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IZA DP No. 16184

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Industry, 1995-2019**

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ISSN: 2365-9793

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ABSTRACT

Job Creation and Job Destruction Dynamics in the U.S. Truck Transportation Industry, 1995-2019*

Every year, approximately 27% of all jobs in the U.S. truck transportation sector (NAICS 484) are reshuffled across motor carriers as existing carriers grow or shrink, new entrants begin operations, and existing firms exit. Studying how these dynamics unfold, especially for young carriers, is critical to further our understanding of employment dynamics in the U.S. trucking industry. This manuscript takes a first look at job creation and job destruction dynamics in truck transportation, with a special emphasis on the roles of carrier age and on job creation and destruction dynamics in the manufacturing sector, the source of demand for most trucking ton-miles. In doing so, we draw on and extend theory in both supply chain management and economics. We test our predictions using archival data from the U.S. Census Bureau's Business Dynamics Statistics program that tracks the universe of truck transportation firms with employee establishments from 1995 through 2019, focusing on firms that are ten years old or younger. Results from fitting a series of linear mixed effects models provide strong evidence that job creation and job destruction dynamics at trucking firms decline rapidly as carriers age. We further find these age-related dynamics are moderated by employment dynamics in the manufacturing sector. We discuss implications of these findings for theory and practice.

JEL Classification: J21, J63, L92

Keywords: job creation, job destruction, motor carrier, U.S. trucking industry, business dynamics statistics

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* We would like to thank Andy Balthrop and Alex Scott for serving as a sounding board for ideas. Burks was supported in part by the Center for Transportation Studies, University of Minnesota. The usual disclaimer applies.

INTRODUCTION

From 1995 through 2019, ~27.6% of all jobs in the U.S. truck transportation industry (NAICS 484¹) were reshuffled across motor carriers due to growth or contraction of existing firms, exit of some existing firms, and entry by new carriers (U.S. Census Bureau 2023a). For example, when Central Freight Lines—a large less-than-truckload (LTL) carrier—announced it was ceasing operations in 2021, other LTL carriers such as Estes Express, TForce Freight (formerly UPS Freight), Saia, and XPO Logistics moved quickly to acquire Central Freight Line’s terminals, equipment, and workers (Hawes 2021). Such reshuffling is emblematic of capitalistic economies (Decker et al. 2014). Studying these dynamics is required to develop a holistic picture regarding the evolution of aggregate employment (and hence capacity) in an industry (Sterk et al. 2021). This is especially important in trucking given public discussions about a driver shortage (Smith 2021). Beyond providing a more nuanced picture of aggregate capacity, understanding what factors cause an industry’s job creation and job destruction to ebb and flow is important given these dynamics can be disruptive to firms and their workers (Haltiwanger 2012).

Despite the high rates of job creation and job destruction in the trucking sector, there has yet to be systematic investigation of this topic. Apart from extending the limited work that examined carrier failure rates following interstate deregulation in 1978 – 1980 (Madsen and Walker 2007; Silverman et al. 1997), studying job creation and destruction in trucking is critical to better understand underlying worker flows (Davis & Haltiwanger, 1992), such as industry level truck driver turnover (Miller et al. 2021a). For example, given evidence that turnover rates are elevated for firms that are either growing or contracting (Davis et al. 2012), the fact that trucking firms create and destroy jobs more rapidly than manufacturers (Davis and Haltiwanger 2001) may

¹ NAICS is the North American Industrial Classification System (U.S. Census Bureau 2017).

help explain part of the persistently elevated rates of driver turnover experienced in parts of the industry (Burks and Monaco 2019). Beyond extending theory in logistics and supply chain management (L&SCM) on trucking employment dynamics, trucking provides a unique setting to extend labor economics theory regarding job creation and job destruction (Decker et al. 2014) because the long-distance truckload sector—the largest portion of trucking by both employment and revenue based on the Economic Census— is nearly perfectly competitive with low barriers of entry (Belzer 2000; Monaco and Burks 2010; Guntuka et al. 2019) and constant returns to scale (Miller and Muir 2020; Muir et al. 2019).² This contrasts to manufacturing operations that have formed the setting for many employment dynamics studies (Davis et al. 1992; Dunne et al. 1989; Lee and Mukoyama 2015).

This work examines job creation and destruction rates in the trucking sector, with a focus on how they are shaped by carrier age as well as job creation and destruction rates in manufacturing. We explain why job creation and destruction rates should decline nonlinearly as carriers age. This differs from prior research by Silverman et al. (1997) that found the rate of firm exit increased with age. We further explain why, for job destruction rates, the relationship between carrier age is more strongly linked to jobs destroyed due to firms exiting versus jobs destroyed through firms downsizing. Drawing on theory regarding derived demand for transportation (Allen 1977) coupled with findings about how changes in customer demand propagate through the supply chain to affect suppliers (Carlsson et al. 2021; Carvalho et al. 2021), we detail why job creation and destruction rates in manufacturing will affect trucking firms' employment dynamics. We draw attention to the manufacturing sector given the Commodity Flow Surveys (CFSs) indicate

² General Freight Long Distance Truckload (NAICS 484121) was the largest single segment of NAICS 484 Truck Transportation by revenue (\$112.4 million, 39.1%) and employment (519,538, 35.1%) in the 2017 Economic Census.

manufacturers generate most for-hire trucking ton-miles (e.g., ~60% in 2017 (Miller, 2020)), coupled with shocks to manufacturing employment being exogenous (Adelino et al. 2017). Beyond average effects, we also detail why job creation and job destruction rates in manufacturing should moderate the impact of carrier age on both job creation and job destruction rates.

To test our predictions, we obtain annual data from 1995 – 2019 for general freight trucking (NAICS 4841) and specialized freight trucking (NAICS 4842) for cohorts of carriers that are 1, 2, 3, 4, 5, and 6-10 years in age from the U.S. Census Bureau’s Business Dynamics Statistics (BDS) database. As detailed by Haltiwanger et al. (2013), BDS provides population-level statistics on jobs created and destroyed for all employer firms that unambiguously identifies firm entry and exit, based on confidential data from the U.S. Census Bureau (U.S. Census Bureau 2023c). We test our predictions by estimating a series of mixed effects models with cross-classified standard errors to account for the complex structure of the BDS data. Consistent with our theory, we find that job creation and destruction rates fall quickly as carriers age. For aggregate job destruction, we find this effect is entirely driven by the age of firm exit, as opposed to continuing firms downsizing operations. We further find strong evidence that job creation and destruction rates in manufacturing impact job creation and destruction rates in the trucking sector, with these dynamics being larger for the youngest trucking firms.

This research makes multiple contributions to theory. Regarding theory in L&SCM, we explain why, contra Silverman et al. (1997), job destruction rates for young trucking firms are likely to follow a liability of newness pattern (Stinchcombe 1965) in that job destruction rates decline rapidly as firms grow older (Coad 2018). We further offer the first examination of young carriers’ job creation rates, which has important implications for industry-wide capacity given findings that young firms contribute disproportionately to job creation (Haltiwanger et al. 2013).

Regarding theory in labor economics (Decker et al. 2014), our study is the first to document how changes in job creation and destruction rates in a customer sector cascade through the supply chain, which complements emerging research that has looked at the impact of exogenous shocks like shale oil extraction on local industry activity (Decker et al. 2022). To the best of our knowledge, we also offer the first evidence that declining job destruction rates as a function of firm age appear disproportionately driven by slowing rates of jobs lost due to firms exiting, as opposed to jobs lost via firms downsizing but staying in operation.

This research also has implications for practice. Our findings that job creation and destruction rates slow rapidly as carriers age indicate decisions made early in carriers' lives have a disproportionate impact on their future outcomes (Sterk et al. 2021), suggesting carrier managers need to be especially cognizant of the path dependence created by early decisions. Another implication for carrier managers is the secular decline in job destruction rates that we observe suggests the common practice of recruiting drivers who have been laid off from other carriers may not be as viable today as it was in the 1990s. Additionally, carrier managers should realize that, to some degree, their success hinges on the success of their shippers. This suggests carrier managers should closely monitor conditions in their shippers' industries and take actions accordingly. Turning to shippers and brokers, the rapid rates of job creation and destruction we observe at young firms indicates these actors should pay special attention to how young carriers are progressing. For policymakers, our results provide no indication that rates of job creation in trucking are declining, which is inconsistent with claims of a worsening driver shortage (Costello and Karickhoff 2019). Further, whereas policy efforts to increase the number of trucking jobs have focused on increasing the supply of truck drivers (White House 2022), our findings highlight the importance of creating stable manufacturing jobs that generate freight volumes to support trucking payrolls.

The remainder of this paper is structured in four sections. The first section summarizes the pertinent literature. The second section lays out the logic for the hypothesized predictions. The third section describes the research methodology and results. The fourth section describes theoretical contributions, explains managerial implications, makes note of limitations, and makes recommendations for future research.

LITERATURE REVIEW

This research touches on two broad bodies of work that have examined issues regarding (i) carrier growth and evolution (Corsi and Scheraga 1989; Feitler et al. 1997; Pettus 2001), dynamics of new trucking firms (Cantor et al. 2017; Corsi and Fanara 1989), and carrier survival (Guntuka et al. 2019; Silverman et al. 1997; Zingales 1998); and (ii) employment dynamism in economics (Decker et al. 2014; Haltiwanger 2012). We describe these bodies separately and explain how this research extends knowledge in each area.

Motor Carrier Growth/Evolution, Survival, and New Entrant Dynamics

Multiple studies have examined issues of carrier growth and evolution, especially following deregulation in 1978 – 1980. Some of these studies focused on how LTL carriers adjusted operations including Corsi (1991), Feitler et al. (1997), Grimm et al. (1993), and Pettus (2001). Rakowski (1988, 1994) and Kling (1988, 1990) examined how LTL market shares evolved following deregulation, with Burks and Guy (2004) further explaining that deregulation caused the emergence of a sharper distinction between LTL and TL operations. A few studies have examined more recent data on related topics, including Scheraga's (2011) work studying strategic fit from 1999 to 2003 and Jin et al. (2017), which studies the strategic purity of TL carriers from 1998 to 2014. While not studying growth explicitly, Giordano (2008, 2014) examined the distribution of trucking firm size using separate samples for TL and LTL carriers, where he found that the

distribution of firm size was inconsistent with Gibrat's law, which states that growth rates are uncorrelated with firm size. However, to the best of our knowledge, no study looks explicitly at the growth of young carriers over the first few years that they age.

Turning to studies that explicitly concern new entrants, extant works have looked at the relationship between carrier age and safety (Cantor et al. 2017; Corsi and Fanara 1989; Miller and Saldanha 2018). These studies indicate younger firms have higher rates of crashes (Corsi and Fanara 1989) and of various safety violations (Cantor et al. 2017). There is also evidence of *ex ante* differences in new entrant safety in that carriers whose first inspections result in few hours-of-service (HOS) violations continue to have fewer HOS violations after two years relative to their peers whose initial inspections result in more violations (Miller and Saldanha 2018).

Focusing now on research regarding carrier exit, studies by Silverman et al. (1997), Zingales (1998), and Madsen and Walker (2007) each examine different dynamics about incumbent and new entrant carrier failure following interstate deregulation in 1978 – 1980. Of special significance, Silverman et al. (1997) found that new entrants formed after deregulation saw a positive relationship between carrier age and exit probability, a finding that is difficult to theoretically reconcile and may have arisen due to methodological issues as noted by Coad (2018). Guntuka et al. (2019) provide the only recent examination of carrier failure, studying exit rates in 2015 and 2016 for carriers in operation in 2014 as a function of crash rates, size, number of commodities hauled, for-hire status, and hazardous material authority. However, this study does not consider carrier age and concerns a period recognized as a freight recession (Terrazas 2019).

Our work extends these studies in several directions. We offer the first systematic examination of job creation rates by young trucking firms, which sheds light onto how industry-level employment dynamics evolve (Haltiwanger 2012). Given ongoing discussions regarding

shortfalls of truck drivers (Costello and Karickhoff 2019, Burks and Monaco 2019), it is important to understand how these rates have evolved over an extended period and what factors affect job creation rates. Our theory explains why job creation rates fall swiftly as carriers age while further highlighting that the youngest carriers will be most sensitive to job creation dynamics in manufacturing. Regarding carrier failure, we contribute both theoretically and methodologically. Theoretically, we explain why job destruction rates, especially due to firm exit, should decline sharply as carriers age, contra Silverman et al. (1997). We further explain why job destruction rates will be elevated when job destruction rates in manufacturing are elevated, with this effect being greatest for the youngest trucking firms. To the best of our knowledge, this is the first time customer sector dynamics have been incorporated into discussions of carrier failure, which is an important addition given demand side factors are considered the primary driver of firm exit (Foster et al. 2008). Methodologically, our reliance on BDS's population-level data derived from confidential U.S. Census Bureau sources allows us to avoid issues such as sample selection due to reporting thresholds (e.g., Silverman et al. (1997)) and challenges with unambiguously determining whether firms have exited (Guntuka et al. 2019). This is not meant as a criticism of these prior studies, as they used the best data available at that time; rather, it illustrates the benefit of leveraging new data sources (Coad 2018).

Job Creation & Job Destruction Dynamics

A large literature in economics has developed examining job creation and destruction dynamics, beginning with seminal works in the late 1980s and early 1990s centered on manufacturing (Davis and Haltiwanger 1992; Dunne et al. 1989), and subsequently expanding to the broader economy. This resulted in the creation of the BDS database (Haltiwanger et al. 2013). To date, much of the economics literature on labor market dynamics has been concerned with quantifying secular trends

showing that job creation and job destruction rates are declining (Decker et al. 2014); devising theories to explain these declines at the level of the overall economy (Pugsley and Sahin 2019) such as a smaller employment response by firms to increases or decreases in productivity (Decker et al. 2020); and comparing job creation and destruction dynamics across countries (Eslava et al. 2022). A smaller body of research has examined whether economic downturns have more deleterious effects for young versus older firms, with Fort et al. (2013) finding young U.S. firms are especially sensitive to recessions, though these effects have not replicated in European samples (see Mina and Santoleri (2021) for a discussion).

In comparison, only one study examines how supply chain linkages impact labor market dynamics³, with Decker et al. (2022) showing that counties with shale oil plays saw more rapid growth in sectors such as transportation & warehousing, as well as construction, relative to matched counties not impacted by shale drilling. Given evidence that suppliers are very sensitive to changes in demand conditions at their customers (Fujii 2016), it is important to systematically investigate whether such linkages exist. For example, finding evidence that job creation and job destruction dynamics in customer industries spill over to supplier industries may point to another explanation for declining job creation and destruction rates: supply chain linkages across sectors. Furthermore, existing theory is silent regarding whether such linkages will be more impactful for the youngest firms. We draw attention to firm age given strong evidence of age's impact on job creation and destruction (Haltiwanger et al. 2013).

Our work contributes to the labor economics literature on job creation and destruction in two ways. First, we provide an initial look at how evolving rates of job creation and destruction in a customer sector (manufacturing) propagate to a supplier sector (trucking). We also devise theory

³ Carlsson et al. (2021) document that firms adjust their payrolls in response to orthogonal demand shocks, yet these demand shocks can stem from multiple sources other than supply chain linkages.

explaining why these linkage effects should be greatest for younger firms, thereby identifying a boundary condition for our theorizing (Goldsby et al. 2013). Second, whereas prior studies have focused on job destruction rates in the aggregate, we leverage splits in the BDS dataset that separately record rates of job destruction due to firms exiting versus job destruction due to firms downsizing yet remaining in operation. This more detailed analysis suggests that the sharp declines in job destruction rates as a function of age is entirely driven by a decrease in job destruction due to a decrease in firm exits. This suggests a boundary condition for theory in labor economics.

THEORY & HYPOTHESES

Given that it is important to align theoretical predictions with the measures at hand (Miller et al. 2021b), the job creation rate for a cohort of trucking companies in year t is defined as the number of jobs added by the subset of carriers in the cohort that expanded operations in year t relative to $t-1$ divided by the average number of workers employed by carriers in that cohort in year t and $t-1$ (U.S. Census Bureau 2023c). We begin by describing why we expect the rate of job creation to decline in an attenuated manner as carriers age (e.g., the relationship between age and job creation rates looks more logarithmic than linear). Multiple complementary mechanisms (Astbury and Leeuw 2010) undergird this prediction. First, learning dynamics of new entrants are likely to be quite rapid at first and then slow with time (Coad 2018; Stinchcombe 1965). For example, managers may quickly learn that their firm is positioned well due to high productivity (Jovanovic 1982; Ericson and Pakes 1995) or because it is serving customers with higher than anticipated demand (Ignaszak and Sedláček 2021). Second, managers at young trucking firms have a strong incentive to grow quickly (Cassidy and Ashe 2022) to increase perceived legitimacy (Stinchcombe 1965) and better accrue resources that can help them survive down markets. Third, younger firms have more flexible human resource management routines that make it more feasible for younger

firms to quickly add workers (Coad 2018). Fourth, the existence of strong economies of scope across hauls for TL carriers (Muir et al. 2019) makes it more challenging for older carriers, which are more likely to have established customer relationships (Stinchcombe 1965), to quickly add to payrolls for fear of creating imbalance in their freight networks (Caplice 2021; Cassidy 2023). For all these reasons, we posit:

H₁: Job creation rates decline in an attenuated manner as carriers age.

We next turn towards hypotheses concerning job destruction rates as a function of carrier age. As with the job creation rate, the job destruction rate for a cohort of trucking companies in year t is defined as the number of jobs lost by the subset of carriers in the cohort that either downsized or closed operations in year t relative to $t-1$ divided by the average number of workers employed by carriers in that cohort in year t and $t-1$ (U.S. Census Bureau 2023c). Broadly, there are two competing explanations for this relationship, which predict opposite effects. The liability of newness thesis proposes that job destruction rates will be most severe for the youngest firms because they lack established relationships with customers (Foster et al. 2016b) and other external stakeholders (e.g., financial institutions), they lack the legitimacy of established competitors, and they lack established operating routines (Stinchcombe 1965). In contrast, the liability of aging thesis argues that job destruction rates will increase as firms age because they accrue features that create frictions that impede adapting to changing conditions (Barron et al. 1994) or major environmental changes cause their current capabilities to no longer apply (Coad 2018). Silverman et al. (1997) provide the only test of how aging affects newly founded carriers exit, finding evidencing consistent with the liability of aging thesis.

While Silverman et al.'s (1997) findings may hold immediately following deregulation, we contend that the liability of newness thesis is more likely to hold for contemporary trucking

operations for two reasons. First, as noted by Caplice (2021), many extremely young carriers have little understanding of their cost structure, which may place them in an untenable position when the market shifts. As newly founded carriers age, per learning curve effects at young firms (Stinchcombe 1965), we would expect them to develop a better understanding regarding their costs. Second, many shippers and brokers are hesitant to transact with extremely young carriers because they don't have a proven operating history (Cassidy and Ashe 2022). Consistent with this, there is strong evidence that young firms have lower levels of demand than older peers (Foster et al. 2008, 2016b). For example, small manufacturers that tend to work closely with a limited number of smaller trucking outfits (Li et al. 2022) may be hesitant to utilize a newly founded carrier for fear that poor performance could cause reputational harm. We therefore posit:

H₂: Job destruction rates decline in an attenuated manner as carriers age.

As noted above, the rate of job destruction is a function of two components: jobs destroyed due to firms downsizing and jobs destroyed due to firms exiting the industry. There is strong reason to expect liability of newness dynamics are more associated with job destruction due to firms exiting than downsizing. Our logic for this claim is that young trucking firms are particularly likely to exit because of limited understanding of cost structures (Caplice 2021), challenges with building balanced freight networks with limited empty mileage (Miller and Muir 2020), and challenges with finding more stable contract business given many shippers are hesitant to work with younger carriers (Cassidy and Ashe 2022). Younger firms also have more challenges with obtaining financing (Gertler and Gilchrist 1994), in part because they lack established relationships with local financial institutions (Stinchcombe 1965). Consequently, unanticipated negative events (e.g., downturns in freight rates, cost structure issues, loss of a major customer, etc.) are more likely to cause younger carriers to fail. In contrast, theory in a different branch of labor economics

(Hamermesh 1995) suggests costs of downsizing should be relatively invariant across firms within a sector. Thus, given that trucking companies with multiple years of experience are likely to want to avoid closing in response to negative events (Stinchcombe 1965), this would make downsizing (as opposed to exiting) more attractive for older firms. We therefore posit:

H₃: Carrier age is more strongly related to job destruction rates due to firms exiting than to job destruction rates due to firms downsizing.

We now explain why job creation and destruction rates in manufacturing are expected to propagate to impact job creation and destruction rates in trucking. To begin, many trucking companies tailor their operations to serve a small number of manufacturers (Li et al. 2022; Marchington et al. 2003), since manufacturers account for ~60% of for-hire trucking ton-miles per the 2017 CFS (Miller 2020). For example, Voss et al. (2011) report that small trucking firms with 1-50 power units receive an average of 39% of their business from their largest customer. Given that about 90% of freight is priced on a contractual basis for which carriers must be invited by shippers to do business (Caplice 2007), there are strong advantages to incumbency (Caplice 2021). There are also network economies for balancing freight flows (Miller and Muir 2020), so the loss of a key customer is challenging to address (Hawes 2022).

We highlight these realities to make clear that the ability of most trucking companies to obtain freight in the short term is strongly linked to the freight volumes at the current shippers to whom they provide services (Marchington, et al. 2003). For example, Hawes (2023) explains how a FreightWorks Transport, a large carrier with more than 100 trucks, failed in 2023 when several key contractual customers withdrew business. While the discussion so far has framed this issue from a negative standpoint, the advantages of incumbency (Caplice 2021) should also hold the opposite direction: carriers whose shippers see a sharp increase in demand should be positioned to grow their businesses (Pozzi and Schivardi 2016; Carlsson et al. 2021). Per Kehrig and Vincent

(2021), it is common for some manufacturers to see unexpected surges of demand, suggesting this dynamic should be common. Given evidence of constant returns to scale in manufacturing (Syverson 2011), it follows that faster rates of job creation by manufactures translate to more rapid increases in freight volumes and, consequently, opportunities for carriers to grow their business (Carlsson et al. 2021). This aligns with findings from Ignaszak and Sedláček (2021), who document that differences in demand conditions newly founded firms face play a critical role in their growth dynamics. Conversely, it also follows that faster rates of job destruction by manufacturers translate to more rapid declines in freight volumes and, consequently, may force carriers to downsize or may drive them out of business. For example, the announcement by Greenbrier that they are closing their railcar assembly facility in Portland, OR (Marsh 2023) may force trucking companies who derive a significant share of their business from transporting materials and components into this plant to either go out of business or downsize. This aligns with recent findings that negative demand shocks at customers translate to reduced activity at suppliers (Carvalho et al. 2021). We therefore suggest:

H_{4a}: Job creation rates in manufacturing positively impact job creation rates in trucking.

H_{4b}: Job destruction rates in manufacturing positively impact job destruction rates in trucking.

We lastly explain why we expect the dynamics associated with manufacturers' creation (destruction) of jobs and trucking firms' creation (destruction) of jobs to be more pronounced for younger carriers. In other words, we now explain why carrier age should moderate the average effects postulated in *H_{4a}* and *H_{4b}*. Concerning job creation, Decker et al. (2020) document that younger firms are more responsive to positive conditions that support growth. In our context, this would imply that younger trucking firms will be more affected by job creation rates in manufacturing. This moderating relationship should arise due to several complementary

mechanisms. First, the lack of established freight networks due to more nascent shipper relationships provides more flexibility to expand output (Cassidy and Ashe 2022). Second, the desire to grow to increase legitimacy and resources is stronger for younger firms (Starbuck 1965), suggesting younger carriers fortunate enough to serve manufacturers who see share increases in demand would have reason to expand. Third, younger firms are less likely to experience internal inertia forces that can hamper how they adjust employment in response to positive conditions (Decker et al. 2020).

Shifting gears to the moderating role of carrier age on the relationship between manufacturers' job destruction rates and trucking firms' job destruction rates, the explanation for this finding is rooted in Stinchcombe's (1965) liability of newness thesis. Given their lack of established operating history, younger firms are more likely to have difficulty replacing lost customer demand (Fort et al. 2013). Greater challenges of replacing lost demand are compounded by younger firms having less demand than older firms of similar size (Ignaszak and Sedláček 2021) given it takes time to develop customer relationships (Foster et al. 2016b). Consistent with this, Foster et al. (2008) note that new entrants have lower levels of demand than older incumbents, suggesting that a loss of demand would be especially detrimental. Beyond demand considerations, younger firms are also likely to have fewer links to financial institutions (Mina and Santoleri 2021), which makes it more difficult for them to survive downturns. We therefore posit:

***H_{5a}**: The effect of job creation rates in manufacturing on job creation rates in trucking is more positive for younger carriers.*

***H_{5b}**: The effect of job destruction rates in manufacturing on job destruction rates in trucking is more positive for younger carriers.*

RESEARCH METHODOLOGY

Data

This research draws primarily from the BDS database (U.S. Census Bureau 2023c), which provides data on the job creation and job destruction dynamics for employer establishments tracked in the U.S. Census Bureau's Longitudinal Business Database (LBD), which links each employer establishment⁴ to a unique firm identifier to account for multi-establishment firms (Haltiwanger et al. 2013). The LBD, in turn, "is constructed by linking annual snapshot files from the U.S. Census Bureau's Business Register (BR) (and incorporating edits to BR data made by the County Business Patterns program) to provide a longitudinal history for each establishment," (U.S. Census Bureau 2023b). Data in the Business Register, "contains the most complete, current, and consistent data for business establishments. The annual Report of Organization survey provides individual establishment data for multi-establishment companies. Data for single-establishment companies are obtained from various U.S. Census Bureau programs, such as the Economic Census, Annual Survey of Manufactures and Current Business Surveys, as well as from administrative record sources." (U.S. Census Bureau 2023d). BDS data has been utilized in many studies, such as Eslava et al. (2022).

While BDS extends back to the 1970s, we focus our analysis on the years 1995 through 2019 (corresponding to March 1995 through March 2019). We start our study in 1995 since NAFTA took effect on January 1, 1994 (Hakobyan and McLaren 2016), which caused some U.S. manufacturing activity to shift to Mexico (Faux 2013). While data currently is available through March 2020, we do not include these data because the day of the year from which employment records are evaluated (March 12) is one day before the declaration of a national emergency due to

⁴ Per (Census Bureau 2023b) an establishment is defined as, "a fixed physical location where economic activity occurs."

COVID-19 (White House 2020). As such we feel it is appropriate to wait till further benchmarking of these data are feasible. BDS only goes to the 4-digit NAICS level, so we pull data for general freight trucking (NAICS 4841) and specialized freight trucking (NAICS 4842).

Data Structure and Variables

Before defining the variables, a few words about the structure of the BDS data are worth noting. Firm age in BDS is based on the age of the oldest establishment in operation (Haltiwanger et al. 2013), which helps alleviate issues that would arise if a newly created firm came into existence by purchasing an establishment with many years of experience. Within BDS, a firm is considered to have entered if there was no record in the LBD in year $t-1$ but there was a record in year t (recall these employment data are for March 12 of the respective year). For example, if a carrier was not in existence as of 2016 but was in existence in 2017, that carrier would be considered to have entered in the 2017 BDS release. In BDS nomenclature, new entrants can only create jobs and based on the program's calculation, have a job creation rate of 200%⁵. As such, we don't focus on firms in their founding year. Continuing with this example, "Year 1" for these firms would cover the period March 12, 2017, through March 12, 2018. If no data for all establishments associated with the firm was available in 2018, the firm would be viewed as having exited the industry (Haltiwanger et al. 2013).

Given our interest in studying carrier age, our BDS data query grouped records by firm age. All statistics are thus calculated for firms that were a particular age in a particular year. One dependent variable is *Job Creation Rate Trucking (JCRT)* is defined as the number of jobs added by the subset of carriers in the cohort that expanded operations in year t relative to $t-1$ divided by the average number of workers employed by all carriers in that cohort in year t and $t-1$ (U.S. Census

⁵ This occurs because the denominator for calculating percent change is the average of the number of jobs observed at year $t-1$ (which would be 0) and the number of jobs in existence in year t .

Bureau 2023c). Our second dependent variable is *Job Destruction Rate Trucking (JDRT)*, defined as the number of jobs lost by the subset of carriers in the cohort that either downsized or closed operations in year t relative to $t-1$ divided by the average number of workers employed by all carriers in that cohort in year t and $t-1$ (U.S. Census Bureau 2023c). Our third and fourth dependent variables, *Job Destruction Rate Trucking Exit (JDRTE)* and *Job Destruction Rate Trucking Downsizing (JDRTD)* decompose *JDRT* into the constituent components⁶. The fact that all the dependent variables are rates makes the effects comparable across cohorts of carriers that differ in size. It should also be noted that BDS is structured so that mergers/acquisitions don't influence the calculations (Haltiwanger et al. 2013).

Our measure of carrier age is based on BDS firm age bins of Year 1, Year 2, Year 3, Year 4, Year 5, and Year 6-10. We do not consider the Year 11-15 bin given Coad's (2018) observation that young firm dynamics tend to run their course 5-7 years after founding. As there are 6 discrete bins for carrier age, we compare the performance of different statistical specifications using a linear trend, a logarithmic trend, and set of 5 dummy variables. As we unfortunately cannot know the average age of all firms in the 6-10 age bin, we use 8 as this is the center point of this range when using linear or natural log specifications. *Carrier Young Linear (CYLin)* is calculated as the age from the BDS bins multiplied by negative one so the coefficients are framed in terms of younger firms relative to older firms. *Carrier Young Log (CYLog)* is calculated as the natural logarithm of age from the BDS bins multiplied by negative one.

⁶ As a technical note, we measure *Job Destruction Rate Exit* as the rate of jobs lost due to establishment exit (a data field in BDS). Young motor carriers overwhelmingly operate one establishment, which means treating establishment exit and firm exit as equivalent is reasonable. As a check, the correlation within the BDS data between the number of establishments that exited and the number of establishments that exited due to firm exit was 0.996. Likewise, the correlation between the number of jobs lost due to establishment closure and the number of jobs lost due to firm exit is 0.977. We opt to utilize the rate calculated from establishment exit because it is already included in BDS and this allows for an additive decomposition of job destruction into the two constituent components.

Our second set of focal predictors concerns job creation and destruction rates in manufacturing. To calculate these measures, we obtained job creation and job destruction rates for each 3-digit NAICS manufacturing sector (21 in total). We then utilized data from the 2012 CFS to determine the ton-miles each sector ships using for-hire trucking to create a weighted average of job creation and destruction rates. This approach helps ensure that elevated rates of job destruction in sectors such as apparel manufacturing in the late 1990s through the Great Recession don't unduly affect our results since apparel manufacturing accounts for just 0.2% of ton-miles. We use 2012 CFS weights since the correlation of 3-digit NAICS weights was 0.990 between the 2007 & 2012 versions and 0.995 between the 2012 & 2017 versions. Older versions of the CFS from 2002 and 1997 do not have breakouts of ton-miles by transportation mode by NAICS origin industry. *Job Creation Rate Manufacturing (JCRMfg)* is thus the weighted average of job creation rates across the 21 3-digit NAICS sectors, and *Job Destruction Rate Manufacturing (JDRMfg)* is thus the weighted average of job destruction rates across the 21 3-digit NAICS sectors.

As we can consider firm age to be strictly exogenous (Coad 2018), we select control variables with a focus on improving the efficiency of parameter estimates, as opposed to reducing concerns of endogeneity due to omitted variables (Miller and Kulpa 2022). We include a linear time trend, labeled *Trend*, that equals 0 in 1995, 1 in 1996, 2 in 1997, etc. We include this linear trend to capture any effects associated with the reported economy-wide decline in both job creation and job destruction rates (Decker et al. 2014). This control also helps capture effects associated with changes in carriers' technology adoption, which has been shown to impact safety (Cantor et al. 2009; Miller et al. 2018), which in turn can impact carrier survival (Guntka et al. 2019). This linear trend should also capture other sectoral level trends, such as the continued penetration of brokerages (Caplice 2021). We include a dummy variable labeled *General Freight (GF)* that

equals 1 for data concerning general freight trucking (NAICS 4841), leaving specialized freight trucking (NAICS 4842) as the omitted category. We control for whether there was a recession each year using the National Bureau of Economic Research's Business Cycle Dating Committee's determination of a recession (FRED 2023) by creating a dummy variable *Recession* that equals 1 if any month of that given year features a recession. While manufacturing job creation and destruction rates are correlated with recessions (Davis and Haltiwanger 1992), we believe controlling for the existence of a recession is justified to help capture dynamics via other channels such as business sentiment and financing constraints (Fort et al. 2013), which aren't necessarily captured by manufacturing job creation and destruction rates. We also control for job creation and job destruction rates in the support activities for mining sector (NAICS 213), to capture dynamics concerning hydraulic fracturing activity. We do this because Decker et al. (2022) report that the rise of shale oil drilling positively impacted creation of transportation and warehousing firms. The associated variables are *Job Creation Rate Mining Support (JCRMS)* and *Job Destruction Rate Mining Support (JDRMS)*.

Lastly, we control for the average size of firms in each carrier cohort by first dividing the number of employees reported for that cohort by the number of firms, and then taking the natural logarithm of this quotient, which we label *Average Carrier Size (ACS)*. The methodological literature studying firm failure is deeply divided regarding whether firm size should be conditioned upon. Barron et al. (1994) argue that size must be held constant to differentiate between the liability of smallness versus liability of newness mechanisms. Coad (2018) argues that since firms that survive tend to grow, size is best viewed as downstream from firm age, and thus studies interested in estimating the total effect of age should not condition on size. However, we believe conditioning on average firm size is warranted for two reasons. First, doing so helps alleviate concerns about

time varying characteristics of young carriers not captured by our linear time trend. Second, there is evidence that the average size of new entrants varies based on industry conditions (Lee and Mukoyama 2015), suggesting Coad's (2018) arguments are not entirely correct, in that some variance in firm size is orthogonal to firm age.

Table 1 displays means, standard deviations, and correlations of our variables. All continuous variables were mean-centered to make the regression intercept interpretable

Table 1: Correlation matrix, means, and standard deviations.

	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>
1. Job Creation Rate Trucking (JCRT)	1.00													
2. Job Destruction Rate Trucking (JDRT)	0.48	1.00												
3. Job Destruction Rate Trucking Exit (JDRTE)	0.60	0.92	1.00											
4. Job Destruction Rate Trucking Downsizing (JDRTD)	-0.10	0.51	0.12	1.00										
5. Carrier Young Linear (CYLin)	0.69	0.71	0.77	0.10	1.00									
6. Carrier Young Log (CYLog)	0.77	0.74	0.84	0.03	0.95	1.00								
7. Job Creation Rate Manufacturing (JCRMfg)	0.30	-0.19	-0.10	-0.25	0.00	0.00	1.00							
8. Job Destruction Rate Manufacturing (JDRMfg)	-0.22	0.44	0.27	0.52	0.00	0.00	-0.50	1.00						
9. Trend	-0.14	-0.25	-0.15	-0.31	0.00	0.00	-0.37	-0.42	1.00					
10. General Freight (GF)	-0.09	-0.02	0.11	-0.29	0.00	0.00	-0.01	0.00	0.02	1.00				
11. Recession	-0.24	0.27	0.17	0.31	0.00	0.00	-0.46	0.50	-0.06	0.01	1.00			
12. Job Creation Rate Mining Support (JCRMS)	0.13	-0.04	-0.03	-0.05	0.00	0.00	0.35	-0.07	-0.26	0.00	-0.13	1.00		
13. Job Destruction Rate Mining Support (JDRMS)	-0.10	0.15	0.07	0.22	0.00	0.00	-0.12	0.09	-0.07	-0.01	0.05	-0.61	1.00	
14. Average Carrier Size (ACS)	-0.37	-0.55	-0.60	-0.07	-0.67	-0.63	0.21	-0.01	-0.27	0.09	-0.04	0.09	0.03	1.00
Mean	19.92	24.82	13.04	11.78	-3.84	-1.14	9.07	9.73	12.13	0.49	0.12	21.69	18.55	6.48
Standard Deviation	4.73	5.98	5.20	2.40	2.28	0.67	0.87	2.27	7.18	0.50	0.33	6.81	7.12	2.27

Data Screening

In screening the data, it became apparent that four records corresponding to general freight carriers in the “year 2” age bin in 1996, “year 3” age bin in 1997, “year 4” age bin in 1998, and “year 5” in 1999 were highly unusual in that employees per firm, rather than being ~6 (standard at that time) jumped to 16. As these records were clear outliers and unduly pulled down *Job Creation Rate* and *Job Destruction Rate*, we elected to remove them from the analysis.

Model Free Evidence

Per Davis-Sramek et al. (2023), we first provide model-free evidence. Figure 1 plots job creation and job destruction rates for general freight carriers in the “year 1” and “year 5” age bin in each year of data. A few things are worth noting. First, we see strong evidence that younger carriers have both higher rates of job creation and job destruction than older carriers, which aligns with H₁ and H₂. Second, the magnitude of job creation and destruction is quite high. For example, the average job destruction rate for carriers in the “year 1” age cohort was 32.8. Third, job destruction rates appear countercyclical; job creation rates appear procyclical. In comparison, Figure 2 shows that *Job Destruction Rate Manufacturing* is far more strongly linked to years with a recession (2001, 2008, 2009). One thing worth noting is that while the 2001 recession is generally considered milder than the Great Recession (Foster et al. 2016a), this does not appear to be the case for manufacturing or trucking. One explanation is that many of the jobs lost in 2001 and 2002 stemmed from offshoring given normalization of trade relations with China in 2000 (Pierce and Schott 2016).

Figure 1: Job creation and destruction rates as a function of carrier age

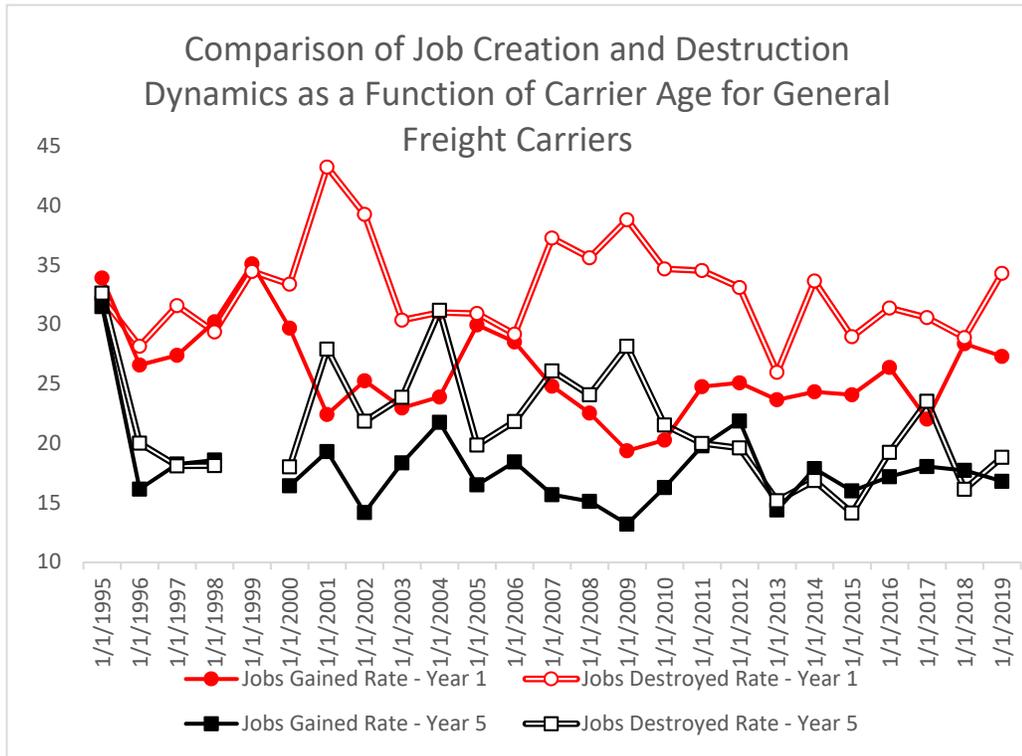
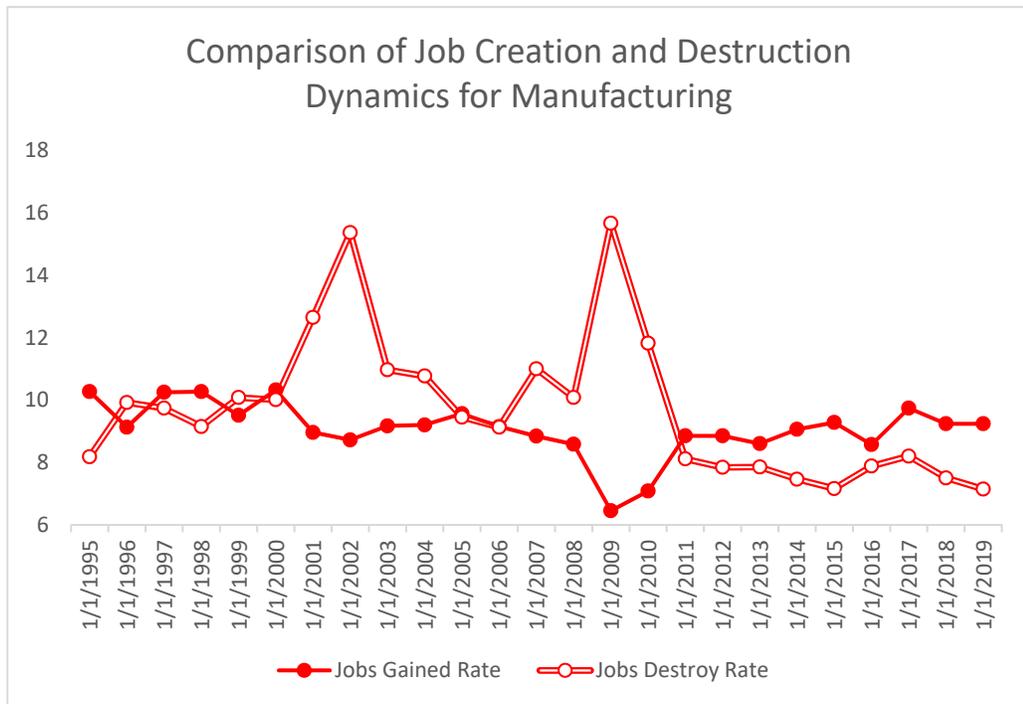


Figure 2: Job creation and job destruction rate in manufacturing.



Statistical Model Formulation

Letting a index the age of carriers in a cohort, letting s index the subsector of trucking in which carriers operating (general versus specialized freight), and letting t index each calendar year, we estimate various specifications of models to test our predictions. Recall H_1 predicts that $JCRT$ will decline in an attenuated manner as a function of carrier age. To test this prediction, we estimate the following two models, the first with a linear carrier age term, the second with a logarithmic one:

$$JCRT_{ast} = \alpha_0 + \alpha_1 CYLin_{at} + \alpha_2 JCRMfg_t + \alpha_3 Trend_t + \alpha_4 ACS_{ast} + \alpha_5 Recession_t + \alpha_6 JCRMS_t + \alpha_7 GF_s + \varepsilon_{ast} \quad (1)$$

$$JCRT_{ast} = \beta_0 + \beta_1 CYLog_{at} + \beta_2 JCRMfg_t + \beta_3 Trend_t + \beta_4 ACS_{ast} + \beta_5 Recession_t + \beta_6 JCRMS_t + \beta_7 GF_s + \varepsilon_{ast} \quad (2)$$

Following Miller et al. (2017), we can test H_1 by examining which of the two specifications fits better using information theoretic approaches, specifically examining each model's corrected Akaike Information Criterion (CAIC) to evaluate whether one model fits substantially better than the other. H_1 will be corroborated if β_1 is positive and the model in Equation 2 fits substantially better than the model in Equation 1. Analogously, to test H_2 , we estimate the following two models in Equations 3 and 4 and ascertain whether the model in Equation 4 results in better fit than the model in Equation 3.

$$JDRT_{ast} = \gamma_0 + \gamma_1 CYLin_{at} + \gamma_2 JDRMfg_t + \gamma_3 Trend_t + \gamma_4 ACS_{ast} + \gamma_5 Recession_t + \gamma_6 JDRMS_t + \gamma_7 GF_s + \varepsilon_{ast} \quad (3)$$

$$JDRT_{ast} = \delta_0 + \delta_1 CYLog_{at} + \delta_2 JDRMfg_t + \delta_3 Trend_t + \delta_4 ACS_{ast} + \delta_5 Recession_t + \delta_6 JDRMS_t + \delta_7 GF_s + \varepsilon_{ast} \quad (4)$$

To test H₃, we use the decomposition of *JDRT* into *JDRTE* and *JDRTD* and estimate Equations 5 and 6. Though *JDRTE* and *JDRTD* are rates, across equation comparisons of the strength of the same predictor are best done when dependent variables have been transformed to have the same standard deviation (Miller et al. 2018, 2022a, 2022b). We consequently denote these standardized measures as *JDRTE** and *JDRTD**. H₃ implies $\psi_1 > \omega_1$.

$$JDRTE_{ast}^* = \psi_0 + \psi_1 CYLog_{at} + \psi_2 JDRMfg_t + \psi_3 Trend_t + \psi_4 ACS_{ast} + \psi_5 Recession_t + \psi_6 JDRMS_t + \psi_7 GF_s + \varepsilon_{ast} \quad (5)$$

$$JDRTD_{ast}^* = \omega_0 + \omega_1 CYLog_{at} + \omega_2 JDRMfg_t + \omega_3 Trend_t + \omega_4 ACS_{ast} + \omega_5 Recession_t + \omega_6 JDRMS_t + \omega_7 GF_s + \varepsilon_{ast} \quad (6)$$

To test H_{4a} and H_{4b}, we examine parameters β_2 and δ_2 from Equations 2 and 4—as a preview of our findings, we find *CYLog* results in a much better fit than *CYLin* for both *JCRT* and *JDRT*—which our theory predicts will both be positive. Lastly, to test H_{5a} and H_{5b}, we expand Equations 2 and 4 as shown in Equations 7 and 8. H_{5a} implies β_8 will be positive, whereas H_{5b} implies δ_8 will be positive.

$$JCRT_{ast} = \beta_0 + \beta_1 CYLog_{at} + \beta_2 JCRMfg_t + \beta_3 Trend_t + \beta_4 ACS_{ast} + \beta_5 Recession_t + \beta_6 JCRMS_t + \beta_8 CYLog_{at} \times JCRMfg_t + \varepsilon_{ast} \quad (7)$$

$$JDRT_{ast} = \delta_0 + \delta_1 CYLog_{at} + \delta_2 JDRMfg_t + \delta_3 Trend_t + \delta_4 ACS_{ast} + \delta_5 Recession_t + \delta_6 JDRMS_t + \delta_8 CYLog_{at} \times JDRMfg_t + \varepsilon_{ast} \quad (8)$$

One of the challenges with the structure of the BDS is that the data is cross-classified at the age cohort and calendar year level. There are 6 age cohorts for each 4-digit NAICS code measured over 25 calendar years (resulting in 12 panels each of 25 records, less the 4 outliers mentioned earlier). To accommodate this complex error structure, we estimate a linear mixed effects model (Cudeck 1996) with two dimensions of residual correlation. First, for each panel, we

allow residuals to follow a spatial power structure—identical to an AR(1) structure except allowing for our four missing records. Second, for each calendar, we allow residuals across the 12 panels to have a compound symmetry structure by including a random intercept (Singer and Willett 2003). All models were estimated using the PROC MIXED command in SAS Version 9.4 using full information maximum likelihood. Following common practice in labor economics, residuals are weighted based on the square root of the employment denominator used in the rate calculations. Given the limited number of panels, Kenward-Roger (1997) corrections to degrees of freedom are utilized. Histograms of the residuals indicated they were approximately normal. Results are provided in Table 2. To give a sense of explanatory power, we report weighted R^2 statistics from estimating our models separately using weighted OLS regression.

Starting with H_1 concerning *JCRT*, Model 2 using *CYLog* has a CAIC that is 58.2 units smaller than Model 1 that uses *CYLin*; as a difference of 10 units or more is considered very strong evidence that one specification is preferred (Burnham and Anderson 2004), H_1 receives corroboration. To ascertain that the *CYLog* tracks the data, in Figure 3 we reproduce results from both specifications as well as a fully saturated dummy variable specification. As can be seen, *CYLog* closely follows the fully saturated structure. The magnitude of this effect cannot be understated; carriers in the “year 1” cohort are predicted to have a job creation rate of 27, *ceteris paribus*, whereas carriers in the “year 6-10 cohort” are predicted to have a job creation rate of 14.65, *ceteris paribus*. Given the standard deviation of *JCRT* is 4.73, this difference amounts to 2.61 standard deviations, which is a large effect (Cohen et al. 2003).

Table 2: Regression Results

	Model 1: <i>JCRT</i>	Model 2: <i>JCRT</i>	Model 3: <i>JDRT</i>	Model 4: <i>JDRT</i>	Model 5: <i>JDRTE*</i>	Model 6: <i>JDRTD*</i>	Model 7: <i>JCRT</i>	Model 7: <i>JDRT</i>
Intercept	21.25*** (29.80)	21.06*** (38.25)	26.84*** (50.76)	26.52**	0.12* (1.74)	0.46*** (3.85)	21.04*** (39.01)	26.47*** (61.81)
Carrier Young Linear	1.43*** (9.50)		1.10*** (8.87)					
Carrier Young Log		5.94*** (16.76)		4.74*** (13.82)	0.92*** (15.35)	-0.04 (-0.37)	6.02*** (17.79)	4.84*** (14.43)
Job Creation Rate Manufacturing	1.21*** (3.19)	1.02*** (2.97)					1.08*** (3.16)	
Job Destruction Rate Manufacturing			0.72*** (6.01)	0.75*** (6.87)	0.06*** (3.92)	0.18*** (6.25)		0.79*** (7.21)
Trend	-0.04 (-0.89)	-0.03 (-0.68)	-0.19*** (-4.87)	-0.16*** (-5.07)	-0.02*** (-4.36)	-0.03** (-2.60)	-0.02 (-0.60)	-0.16*** (-4.98)
General Freight	-0.61 (-1.11)	-0.85** (-2.59)	-0.06 (-0.16)	-0.18 (-0.58)	0.22*** (4.03)	-0.55*** (-5.71)	-0.88*** (-2.84)	-0.19 (-0.65)
Average Carrier Size	0.76 (0.67)	1.81** (2.24)	-7.32*** (-7.14)	-6.00*** (-7.53)	-0.98*** (-7.17)	-0.48** (-1.98)	2.01** (2.60)	-5.72*** (-7.30)
Recession	-1.73** (-2.17)	-1.97** (-2.49)	1.67** (2.35)	1.64** (2.43)	0.20** (2.16)	0.26 (1.55)	-1.99** (-2.52)	1.62** (2.42)
Job Creation Rate Mining Support	0.01 (0.14)	0.01 (0.42)					0.02 (0.46)	
Job Destruction Rate Mining Support			0.09*** (3.10)	0.09*** (3.21)	0.01* (1.84)	0.02*** (3.12)		0.08*** (3.21)
Carrier Young Log × Job Creation Rate Manufacturing							0.65*** (2.88)	
Carrier Young Log × Job Destruction Rate Manufacturing								0.25** (2.63)
Number of Observations	296	296	296	296	296	296	296	296
Corrected Akaike Information Criterion (CAIC)	1429.1	1370.9	1477.5	1435.6	340.7	688.0	165.2	1431.0
R ² Weighted OLS	0.633	0.743	0.790	0.824	0.842	0.429	0.751	0.828

Figure 3: Model implied results for JCRT as a function of carrier age.

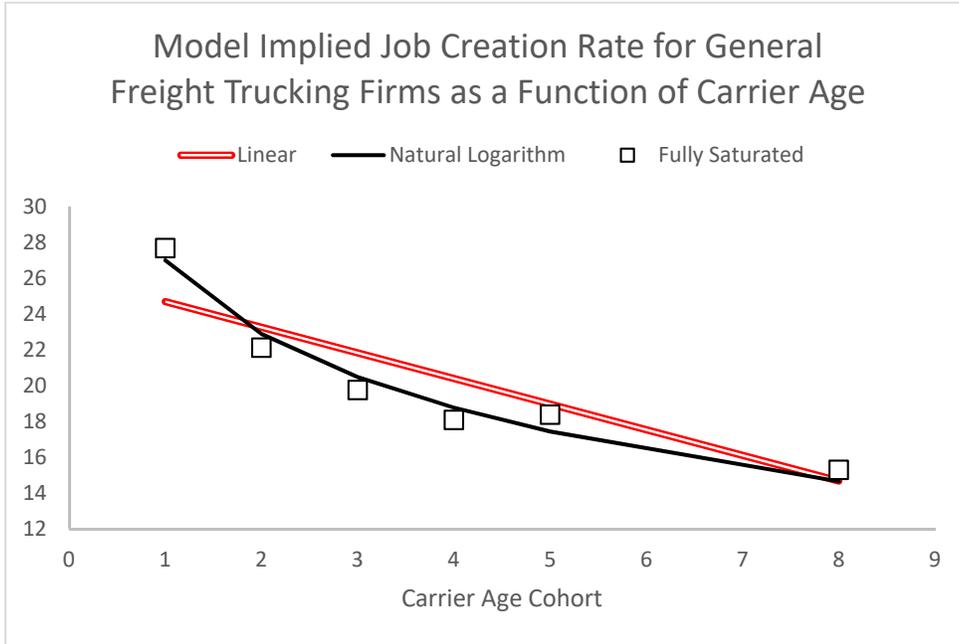
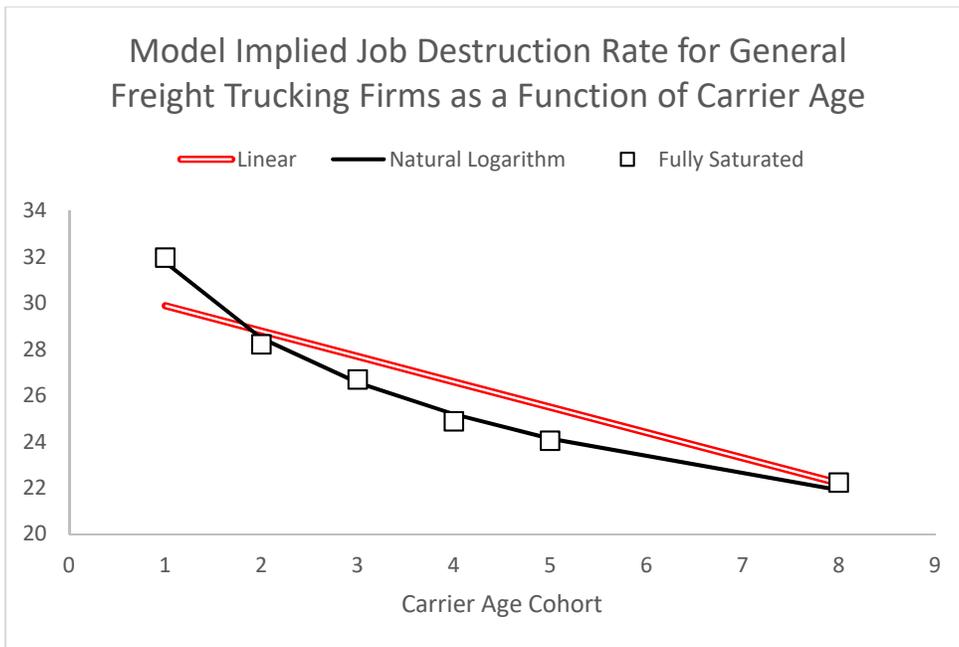
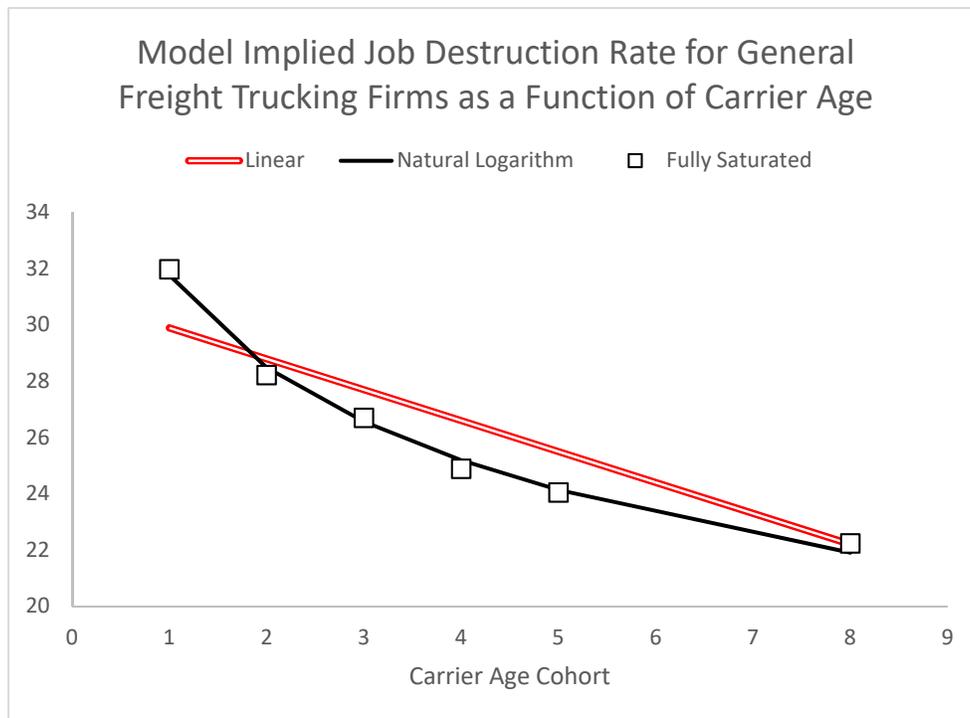


Figure 4: Model implied result for JDRT as a function of carrier age.



Turning to H₂ concerning *JDRT*, we likewise see comparing Models 3 and 4 that *CYLog* results in far better fit than *CYLin*, with the CAIC being 41.9 units smaller. This again provides strong evidence corroborating H₂. As before, in Figure 4 we plot the two single parameter specifications relative to a fully saturated dummy variable specification and observe that *CYLog* closely tracks the fully saturated specification. As before, the magnitude of this effect is very pronounced; carriers in the “year 1” cohort are predicted to have a job destruction rate of 31.8, *ceteris paribus*, whereas carriers in the “year 6-10 cohort” are predicted to have a job destruction rate of 21.9, *ceteris paribus*. Given the standard deviation of *JDTR* is 5.98, this difference amounts to 1.64 standard deviations, which is a large effect (Cohen et al. 2003).

Figure 4: Model implied result for *JDRT*.

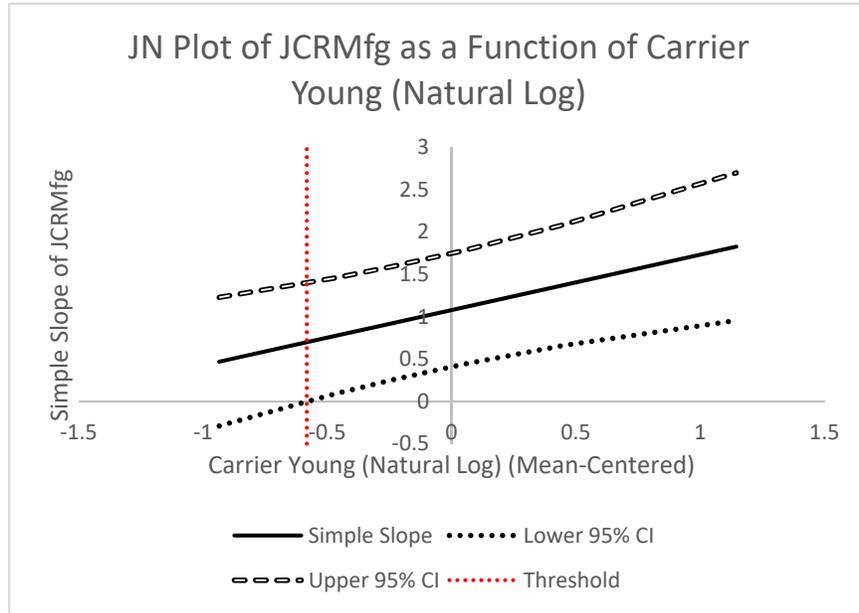


Turning now to H₃, Model 5 reports that *CYLog* is strongly linked to job destruction due to carrier exit, with a doubling of carrier age being associated with a ~0.92 standard deviation decrease in jobs destroyed due to carrier exit. In contrast, Model 6 reports a nonsignificant relationship between *CYLog* and job destruction due to downsizing. To test H₃, we use the rules

of random variables and test whether these parameters differ significantly, finding they do ($\psi_1 - \omega_1 = 0.96, z = 7.93 [p < 0.01]$). Consequently, it appears carrier age is much more strongly linked to jobs lost due to carrier exit than jobs lost due to downsizing.

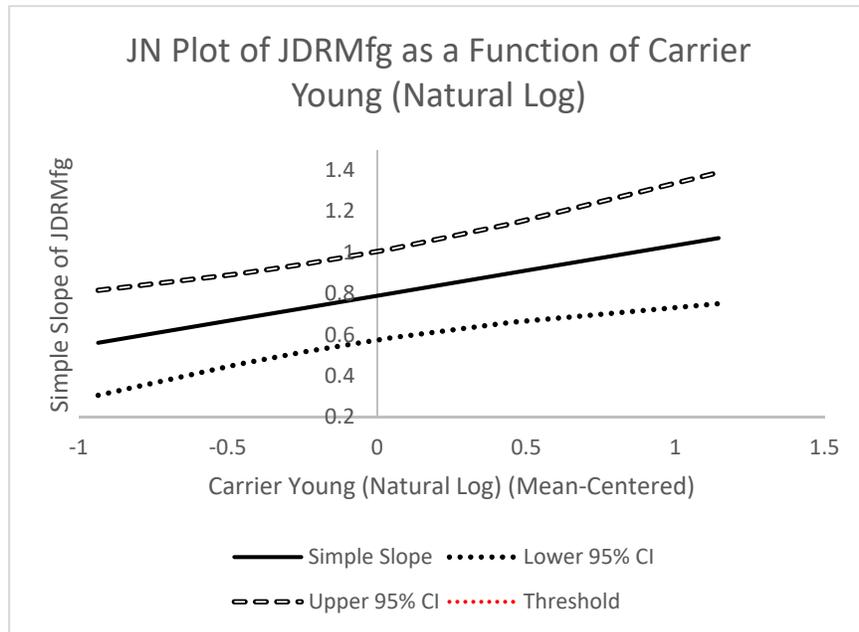
Moving to H_{4a}, in Model 2 we observe the JCRMfg is positive and significant ($\beta_2 = 1.02, z = 2.97$), indicating carriers create jobs more rapidly when manufacturers are also creating jobs more rapidly, *ceteris paribus*. Thus, H_{4a} receives corroboration. Concerning H_{4b}, in Model 4 we observe the JDRMfg is positive and significant ($\delta_2 = 0.75, z = 6.87$), indicating carriers destroy jobs more rapidly when manufacturers are also destroying jobs more rapidly, *ceteris paribus*. However, these positive average effects are not invariant across carrier age. As shown in Model 7, the two-way interaction between *CYLog* and *JCRMfg* is positive ($\beta_8 = 0.65, z = 2.88$), indicating younger carriers are more sensitive to manufacturers' job creation rates. To better understand this effect, Figure 5 presents a Johnson-Neyman (JN) plot (Bauer and Curran 2005) showing the region of significance of *JCRMfg* as a function of carrier age. The threshold for the region of significance indicates that manufacturers' rates of job creation do not affect the job creation rates of carriers that are 6-10 years old, whereas this effect is significant for younger carriers. Thus, H_{5a} receives corroboration. Lastly, in Model 8 the two-way interaction between *CYLog* and *JDRMfg* is positive ($\delta_8 = 0.25, z = 2.63$), indicating younger carriers are more sensitive to manufacturers' job destruction rates. Figure 6 displays this effect in a JN plot. Unlike in Figure 5, we see the region of significance for *JDRMfg* never intersects 0, indicating that manufacturers' job destruction positively affects job destruction for all our carriers, though this effect is more pronounced for younger carriers. Thus, H_{5b} receives corroboration.

Figure 5: Johnson-Neyman plot of *JCRMfg* conditional on *CYLog*.



Note: "Carrier Young" is the natural log of carrier age multiplied by minus one. This means an increase, e.g., from -1.609 to -1.386 log years, represents an increase (of a year, in this example) in the youth/a decrease in the age of the firm. The mean of Carrier Young is -1.14, or a carrier age of 3.127 years.

Figure 6: Johnson-Neyman plot of *JDRMfg* conditional on *CYLog*.



Before moving to the discussion, we wish to note a few additional features of our results. First, we observe very different effects for *Trend* for *JCRT* and *JDRT*. Whereas there is no long-term trend in young carriers' job creation rates once we condition on the other predictors, there is a strong secular decline in job destruction rates of 0.16 percentage points per year. We will return to the implications of these findings later. Second, *ACS* also has very different effects across measures, with large average carrier size being associated with higher growth rates but much reduced job destruction rates. Third, our models display strong explanatory power, with weighted R^2 statistics of 0.751 for the full model for *JCRT* and 0.828 for *JDRT*. Per Busenbark et al. (2022), high R^2 values help assuage concerns about omitted variable bias because it is difficult to conceive of omitted predictors that reside theoretically upstream and would have pronounced enough partial correlations to shift the results.

DISCUSSION

Theoretical Implications

This research makes theoretical contributions to both SCM and economics. Starting with the SCM literature, this research provides strong evidence of a liability of newness (Stinchcombe 1965) in trucking as it pertains to job destruction and carrier exit. Our results reveal that younger carriers have much higher job destruction rates, especially for jobs lost due to firm exit. As job destruction rates due to firm exit represent a size-weighted rate of firm exit (Haltiwanger et al. 2013), our results indicate younger trucking firms are much more likely to fail than older peers. This contrasts with findings from Silverman et al. (1997, p. 46), who argued carriers follow a liability of aging pattern (Barron et al. 1994; Coad 2018) whereby exit probability increases as carriers age. Given the superior coverage of the BDS data, the fact BDS unambiguously tracks exit, and the timelier nature of our findings, this suggests future researchers should press forward assuming the liability of newness holds for job destruction in trucking, especially jobs loss due to firm exit., Given the

large impact of carrier age on job destruction rates due to carrier exit (see Table 1), our results further indicate that studies of carrier exit must include carrier age as a predictor.

A second way our research extends theory in SCM is by providing the first examination of young carriers' job creation rates. This has important implications given disagreement about whether there is a structural shortage of truck drivers, with media outlets concluding there is (Goodman 2022; Yukevich 2021), whereas academic publications point to the labor market for truck drivers behaving in a manner consistent with theory in labor economics (Burks and Monaco 2019; Miller et al. 2021a; Phares and Balthrop 2022). Our study is the first to analyze job dynamics at truck transportation establishments, which are the largest single employer of heavy and tractor-trailer truck drivers (Bureau of Labor Statistics 2023b)⁷. We find young carriers have a disproportionate impact on job creation, with one year old carriers creating jobs almost 37% more rapidly than five-year-old firms. The fact job creation rates fall as carriers age points to the existence of potential frictions (Pozzi and Schivardi 2016) that may inhibit older carriers' ability to expand operations (Eslava and Haltiwanger 2018), such as less flexible administrative structures (Coad 2018) or established freight networks that cannot be quickly adjusted without sacrificing economies of scope (Miller and Muir 2020). Our findings regarding lower rates of job creation for older carriers point towards two reasons why trucking capacity may not adjust as quickly to changing demand conditions as shippers would like: (i) the existence of adjustment frictions that increase as carriers age (Decker et al. 2020) and (ii) the need for newly created carriers to ramp up. To the best our knowledge, our work is the first to advance the existence of these two mechanisms, which may play a central role in informing discussion about the truck driver shortage.

⁷ In 2017, Truck Transportation (NAICS484) employed 870,170 (or 49.7%) of the 1,748,140 Heavy and Tractor-Trailer Truck Drivers (Standard Occupational Code 53-3032) who were employees of non-farm-based businesses (BLS 2017). (The total employment number includes owner-operators who used a business form in which they reported themselves as employees for tax purposes, but not owner-operators who used other business forms.)

A third way this research contributes to theory in SCM is documenting how both job creation and job destruction in trucking are tied to the dynamics in freight generating sectors, particularly manufacturing. Regarding job destruction and motor carrier exits, prior research &&& (Guntuka et al. 2019; Silverman et al. 1997) has not considered how dynamics in downstream freight generating sectors could affect carriers' propensity to shed jobs or exit. However, looking at the absolute value of the z-scores in Table 2 Model 4, the job destruction rate in manufacturing ranked as third most important predictor—behind only the natural logarithm of carrier age and average carrier size—and far surpassing the *ceteris paribus* effect of the Global Financial Crisis in 2008-2009. Thus, our research points to the critical role of recognizing the derived nature of transportation demand (Allen 1977) when studying carrier exit, which aligns with evidence that firm exit is primarily driven by demand side factors (Foster et al. 2008). Regarding job creation, the fact we find a strong relationship between manufacturers' rate of job creation and trucking firms' rate of job creation adds a new wrinkle into discussions regarding potential shortfalls of trucking capacity by highlighting that trucking firms can only create jobs if downstream demand conditions will support the additional freight volumes necessary to keep more drivers busy. This demand side perspective complements existing supply side discussions about carriers having the ability to recruit (Phares and Balthrop 2022) and retain (Miller et al. 2021a) drivers.

Turning to the economics literature on job creation and job destruction, one way this research contributes is to suggest the possibility—at least in truck transportation—that the impact of firm age on job destruction operates more strongly by influencing firm exit, as opposed to firms downsizing operations. To date, existing conversations about the relationship between firm age and job destruction focus on the rate of jobs lost both due to firm contraction as well as firm exit (Haltiwanger et al. 2013). However, there is little reason to think that losing demand from shippers should differentially affect the likelihood that firms downsize based on their age, since downsizing costs should be relatively invariant as a function of age (Hamermesh 1995). In contrast, the

mechanisms underlying liability of newness (Stinchcombe 1965), such as less knowledge about market demand (Foster et al. 2016b) or less established customer relationships (Coad 2018), suggest that losing demand from shippers will be especially challenging for the youngest carriers. Thus, our theory thus contributes to labor economics by identifying an unrecognized boundary condition (Goldsby et al. 2013; Makadok et al. 2018).

The second way our research contributes to labor economics is, to the best of our knowledge, by providing the first documented evidence regarding how job creation and destruction rates in a downstream sector (manufacturing) cascade to the upstream sector (trucking) and, furthermore, identifying a boundary condition (Goldsby et al. 2013) by explaining that the effects of downstream job creation and destruction should be larger for younger upstream firms. To date, existing work has examined how exogenous shocks like shale oil extraction impact job creation in the counties affected by said shocks (Decker et al. 2022). Our work, in contrast, looks at how exogenous variation (from the perspective of trucking companies) in job creation and destruction rates in manufacturing, through their impact on shipment volumes, influences job creation and job destruction in trucking. We provide a general theoretical explanation as to why (i) these cascading effects should exist (e.g., carriers can't quickly shift capacity to other shippers given network economies and the advantage of incumbency); and (ii) these cascading effects should be greater for younger firms (e.g., due to the various mechanisms undergirding the liability of newness) (Stinchcombe 1965) that should be broadly applicable across sectors. This also suggests avenues for further inquiry (Keas 2018).

Managerial and Policy Implications

Our findings also have important implications for for-hire carriers, shippers, brokers, and policymakers. Beginning with for-hire carriers, the sharp declines in creation and destruction rates suggest decisions made by managers early in a carrier's life have profound consequences. On the one hand, younger carriers can be nimbler than their older counterparts because they benefit from

learning dynamics (Coad 2018; Stinchcombe 1965), have an incentive to grow (Cassidy and Ashe 2022), and have more flexible human resource structures (Coad 2018). Taking advantage of these benefits early provides substantial job creation and revenue generation potential. On the other hand, carrier managers should watch out for and plan for several challenges associated with being young. Carrier managers' failures early on to understand their firm's cost structure (Caplice 2021), position themselves attractively to hesitant shippers (Cassidy and Ashe 2022), and make contingency plans in the event that loads decline can spell disaster. Unfortunately, our results also suggest that survival of young carriers is often a matter of luck (Barney 1986), in that carriers' load volumes are contingent upon their shippers' success, which is beyond carriers' control given firm-level demand shocks that manufacturers experience tend to be independent across manufacturing firms (Franco and Philippon 2007). Given that many small carriers obtain 40% or more of their loads from a single shipper (Voss et al. 2011), monitoring current conditions in key shippers' sectors is a crucial part of young carriers' strategic planning.

Another implication for carrier managers is that the common recruiting technique of hiring drivers who have been laid off by other carriers has become less tenable given we find a secular decline in the rate that carriers destroy jobs each year. Over our 25-year inclusive study period, we find that the job destruction rate for trucking companies declined by 3.84 percentage points, other factors held constant. This decline represents a 0.64 standard deviation decline in the job destruction rate, which is considered a large effect in statistics (Cohen et al. 2003). While not the focus of our theorizing, we expect this secular decline may stem, in part, from small, young carriers becoming less reliant on anchor shippers due to the increased availability of brokerage options (Li et al. 2022). The continued secular penetration of brokers may reduce the frictions that carriers experience in reallocating capacity if they experience declining demand, but as reported by Hawes (2022, 2023), losing key customers can reduce carriers' survival chances. For carriers looking to hire drivers, this secular decline suggests the need to consider alternative recruiting strategies. In

this regard, Burks and Monaco (2019) and Phares and Balthrop (2022) offer insight into which individuals are most likely to become truck drivers.

Turning to shippers, especially smaller shippers who tend to work with a limited number of smaller carriers on a contractual basis (Li et al. 2022; Voss et al. 2011), our findings suggest it is especially important to keep tabs on how young carriers are performing given these firms are especially sensitive to going out of business. Our results indicate a doubling of carrier age (e.g., going from 1 to 2 years of age or going from 2 to 4 years of age) is associated with a 0.92 standard deviation decline in the rate of job destruction due to carrier exit, which is statistically a large effect size (Cohen et al. 2003). Shippers working contractually with very young carriers need to monitor these firms to try and identify early warning signs that these carriers may shut down. While this may increase the administrative burden of managing carrier relationships, this helps ensure shippers aren't caught by surprise if a carrier closes, which can force shippers to both hunt down their loads already picked up but not yet delivered or scramble to find capacity on the spot market, which can be costlier than obtaining carrier capacity on a contractual basis (Scott et al. 2017).

Turning now to brokers, one implication is that brokers seeking to rapidly grow their capacity by onboarding carriers that have a strong likelihood of adding drivers would be well-served to focus on bringing in young carriers (e.g., one or two years old) into their networks. Our results indicate that a doubling of carrier age reduces the rate of job creation by 5.94 percentage points, or 1.26 standard deviations, which is statistically a large effect size (Cohen et al. 2003). Thus, while many young carriers will fail, the ones that survive are likely to grow and, in doing so, account for a disproportionate amount of job creation (Decker et al. 2014). This suggests brokers should be continually integrating cohorts of young carriers into their networks to leverage the capacity of the subgroup of younger firms that turn into high growth firms.

Turning lastly to policy makers, this research informs discussion of the truck driver shortage (American Trucking Associations 2021; Whitehouse.gov 2022) in three ways. First, we

are the first to examine job creation and destruction in the truck transportation sector, which is important because it makes up almost half of the overall labor market for heavy and tractor trailer truck drivers (Bureau of Labor Statistics 2023b). Our results thus provide a unique look at central part of the driver labor market. Second, unlike the job destruction rate, where we observe a declining secular trend for young firms, job creation rates show a nonsignificant linear trend once we condition on the job creation rate in manufacturing (which was declining over this time). The fact that we don't see a decrease in the job creation rate for young trucking firms speaks against claims of a chronic truck driver shortage, since if the driver shortage is worsening, as argued by the American Trucking Associations (ATA) (Costello, B. & Karickhoff, A. (2019)), we would expect this secular trend to be negative. When coupled with evidence that the overall labor market for truck drivers behaves as theorized by labor economics (Burks and Monaco 2019; Miller et al. 2021a; Phares and Balthrop 2022), and that shortage concerns associated with high driver turnover are focused on a specific subsector (Burks and Monaco 2019; Costello 2019b; Miller et al. 2021a), our results are inconsistent with the chronic driver shortage thesis.

Related to this first point, the third way this manuscript informs public policy is highlighting how demand side effects play a key role in the ability of trucking companies to create jobs. Since firms are unlikely to adjust employment in response to transitory increases in demand (Carlsson et al. 2021), part of the reason trucking capacity may lag demand during bull market cycles is carriers are hesitant to expand unless they have confidence that higher demand levels will be sustained. Thus, supply side efforts such as reducing the minimum driving age (Valdes-Dapena 2022), expanding apprenticeships, and increasing recruitment from non-traditional trucking worker pools (FMCSA 2022) may be addressing the wrong problem (Whitehouse.gov 2022). Rather, our findings highlight the importance of demand side policies that spur job creation in manufacturing that can provide the freight volumes necessary for carriers to expand.

Limitations

As with all research, this manuscript has limitations that should be kept in mind. First, our data is only available at the 4-digit industry level, which separates general from specialized freight, but which precludes us from observing the further subsectors within each of these (e.g., long distance versus local, or truckload versus less-than-truckload). Partially mitigating this limitation is the fact that data from the Current Employment Statistics program—available from the authors upon request—indicates employment shares across trucking subsectors were stable over our study period. Second, while heavy and tractor trailer truck drivers are the largest employee group within truck transportation, making up ~59% of total employment (Bureau of Labor Statistics 2023a), and are thus likely to drive firm-level employment dynamics, the BDS does not permit occupational breakouts, so we cannot separate out changes in driving jobs from changes in other jobs within truck transportation. Third, we cannot directly observe whether carriers obtain freight from manufacturers and, instead, rely on the CFS reporting that shipments originating from manufacturing plants account for the majority of for-hire trucking ton-miles. Fourth, as with all research that fits regression models to archival data, the mechanisms we postulated are not directly included in our models, given mechanisms are unobservable entities that cannot be operationalized as observed variables (Astbury and Leeuw 2010; Miller and Kulpa 2022). This being said, our theorizing draws on mechanisms such as those that undergird the liability of newness prediction (Stinchcombe 1965) that have stood the test of time, which increases confidence in their veracity per Meehl (1990). Furthermore, we have sought to bolster the evidence for our mechanisms via corroborative reporting from industry outlets (Cassidy and Ashe 2022; Hawes 2022, 2023).

Directions for Future Research

This manuscript suggests numerous directions for future research. Focusing on research that could be conducted with publicly available data, one avenue would be to examine how state- or even country-level changes in manufacturing employment affect state- or country-level changes in trucking employment. Such data are available from either the Quarterly Census of Employment

and Wages (QCEW) from the Bureau of Labor Statistics or County Business Patterns (CBP) from the U.S. Census Bureau. Unfortunately, these data do not parse job creation and job destruction, but this would provide a geographic dimension that extends our national analysis. Second, given evidence from Decker et al. (2022) regarding the profound impact that shocks in shale oil drilling have on the local economy, researchers could examine how the shale boom and bust cycles that have occurred over the past 20 years cascade to affect logistics employment (e.g., warehousing, trucking, support activities for transportation, etc.). QCEW and CBP data provide data on net employment that could be drawn upon, whereas confidential access to BDS via a U.S. Census Bureau Research Data Center would allow for job creation and destruction dynamics to be investigated in this setting. A third avenue for further research is to conduct case studies of young trucking companies to understand the processes that bring about heterogeneity in how they create or destroy jobs. Per Ylikoski (2019), this would help provide color regarding the mechanisms underlying the macro-level dynamics reported in this research.

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