of Long-Run Conditions in Long-Distance Truckload Motor Freight?

The pandemic shutdown of significant parts of the U.S. economy in early 2020, and the policy actions taken afterwards during 2020 and 2021 to support economic recovery created an exceptional period in the history of our economy (Phares, Miller and Burks 2023). The indirect measure of labor shortages we identified in Section 2, a large and persistent increase in job openings, showed a qualitative change from prior periods for much of the economy. In particular, the level of job openings in the super-segment of Transportation, Warehousing, and Utilities, which is the closest proxy available for jobs in truck transportation, rose from a low of 274,000 in April 2020 to a peak of 705,000, or more than two-and-a-half times higher, in December of 2021 (Bureau of Labor Statistics Staff 2023t). The total number of employees in general freight long-distance truckload motor freight, the nearest proxy we have for drivers in this segment, rose from 498,300 in July of 2020 to 555,100 in August of 2022, an increase of 11.4 % (Bureau of Labor Statistics Staff 2023a). The producer price index specifically for general freight long-distance truckload rose from 145.0 in May 2020 to a peak of 232.5 in May 2022, an increase of more than 60% (Bureau of Labor Statistics Staff 2023s). Finally, the number of new establishments in long-distance truckload (NAICS 484121), a proxy for the entry of owner-operators and small trucking firms into the long-distance truckload market, also grew substantially, from 45,901 in Q1-2020 to 62,667 in Q4-2022, an increase of 36.6% (Bureau of Labor Statistics Staff 2023m).

There are two important points to be made about this period. First, as noted in the statistics cited in the preceding paragraph, and despite worries expressed by truckload motor carrier managers (Gallagher 2021), important industry analysts and the data agree that the labor supply and overall capacity response to the increase in freight demand was substantial and robust (Solomon 2021). Second, by the end of 2022, the long run path of both truckload capacity and the truckload labor market had peaked, and was returning to a down cycle, similar to the cycles oversupply and downward pressure on rates discussed in Section 2. Two of the key indicators mentioned in the prior paragraph have fallen significantly since their peaks. Job openings in the Transportation, Warehousing, and Utilities super sector fell from 705,000 in December 2021 to 444,000 in June 2023, a drop of 37% (Bureau of Labor Statistics Staff 2023t). More importantly for our argument, the producer price index specifically for general freight long-distance truckload fell from 232.5 in May 2022 to 177.5 in August 2023, a drop of 23.7% (Bureau of Labor Statistics Staff 2023s). The fact that nationally-representative data on the total number of employees, and on the total number of establishments, in long-distance truckload have not yet shown declines (Bureau of Labor Statistics Staff 2023a; Bureau of Labor Statistics Staff 2023m) is consistent with the views of multiple industry stakeholders and observers, who have called out over-capacity due to a decline in demand (in contrast to a shortage of drivers leading to a shortage of capacity), and declining profits for many firms (Solomon 2021; Maiden 2023a; Maiden 2023b). One of the industry's prominent driver pay specialists said, "Yes, the freight market has been in a down cycle since the middle of 2022" (Shaver 2023), and a prominent analyst expressed the hope that things might turn around by mid-2024 (Fuller 2023).[24,25]

The conclusion we draw is that the special circumstances of the pandemic recovery did not change the underlying market fundamentals of the competitive situation facing long-

[24] Section 14 Appendix F displays two graphs associated with the pandemic recovery period and its over-supply aftermath, one for total employees, and the other for the producer price index, for general freight long-distance truckload (NAICS 484121).

[25] It is noteworthy that a human resources firm specializing in long-distance truckload truck drivers issued a report in 2023 based on 36,000 survey responses from client employees citing the reduced ability to assign enough weekly miles to drivers "amid a freight slowdown" as the largest current challenge to retention (Workhound Staff 2023). This is consistent with the part of the "driver misery index" in the model of Section 6 that captures dissatisfaction due to too little work.

distance truckload motor carriers. The pandemic recovery era saw some of the supply chain issues the ATA has been warning of for years, but they were due to the special circumstances of that period. Now it appears that the cyclical pattern of under- and over-capacity resulting from somewhat lagging supply responses to what can be very rapid changes in the derived demand for trucking has returned. We expect the long-term issue of structurally high driver turnover, and the associated perception of managers battling this ongoing issue that there is a long-term driver shortage, will re-emerge.

8. Discussion and Implications for Technology and Policy

The main point of the model presented in Section 6 is to exhibit the causal structure of tradeoffs between the different components of total operational costs that could lead a cost-minimizing individual firm to rationally choose to set wages at a modest level and dispatch intensity relatively high, so that turnover is relatively high because many drivers don't earn enough to be willing to tolerate the limited home time and the other negative features of the working conditions. Then, due to the structure of competition between firms described in Section 5, a similar strategy is likely to be employed by the majority of the firms in this segment of the industry. Let us briefly recap the evidence (presented in more detail in Section 4) that the "run hard, pay modestly, and have high turnover" mixture of costs is the one that a majority of medium and large firms in long-distance truckload have chosen, since the mid-1980s.

The ATA itself reports that, among the firms that respond to its employment surveys, general freight long-distance truckload firms reported uniquely high driver turnover as compared to drivers in other long-distance operations. In Section 4 the authors reported that the average annualized turnover rate published by the ATA from Quarter 3 of 1996 through Quarter 1 of 2023 was 92.7% for large truckload firms (those with $30 million or more in annual revenue), and 77.6% for smaller truckload firms. We compared this to less-than-truckload linehaul drivers at 11.8%, and drivers in the National Private Truck Council membership survey at 15%. While the survey data begins only in 1996, statements by industry stakeholders show that this pattern of turnover rates first arose in the mid-1980s, soon after the economic deregulation of the trucking industry in 1980 (Casey 1987; Mele 1988; Cooke 1989). Again, from

Section 4, even during the lowest point of the Great Recession, when blue collar jobs were very hard to find, the lowest turnover level reached by large truckload firms was still 39%, while smaller ones reported 35%. And turnover rates rose again with the economic recovery.

There is one further piece of evidence to consider. Observing the persistence of high turnover in its industry segment after deregulation, one of the largest general freight long-distance truckload motor carriers, J.B. Hunt, in 1996 decided to try to break out of the "run hard, pay modestly, and experience high turnover" pattern. They announced they would raise starting wages by 35%, close their training school for inexperienced drivers, and hire only experienced drivers. They expected the reduction in crashes and turnover to pay for the higher wage costs. They implemented this plan in February 1997. Their results were extensively analyzed (Belzer, Rodriguez and Sedo 2002; Rodriguez, Rocha et al. 2003; Rodriguez, Targa and Belzer 2006). Investigators found that turnover rates and crash rates were both cut in half. However, in March of 2002 managers at Hunt unwound this change, cutting their starting pay back to near its earlier level (Corridore 2003). This shift was associated with a change of strategic focus from long-distance truckload freight movements towards intermodal freight, in which drivers only pickup and delivery at either end of a linehaul that is done with trailers or containers on railcars.[26] A reasonable conclusion is that moving from the "run hard, pay modestly, and have high turnover" cost mixture to that of "run hard, pay more, and have lower turnover," was not actually cheaper, and was therefore less profitable. The Hunt case is, in effect, the "exception that proves the rule." The model presented in Section 6 provides a foundation in economics for this explanation.

8.1 Implications for Technological Changes

The first application of our model concerns two technological changes. One is the introduction of truck simulators in commercial truck driver training, and the other is the introduction of partially automated trucks. The first simulators were developed nearly 100

[26] Hunt reported 38.6% of revenue (with 6,879 drivers) from random-dispatch truckload and 31.5% (with 1,410 drivers) from intermodal services in fiscal year 2000 (Roberts and Thompson 2001). In fiscal 2012 the percentages were 9.6% (with 1,282 drivers) for truckload, while intermodal was 60.8% (with 4,331 drivers) (Garrison and Thompson 2013).

years ago for the purposes of training pilots to fly using instruments alone (i.e., without visual references) (Page 2000). They were developed over time for further training of pilots, and for vehicle applications such as maneuvering armored combat vehicles (Orlansky, Dahlman et al. 1994). The extension to training drivers of large commercial vehicles began to be used around the end of the 20th century (Rudolfs 2006). Research shows their effectiveness in teaching maneuvering and safe driving behavior (Hirsch, Choukou and Bellavance 2017). The question to be addressed here is this: suppose the effectiveness of training with simulator is either the same or better than without them, and that the effect of adding them is to substitute cheaper tools and teaching practices for more expensive ones using actual trucks, so that the net cost of effectively training a new commercial truck driver decreases (Allen and Tarr 2005; Morgan, Tidwell et al. 2011). If this is the case, we can look to the comparative statics of our model to predict the results once competition over costs spreads the use of simulators sufficiently throughout the industry. If the value of P_T, the cost of training a driver decreases, holding the other parameters fixed, the prediction is that the dispatch intensity will rise and driver misery will increase (due to too little home time), the wage rate will fall, the stock of trucks and drivers will fall, the turnover rate will rise, and to compensate, the number of trainees will rise (see Table 3). This is a surprising side effect of introducing simulators, if the introduction actually lowers the net cost of training.

The second technological change is the introduction of partially automated trucks. We need to specify what is meant by this. ATA Chief Economist Costello put it this way in 2019, "While we are still decades away from truly driverless Class 8 trucks running on the highway as a normal part of the industry; advanced driver-assist technologies in heavy-duty tractor trailers could eventually have a positive impact on the driver shortage by making the job less stressful, and the more sophisticated technology may also attract younger individuals to truck driving" (Costello and Karickhoff 2019b). This level of driver assistance—in braking, steering, warning—is typically designated Level 2 in the taxonomy of the Society of Automotive Engineers (SAE) (Society of Automotive Engineers 2016; Viscelli 2018). It was already penetrating the heavy duty truck fleet as of 2021 (FMCSA Staff 2021). In terms of our model, the effects of this change are naturally interpreted as representing a decrease in β, the model parameter expressing the aversion of the typical driver to getting either too little work (and not enough pay) or too much work (and not enough home time). The results predicted are clear, and match those for a decline in the cost of training, P_T. If β falls, then holding all other parameters constant, dispatch intensity will rise, the wage rate will fall, the stocks of driver and trucks will fall, and driver misery and the optimal turnover rate will rise, and to compensate for higher turnover, the number of trainees will also rise.

A further point can be made about more complete truck automation. Although it hasn't happened as of mid-2023, at some point it may become possible for an automated driving system in a tractor-trailer to partially replace the driver; this would be SAE automation Level 4 (Society of Automotive Engineers 2016; Hickman, Levy et al. 2018). We specify "partially replace," because drivers carry out many other necessary duties besides just guiding the vehicle through traffic down the highway.[27] A 2020 analysis of data collected by the Bureau of Labor Statistics from firms about the requirements of truck driving jobs showed that a significant fraction of drivers' time is used in other tasks besides driving, many of which are essential to the freight transportation business (Gittleman and Monaco 2020). Let us suppose, however, that an automated system might be good enough to drive unattended on specific and well-defined sections of the interstate system while the driver, who would be needed to handle other tasks and to drive most of the time, used a sleeper berth to take an off-duty break (Hickman, Levy et al. 2018; Viscelli 2018). In terms of our model, in effect this would make λ, the parameter specifying the number of drivers required per truck, decrease to less than one. Holding all other parameters fixed (including the number of shipments or loads), the comparative statics of the model (Table 3) predict that the stocks of trucks and drivers would fall, as would the number of trainees. Dispatch intensity and the wage rate would both rise, but the wage increase would not be sufficient to keep either driver misery or optimal turnover from also rising. This result is not what would be expected by industry stakeholders.

[27] Costello also notes that "Many years from now and well beyond the dates of this report, one could envision an environment when the longer, line-haul portion of truck freight movements are completed by autonomous trucks and local pick-up and delivery routes are completed by drivers. However, motor carriers should not count on this being an option for many decades" (Costello and Karickhoff 2019b). While automation technology has improved since this statement was written, the evaluation still seems correct (Viscelli 2018).

8.2 Implications for Teenaged Truckers

Finally, we turn to a policy change for which the industry has lobbied (Spear 2023). Under present regulations, drivers aged 18, 19, and 20 can only operate vehicles requiring a Class A commercial driver's license within the boundaries of each individual state.[28] At the direction of Congress, the USDOT has established a pilot program to give drivers in this age group an "apprenticeship" option to be able to train for, and then drive, tractor-trailers in interstate commerce (Federal Motor Carrier Safety Adminstration 2023). There are at least three significant issues with this concept.

First, despite evidence showing that training is also very important at any age (Dunn, Soccolich and Hickman 2020), this population is significantly more dangerous on the highway than are older drivers (IIHS Staff 2023). The ATA's non-profit research arm, the American Transportation Research Institute (ATRI), documented this when it issued a report exploring how the subset of teenaged drivers who were safe enough to be like older drivers could be selected (Boris and Luciana 2017; Brewster, Boris and Luciana 2021). However, this work has not been highlighted since the bipartisan Infrastructure Investment and Jobs Act (2021) required the FMCSA to start the younger driver apprenticeship program, which does not use such a selection process.

Second, the reason for teenagers is not just to have a larger pool to draw from, but the perception that younger drivers might like the job more, especially because they may not mind being gone from home as much. ATA Chief Economist Costello argued this is a "reason to consider drivers under 21 years old. That is the age when, in many cases, a person wouldn't mind being on the road, before starting a family". This appears to be true of younger drivers within the pool of those currently able to legally drive in interstate trucking. While a study by ATRI found that drivers from 21 to 30 who had just completed a driving apprenticeship program ranked pay first and "more regular or flexible hours" (i.e., more ability to be at home when desired) as either second or third factors leading them to stay with a carrier, about a sixth cited "love of the job" (Leslie and Crownover 2022). So, which dispatches will drivers 18 to 20 who

[28] As the ATA notes, the formal restriction is that younger drivers cannot haul interstate freight (i.e., freight that moves across a state line as part of its transit), irrespective of whether the current dispatch/truck movement is only intrastate (Costello and Karickhoff 2019b; Spear 2023).

“love the job” get? A good bet would be the longest and most irregular ones, such as cross-country loads that lead to long times away from home, and often create the greatest safety challenges due to fatigue.

Third, drivers and firms participating in the pilot are, by definition, self-selected. They cannot remotely represent the entire populations of firms and teenagers, and this fact essentially guarantees that if the pilot is successful, a scaled-up rollout to the industry and teenagers at large will not match this success, a problem experimental economists have labeled “voltage drop” (Al-Ubaydli, List et al. 2017; List 2022). In addition, as the Insurance Institute for Highway Safety pointed out, the original plan for the analysis of the pilot program will compare the self-selected participants, who are subject to a number of safety restrictions, to control drivers who are not subject to these restrictions, making the comparison statistically invalid (IIHS Staff 2023).

But there is worse news. If the picture of how long-distance truckload market segment works presented herein is accurate, allowing teenagers to operate tractor-trailers in interstate commerce will not actually produce the intended result, a “reduction in the driver shortage,” or as we think this goal should be stated more accurately, a reduction in the turnover rates that lead to the perception of a shortage. A manager of an LD TL firm that has truck tractors without drivers might look at a successful employee’s younger sibling (usually a brother) and think “I know he is careful like his older brother, and if it weren’t for this age regulation, both he and the company would be better off if he could drive for us.” Unfortunately, the kernel of truth in this perception is what economist Robert Frank once called an idea that is “good for one, but dumb for all” (Frank 1999). Even if some specific teenaged driver could be safe and effective, changing the regulations will mean that every firm can use any such driver who passes through the final program developed from the pilot, and the global effect is not likely to be what our imagined manager expects.

In terms of our model (Section 6), this change would be best interpreted as a decrease in β, the model parameter expressing the aversion of the typical driver to getting either too little work (and not enough pay) or too much work (and not enough home time). The story will be the same as if partial truck automation causes the job to be more attractive, a case which we analyzed above. The comparative statics (Table 3) show that, holding all other parameters unchanged, if β falls, among other outcomes, the optimal dispatch intensity will rise, the optimal wage will fall, and the optimal turnover rate will rise. The net result predicted is that having more teenaged drivers who like the job better but on average have weaker safety performance will raise the preventable crash rate and the turnover rate together!

9. Concluding Remarks and Directions for Future Research

Before closing we must note that our study has some limitations, as is true of all empirical work. The limitations primarily have to do with limitations in the data utilized, primarily because either it cannot be established that the data is nationally representative, or because it is but it is a proxy for information on the specific subpopulations of interest. In addition, our formal model necessarily uses some simplifying assumptions. These issues are detailed in Section 13, Appendix E, Limitations.

ATA projections of a driver shortage notwithstanding, we have argued that there is no convincing empirical evidence that there exists a long-term shortage of drivers in long-distance truckload motor freight. The demographic challenges that firms buying labor in this market are no different than those facing other blue-collar labor markets. Ordinary market processes appear to drive adjustments between freight demand and freight capacity perfectly well, as the already-observed cyclical variations in spot market and contract rates suggest. It may well be that the changes that can be expected when freight capacity must increase in response to an increase in demand, such as a secular increase in wage rates will from time to time challenge the ability of managers of long-distance truckload motor carriers to adjust their strategies. But—with the exception of the special case of the immediate stages of the COVID pandemic recovery from mid-2020 through mid-2022—there is just no evidence that the various dooms foretold by the ATA, such as “there will likely be severe supply chain disruptions resulting in significant shipping delays, higher inventory carrying costs, and perhaps shortages at stores” (Costello and Karickhoff 2019b), either have or will come to pass.

Competitive conditions in long-distance truckload do create a labor market structure characterized by much higher turnover rates than are typical in many other jobs requiring similar human capital, and this will be likely to continue to cause managers in this part of the market to perceive a shortage of drivers. Our formal model of cost minimization for a long-distance truckload motor carrier provides a causal foundation in microeconomics for this situation. And using this model, we showed that two technological changes (truck simulators in driver training and partially automated trucks) and one policy change currently being piloted by the USDOT (teenage drivers in interstate trucking), are likely to have opposite results to those that are expected by industry stakeholders.

In closing, it is worth asking to what extent a similar analytic approach, using a formal analysis of cost tradeoffs facing managers, might be used to explain other high turnover settings. For instance, are there relevant cost tradeoffs that might explain high turnover rates at Wal-Mart (Lichtenstein 2007), or in call centers (Burks, Cowgill et al. 2015)? This could be an area for future research.

10. Appendix A. The overall structure of for-hire trucking, or Truck Transportation (NAICS 484)

In local and near-regional trucking, segments (groups of firms providing one type of service, and not others) are not as well defined as in longer distance transportation. The basic economic reason is that the farther the shipment is moving, the more cost-disadvantageous it is to run partly empty. Therefore, the farther the shipment is moving, the relatively more important is specialization that permits loads to be full more of the time. An example is specialization by shipment size, if hauling general commodities.

Table A1. NAICS 484: For-Hire Trucking Segments Grouped by Geographic Scope and Shipment Size

From: 2017 Census	Firms	Estabs	Annual Revenue	Annual Payroll	Employ-ees	% Firms	% Estabs	% AnnRev	% Emps
Long-distance TL	31,908	36,828	$112,441,276	$23,819,680	519,358	28.6%	29.4%	39.1%	35.1%
Long-distance Other (4 types)	11,729	13,813	$50,894,893	$10,960,538	217,654	10.5%	11.0%	17.7%	15.6%
Long-distance LTL	4,410	8,360	$46,191,773	$15,354,176	271,447	4.0%	6.7%	16.1%	22.2%
Local (7 types)	63,335	66,117	$78,129,873	$20,020,744	445,463	56.9%	52.8%	27.2%	27.1%
Totals	111,382	125,118	$287,657,815	$70,155,138	1,453,922	100.0%	100.0%	100.0%	100.0%

Source: 2017 Quinquennial Economic Census (2022 data not available until late 2024)' "Estabs" is "Establishments"

In long-distance trucking, there are two important breakouts, one between general and specialized commodity hauling, and the second by shipment-size specialization.

The segments identified by the detailed breakouts in the last quinquennial Economic Census that have been grouped into each row above as follows:

LONG-DISTANCE TL:
484121: General freight trucking, long-distance, truckload
4842102: Long-distance used household and office goods moving
4842301: Hazardous materials trucking (except waste), long-distance
4842302: Agricultural products trucking, long-distance
4842303: Other specialized trucking, long-distance

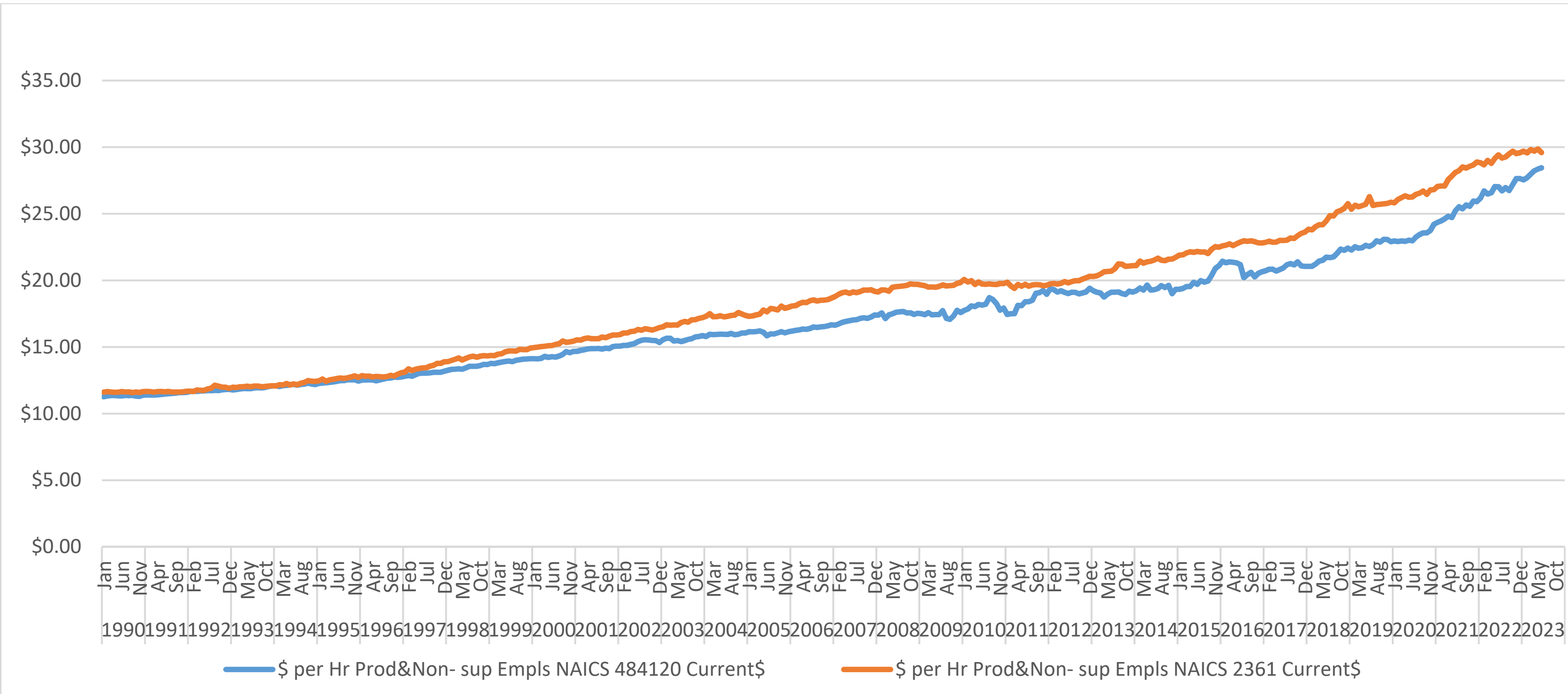
LONG-DISTANCE LTL
484122: General freight trucking, long-distance, less than truckload

LOCAL
4842203: Dump trucking
4842204: Local specialized trucking without storage
4842202: Local agricultural products trucking without storage
4842201: Local hazardous materials trucking (except waste)
4842103: Local used household and office goods moving, with storage
4842101: Local used household and office goods moving, without storage
4842205: Local, specialized freight (except used goods) trucking

Note that trucking industry analysts generally include FedEx, UPS, and the dozens of regional parcel carriers as part of the trucking industry. FedEx has ground-based parcel movements (FedEx Ground) and an LTL operation (FedEx Freight), although it also moves many parcels by air. UPS sold its LTL operation (UPS Freight) in 2021 (it is now TForce Freight), but it started as a ground parcel firm using trucks, and only added air movements later, to compete with FedEx. However, from the standpoint of government statistics, all the parcel carriers that operate over longer distances than local movements, large and small, are counted in a distinct industry category, NAICS 492100 Couriers and Express Delivery Services, which is part of a larger segment, 493000, Couriers and Messengers, which includes local messengers.

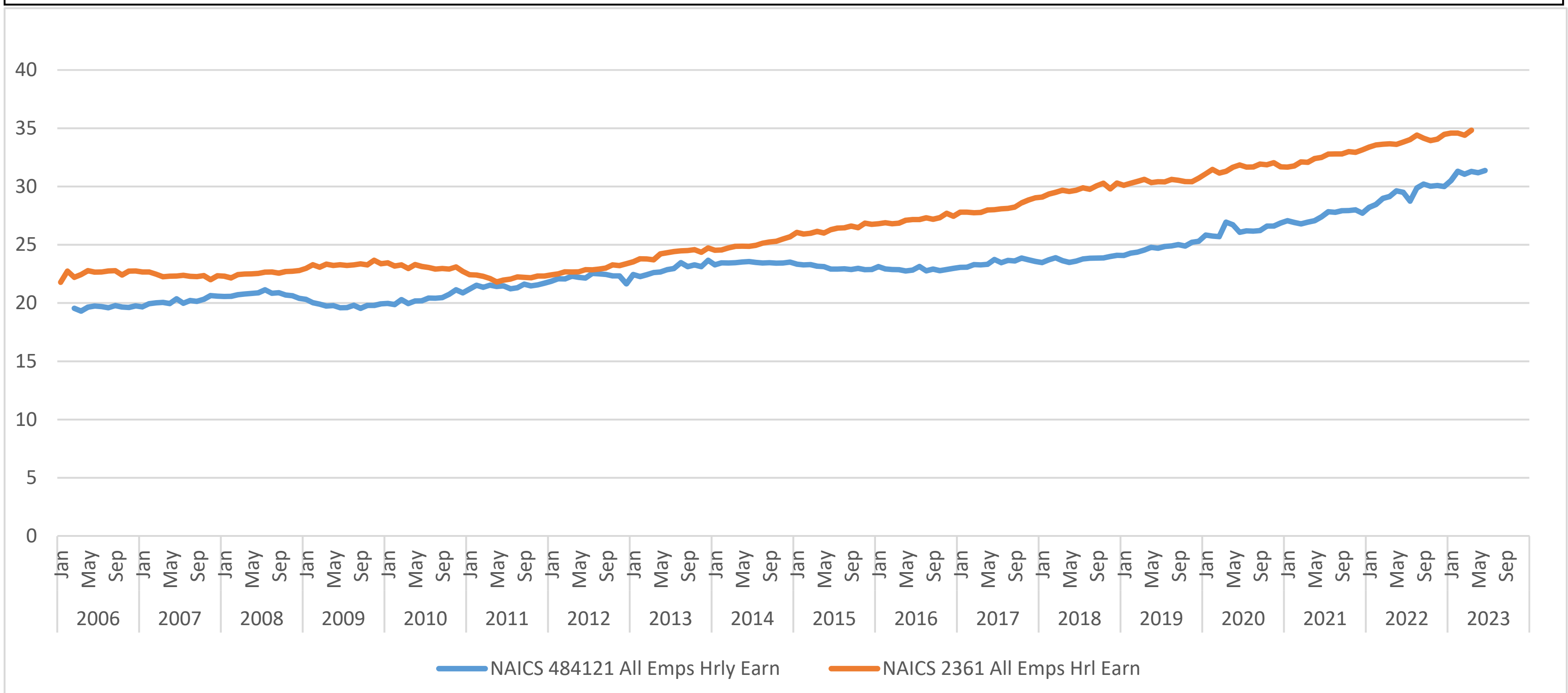
11. Appendix B. Graphical Evidence on Relative Wages in General Freight Long Distance and Residential Construction

Figure 6. Seasonally Adjusted Current $ Hourly Earnings of Production and Non-Supervisory Workers in Residential Construction (NAICS 23610) and in General Freight Long Distance (NAICS 48412)



As noted in Section 2, one measure suggested by Blank and Stigler (1957) to identify an occupational labor shortage is an increase in current wages relative to typical occupations that are alternatives for workers. Global Insight specifically called out production and non-supervisory employees in Residential Construction (Global Insight Inc. 2005) as a relevant alternative occupation for drivers, and Burks and Monaco (2019) found that 11% of individuals entering this occupation came from the construction industry, the largest single source industry outside of transportation and warehousing. As noted in the text, using Production and Non-supervisory Employees is a proxy; although drivers are most numerous, making up 59% of all employees in NAICS 484, this group still includes sales and clerical workers, plus mechanics, in addition to drivers, and it includes both truckload and less than truckload. For comparison, we also examine a second proxy: all employees in both Residential Construction and General Freight Long-distance Truckload, which adds managerial and executive employees, but restricts the comparison to the target sub-segment of Truck

Figure 7: Hourly Earnings All Employees
NAICS 484121 Gen Freight Long-distance Truckload & NAICS 2361 Residential Construction



Transportation. As can be observed in Figure 6 (1990 to 2023), it is Production and Non-supervisory Workers in Residential Construction, not General Freight Long-Distance, that shows the evidence of a relative wage increase. Nominal wages were very similar until about the 2000 dotcom recession. Then they diverge. A similar appears in Figure 7 (2006-2023), when we restrict the trucking employees to our target segment (which also limits the years available). The nominal hourly earnings appear to start to converge about 2011, but then Residential Construction again widens the gap. These graphs exhibit the opposite of the expected relationship, and it is consistent with Global Insight's view that the low relative earnings of truck drivers (here focused on long-distance drivers) are an issue (Global Insight Inc. 2005). See Sections 5 (Competitive conditions in general freight long-distance truckload) and 6 (A model of cost tradeoffs in general freight long-distance truckload) for our explanation of why relative wages are modest in long-distance truckload.

12. Appendix C. Details of the cost-minimizing model; solutions and limitations

1. $W_S^* = \left[\frac{P_K}{(2\beta P_T - 1)\lambda\beta P_T}\right]^{(1/2)} (2(\beta P_T - 1))$

2 $\rho^* = \left[\frac{\beta P_K P_T}{(2\beta P_T - 1)\lambda}\right]^{(1/2)}$

3. $K^* = S\left[\frac{(2\beta P_T - 1)\lambda}{\beta P_K P_T}\right]^{(1/2)}$

4. $D^* = S\lambda^{(3/2)}\left[\frac{(2\beta P_T - 1)}{\beta P_K P_T}\right]^{(1/2)}$

5. $\mu^* = \left[\frac{P_K}{(2\beta P_T - 1)\lambda\beta P_T}\right]$

6. $\varphi^* = \left[\frac{P_K}{(2\beta P_T - 1)\lambda P_T}\right]$

7. $T^* = S\left[\frac{\lambda P_K}{(2\beta P_T - 1)\beta}\right]^{(1/2)} (P_T)^{(-3/2)}$

As noted in Section 6, the model presented makes a number of simplifying assumptions. For instance, here each shipment (S) is treated as a full truckload (TL), rather than any smaller amount. Shipments are also treated as if they are uniform (all take the same number of miles and amount of effort to handle.) Drivers are operating tractor-trailers, but we just consider "trucks" since we do not attempt to incorporate trailer switches. Finally, we think here of each driver as working for repeated time units of one standard length, such as a calendar month. The more shipments a driver handles per month, the longer before the driver gets home, and the less time the driver has at home, once there. An additional assumption that is not really a limitation is this: although actual TL drivers are paid by the mile, since in real operations the miles are standardized for each load, we treat wages as paid "per shipment." Except for the last, these assumptions make the model simpler than the reality, but the key point is that stated in Section 6: we have retained the variables that are of central causal importance in the cost structure of a typical long-distance truckload motor carrier, so that we have captured the most important features of the cost minimization problem faced by truckload firm managers.

12. Appendix D. Numbers and Mean Wages for Occupation SOC 53-3032, Heavy and Tractor-Trailer Truck Drivers within Truck Transportation (NAICS 484)

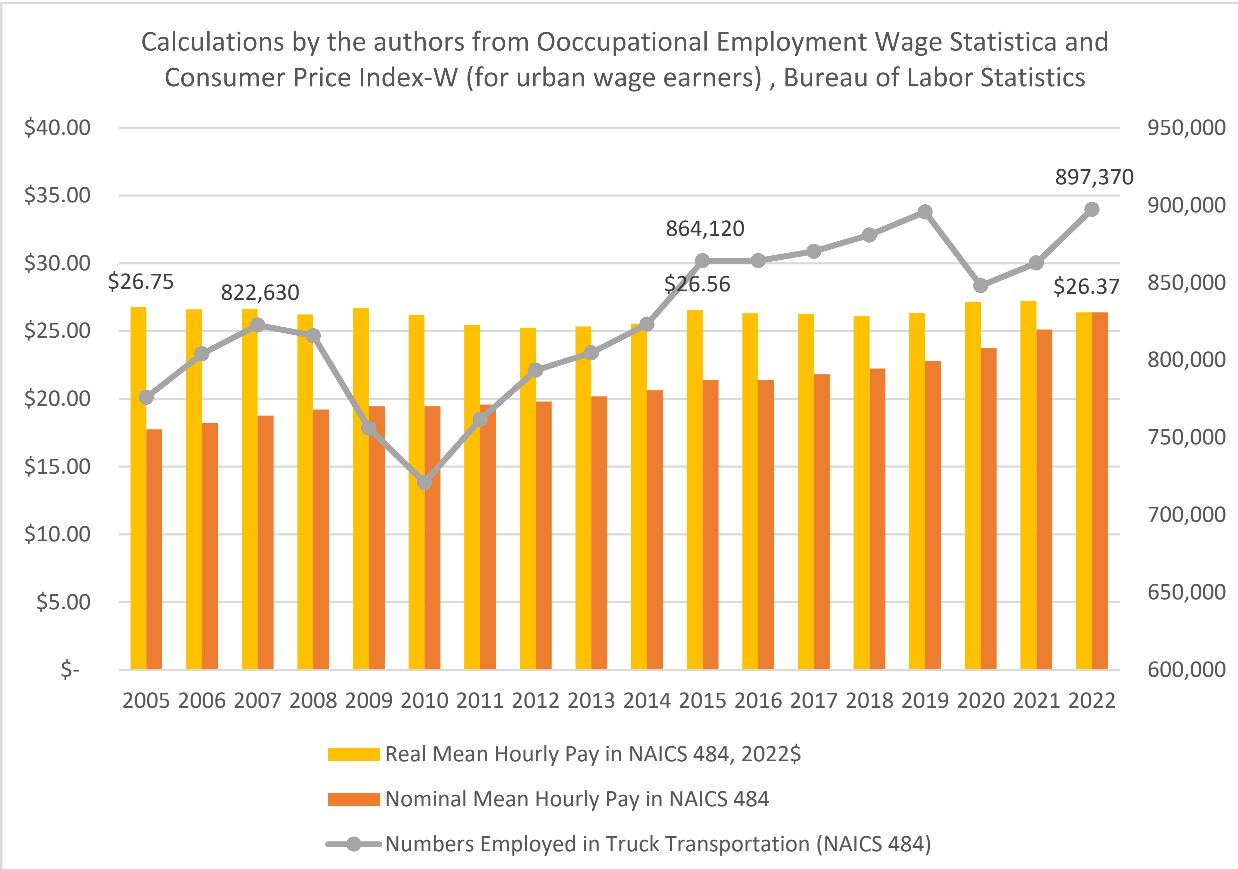


Figure 8. Mean Hourly Wages and Numbers, Heavy and Tractor-Trailer Truck Drivers Employed in Truck Transportation (NAICS 484)

Although the occupational category SOC 53-3032 (Heavy and Tractor-Trailer Truck Drivers) is too broad to be a strong proxy for the narrower category of tractor-trailer drivers in long-distance truckload motor freight (NAICS 484121), the history of numbers employed in all of Truck Transportation (NAICS 484000) and the mean hourly pay in this category are relevant parts of the background to the more specific issues that are the focus of the present paper. As we can see in Section 10: Appendix A, NAICS 484121 had about 35% of the total employees in Truck Transportation (NAICS 484000) in the 2017 quinquennial Economic Census, and this number rises to nearly 50% if other types of long-distance trucking with predominantly truckload operations are included. If drivers are in the same proportion as other employees, their numbers should be similar. It should be noted that the OEWS source is not constructed as a time series—each year is a rolling panel of six samples covering three sampling years, so direct year-to-year comparisons are not appropriate. It may still be observed that mean real hourly wages are essentially unchanged over the period shown, despite a steady increase in nominal wages and measurable fluctuations in total numbers.

13. Appendix E. Limitations in the data used

As noted in various parts of the text, there is no publicly available nationally representative data series precisely on the drivers in long-distance truckload motor freight. As a result, we utilize several data series that are publicly available and nationally representative, and which include these drivers as a large subset. We treat these data series as proxies for data about the specific population of interest, specifying in each case the limitations imposed by the fact that they are proxies.

A limitation of regression studies of occupational choice, such as Phares and Balthrop (2022), is the necessity of using Current Population Survey data in which heavy and tractor trailer truck drivers (SOC 53-3032) are categorized together with two groups operating lighter vehicles (SOC 53-3031 and SOC 53-30330). However, this is mitigated by the fact that heavy and tractor-trailer truck drivers make up approximately 56%, or 1.984 million, of the 3.534 million total drivers in all three categories (Bureau of Labor Statistics Staff 2023p; Bureau of Labor Statistics Staff 2023q; Bureau of Labor Statistics Staff 2023r). Burks and Monaco (2019) increased the focus on heavy and tractor-trailer truck drivers in their analysis substantially by ruling out observations of drivers in industries that primarily employ the other two categories of drivers.

14. Appendix F. Graphs displaying the pandemic recovery and indications of oversupply of long-distance truckload services

Figure 9 Number (thousands) All Employees, Seasonally Adjusted, in General Freight, Long Distance, Truckload (NAICS 484121)

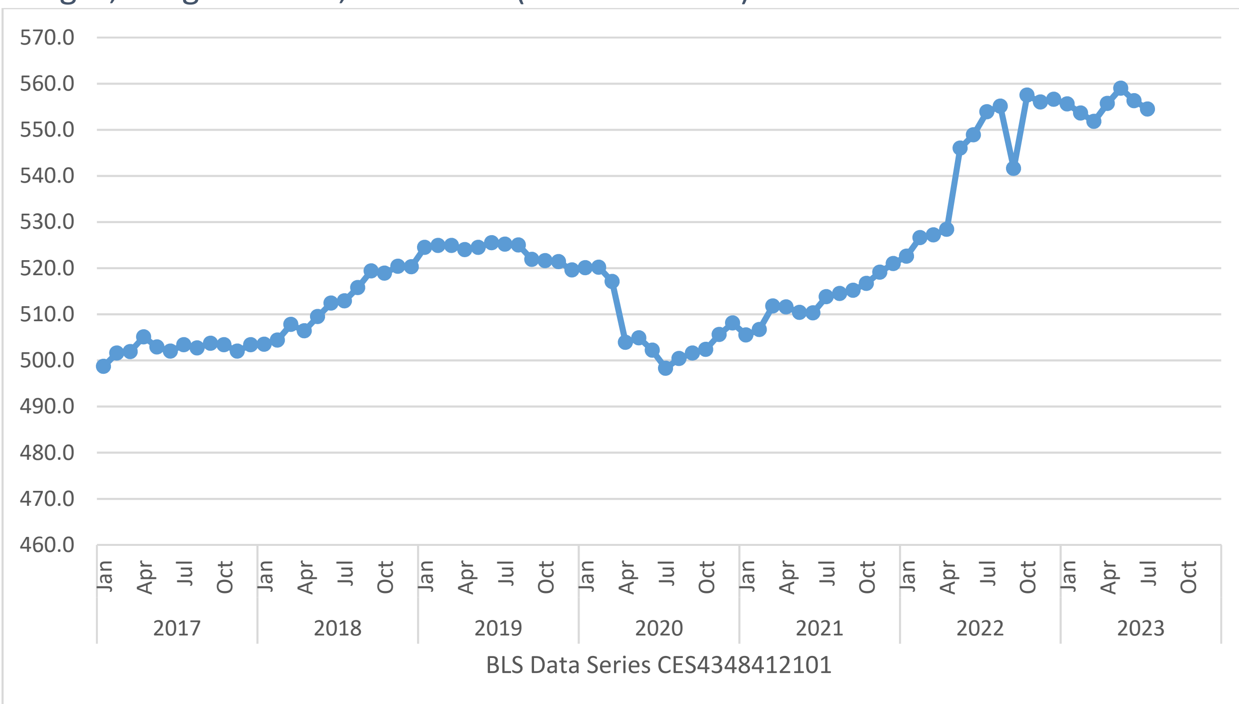
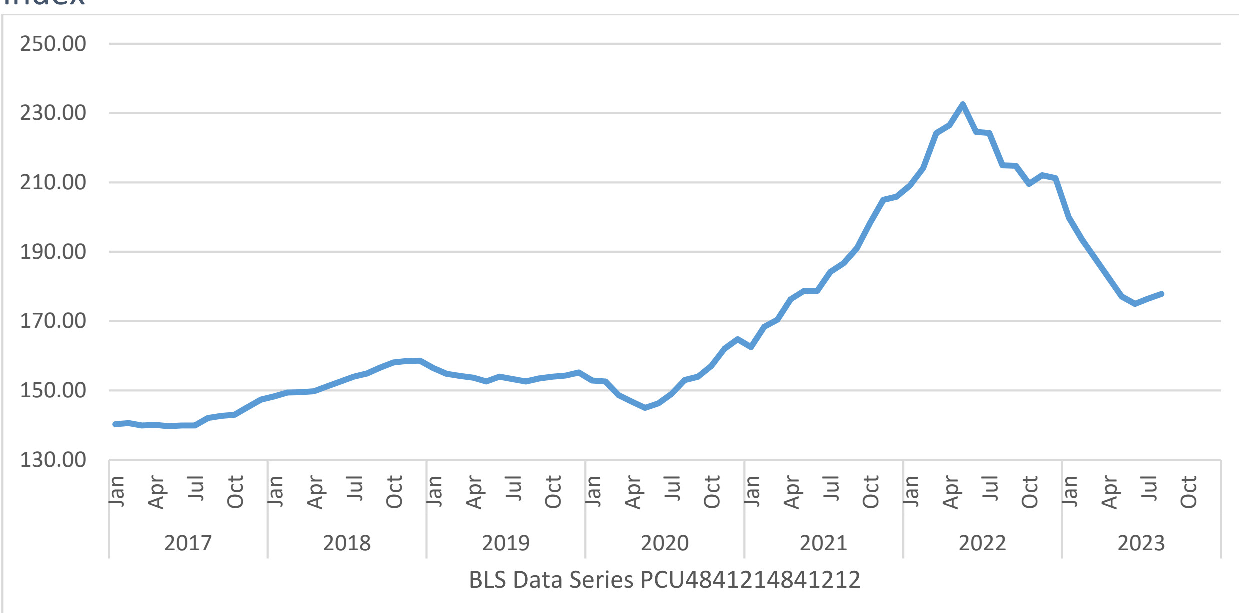


Figure 10 General Freight Long-Distance Truckload (NAICS 484121) Producer Price Index



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