This PDF is a selection from a published volume from the National Bureau of Economic Research

Volume Title: The Role of Innovation and Entrepreneurship in Economic Growth

Volume Authors/Editors: Michael J. Andrews, Aaron Chatterji, Josh Lerner, and Scott Stern, editors

Volume Publisher: University of Chicago Press

Volume ISBNs: 978-0-226-81078-2 (cloth), 978-0-226-81064-5 (electronic)

Volume URL: https://www.nber.org/books-and-chapters/role-innovation-and-entrepreneurship-economic-growth

Conference Date: January 7-8, 2020

Publication Date: Februrary 2022

Chapter Title: What's Driving Entrepreneurship and Innovation in the Transportation Sector?

Chapter Author(s): Derrick Choe, Alexander Oettl, Rob Seamans

Chapter URL: https://www.nber.org/books-and-chapters/role-innovation-and-entrepreneurship-economic-growth/whats-driving-entrepreneurship-and-innovation-transportation-sector

Chapter pages in book: p. 251 – 285

5

What's Driving Entrepreneurship and Innovation in the Transportation Sector?

Derrick Choe, Alexander Oettl, and Rob Seamans

5.1 Introduction

The transportation sector—including the movement and storage of physical goods and the movement of people—is an important contributor to the US economy. It directly accounts for 3.2 percent of US gross domestic product (GDP) and indirectly affects many other sectors (figure 5.1). Personal transportation makes up a large portion of American consumption; according to the Bureau of Transportation Statistics, households spent an average of $9,737 on transportation in 2017, the second largest household expenditure category after housing.[1] Economists have highlighted the multiple ways in which transportation affects innovation and growth, including opening up geographically distant markets for entrepreneurs (Donaldson 2018), linking together people and thereby increasing the recombination of ideas (Agrawal, Galasso, and Oettl 2017), sparking new innovations by the arrival of a new product (Sohn, Seamans, and Sands 2019), and more.

Derrick Choe is a first-year doctoral student at NYU Stern School of Business.

Alexander Oettl is an associate professor of strategy and innovation at the Scheller College of Business, Georgia Institute of Technology, and a research associate of the National Bureau of Economic Research.

Rob Seamans is an associate professor of management and organizations at NYU Stern School of Business.

We thank Michael Andrews, Aaron Chatterji, Mercedes Delgado, Gilles Duranton, Jeff Furman, Adam Jaffe, Ben Jones, Shane Greenstein, David Popp, Scott Stern, Joel Waldfogel, and Kate Whitefoot for helpful comments and suggestions. Seamans acknowledges generous support from Google's Tides Foundation. For acknowledgments, sources of research support, and disclosure of the authors' material financial relationships, if any, please see https://www.nber.org/books-and-chapters/role-innovation-and-entrepreneurship-economic-growth/whats-driving-entrepreneurship-and-innovation-transport-sector.

1. https://www.bts.gov/browse-statistical-products-and-data/transportation-economic-trends/tet-2018-chapter-6-household.

Across the US economy, firms are increasingly adopting new technologies, including artificial intelligence (AI), robots, sensors, and others, and the transportation sector is no different. For example, Uber bought the autonomous trucking startup Otto for $680 million in 2016,[2] and Amazon bought warehouse robotics company Kiva for $775 million in 2012.[3] While fully autonomous vehicles (AVs) are still some ways off in the future—a topic we discuss later in this chapter—Kiva has led to dramatic changes in the way that Amazon organizes some of its fulfilment centers. Whereas in the past, a human picker would go up and down aisles of shelving units to pick the order, now the Kiva robots bring the shelving units to a central location, where the human picker is located (CEA 2016).

The costs associated with moving goods and individuals differ greatly. While the real cost of moving goods is 90 percent less than it was at the beginning of the twentieth century, transporting individuals remains costly (Glaeser and Kohlhase 2004). In this chapter, we review recent trends in the transportation sector and conduct deeper investigations into recent changes and innovations in the movement (and storage) of (1) goods and (2) people.

The key takeaways from this chapter include:

- Despite the rapid expansion of Internet-enabled services and the digital economy, the importance of transporting physical goods has not diminished.
- In aggregate, the transportation sector has grown (20 percent employment growth over 5 years), but this average increase masks large differences in the composition of the transportation sector (rail and sea transport are down, couriers and warehousing are up).
- Transportation's share of value added in the economy has also increased (an absolute increase of 0.3 percent over 5 years).
- As such, warehousing and the automation contained therein (robots, AVs, drones) will play a critical role in this increasingly important component of the transportation supply chain.

In the sections that follow, we first describe what we currently know about the sector from prior academic research and aggregate government statistics. We then highlight recent innovations in the transportation and storage of goods, with a deep dive into the warehouse sector—an area of increasing activity. We then review existing work in the personal mobility domain, focusing on the impact of ride sharing platforms and the potential for AVs to transform the economy. How these new innovations affect the sector and the economy more broadly will ultimately depend on a variety of factors, including government regulation, technological advancement, and customer

2. https://techcrunch.com/2016/08/18/uber-acquires-otto-to-lead-ubers-self-driving-car-effort-report-says/.

3. https://techcrunch.com/2012/03/19/amazon-acquires-online-fulfillment-company-kiva-systems-for-775-million-in-cash/.

demand. In our final section, we conclude and discuss opportunities for future work.

5.2 What Do We Know?

5.2.1 Prior Literature

Prior literature has highlighted the many ways in which transportation can affect innovation and economic growth. As the exchange of goods and services is contingent on the movement of materials and workers, transportation plays a key role in economic output. Investments in infrastructure and transportation technologies transform the urban landscape, and they spur productivity growth and innovative activity.

Innovations in transportation infrastructure directly impact the spatial distribution of workers. Baum-Snow (2007) finds that the development of interstate highways contributed to the post–World War II suburbanization of the US. Along with contributing to population shifts within cities, transportation influences the distribution of work across cities. Duranton and Turner (2012) estimate that a 10 percent increase in a city's initial stock of highways leads to a 1.5 percent increase in employment over a period of two decades. Taken together, these results indicate that transportation infrastructure has two distinct effects on input reorganization and growth: it can increase urban employment growth while also leading to population growth in surrounding areas (Redding and Turner 2015).

In addition to this work estimating the long-run effects of interstate highway development, other researchers have focused on the localized effects of within-city transportation infrastructure. In particular, studies have investigated the value of these transportation networks by estimating the proximal effects of subway line development on real estate prices. Billings (2011) finds that access to light rail transit increased single-family property values by 4 percent and condominium values by 11 percent. Gibbons and Machin (2005) study the London subway network and find that homes near newly developed stations experienced price increases of around 9 percent relative to those unaffected by transportation changes. The authors compare the price effects of proximity to subway stations to the price estimates of other local amenities, such as primary school performance, and find that households seem to value transportation higher relative to other local factors.

Changes to the flow of people are accompanied with innovative activity; transportation's positive impacts on economic performance through worker movement are also the product of resulting positive knowledge externalities. Agrawal, Galasso, and Oettl (2017) find that the stock of regional highways increases inventive productivity not only through its labor agglomeration effects but also through improvements to knowledge flows—increasing output beyond that explained by the influx of new innovators. Perlman (2016) provides historical evidence that the nineteenth-century "transportation revolution"—marked by the development of railroad networks—increased patenting activity through increased market access, among other covariates.

In addition to its impact on the geography of labor, transportation infrastructure serves as a catalyst to firm growth and productivity. Gains in accessibility to new roads lead to increases in the number of establishments, employment, and output per worker (Gibbons et al. 2019). Baum-Snow et al. (2017) further decompose the effects of highway growth on economic activity in China; they find that areas most proximal to dense highway networks show increased output, employment, and wages, and shift toward business services and manufacturing. Distal areas from these clusters demonstrate an opposite effect; they grow more slowly and specialize in agriculture.

These economic benefits to transportation may rely on improvements to the transfer of physical goods. The development of colonial India's railroad system transformed agricultural trade; by decreasing the cost of transporting origin-destination products and increasing trade flows, this expansive change in transportation infrastructure increased per capita agricultural incomes (Donaldson 2018). Additionally, economic gains to transportation may require sufficient ease of transporting capital along with goods. In examining the effects of railway access on economic growth, Banerjee, Duflo, and Qian (2012) find suggestive evidence that production factor immobility may limit the localized economic benefits to transportation infrastructure. These studies highlight the distinction between worker and capital flows; the regional benefits to government investment in transportation networks may be limited by the movement of physical production factors.

Historically, waterways have played a crucial role in determining market access, economic development, and innovation. Sokoloff (1988) finds evidence that navigable waterways explain early regional variation in patent activity across the US. The author suggests that during the Industrial Revolution, areas like southern New England and New York exhibited high growth in patenting due to increased access to low-cost river and canal transportation. The economic changes attributable to transportation infrastructure are persistent long after initial natural advantages afforded by geography become obsolete. Bleakley and Lin (2012) find that despite the decline in portage in the southeastern US, original portage cities remain denser than comparable regional counterparts, suggesting a degree of path dependence resulting from historical transportation activity.

More recent work has begun to focus on a more basic form of transportation infrastructure: the walkability of streets. In Roche (forthcoming), the author examines how the physical layouts of street networks facilitate idea exchange among knowledge workers. The paper demonstrates that neighborhoods that are easier to traverse by foot also produce more patents (even after controlling for population and other density related measures) and are more likely to build on geographically proximate knowledge inputs.

Table 5.1 **Industry summary statistics**

Industry title	NAICS code	2018 employment (in thousands)	2018 real average weekly wage (US$)	Five-year employment growth (percent) (2013–2018)	Five-year real wage growth (percent) (2013–2018)
All Transport/Warehousing	48/49	5419.1	940.0	20.3	1.7
Air Transport	481	501.4	1,107.1	12.8	1.2
Rail Transport	482	214.3		−7.4	
Water Transport	483	64.7		−0.9	
Truck Transport	484	1491.3	1,004.6	7.9	0.7
Transit/Ground Passenger Transport	485	487.4	663.0	8.7	8.7
Pipeline Transport	486	48.6		9.3	
Scenic/Sightseeing Transport	487	34.3		17.3	
Support Activities for Transport	488	711.8	955.5	18.9	0.6
Couriers and Messengers	492	725.5	784.6	33.4	14.9
Warehousing and Storage	493	1139.9	845.2	59.2	3.5

Note: These data come from BLS Current Employment Statistics. We omit the Postal Service, as well as wage data for rail, water, pipeline, and scenic/sightseeing transportation, as these aggregate data are not available from BLS CES.

5.2.2 Basic Statistics

In the US, the transportation sector (NAICS codes 48–49) contributes approximately 3 percent to US GDP and comprises multiple sub-industries, including air, rail, water, truck, pipeline, and passenger transport. It also includes couriers, messengering, warehousing, and storage businesses. Descriptive statistics of select sub-industries are presented in table 5.1. Between 2013 and 2018, sector-wide employment grew by over 20 percent, and real wages grew by 1.7 percent. However, this aggregate growth masks significant heterogeneity. Over the same period, rail and water transport saw 7 percent and 1 percent declines in employment, respectively. Conversely, the warehousing and storage (NAICS 493) and couriers and messengers (NAICS 492) sub-industries experienced the largest employment growth of all sub-industries with growth of 59 percent and 33 percent in employment, respectively. These two industries also saw real wage growth of 3 percent for warehousing and 15 percent for couriers and messengers. Providing a deeper understanding of the antecedents and consequences of this rapid growth in the warehousing sector will be an important point of focus for this chapter.

Figure 5.1 presents data on employment by transportation sub-industry over a longer period. Using data from the BLS Current Employment Statistics (BLS CES) survey to provide employment by transportation sub-industry, we see that the growth in warehousing started in 2010. Drawing from Bureau of Economic Analysis data, figure 5.2 plots value-added by

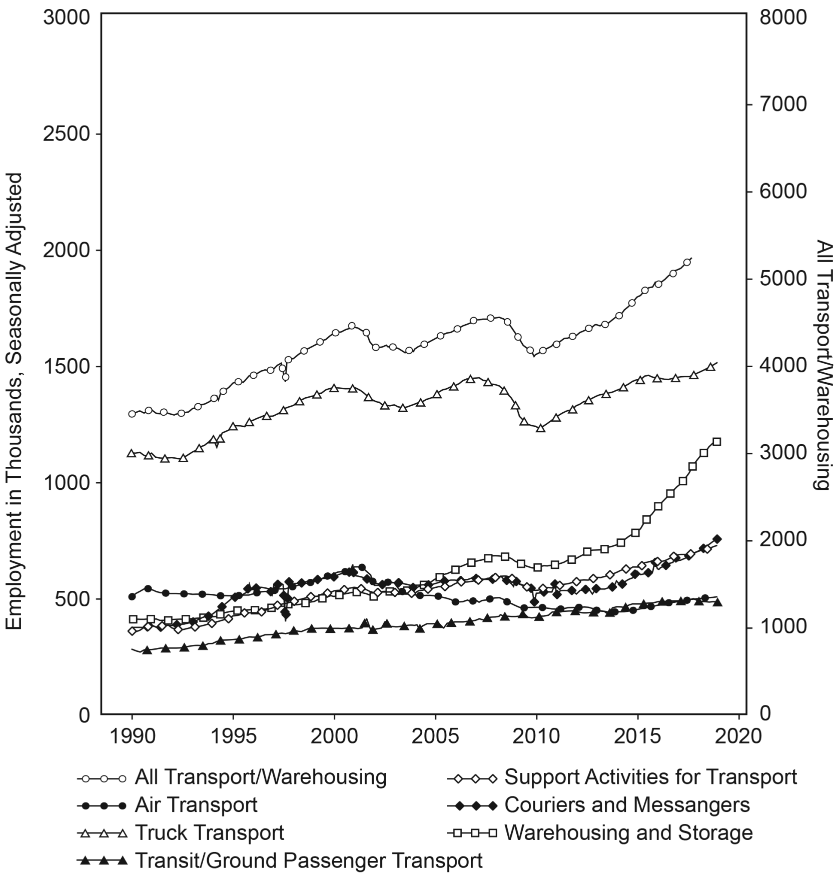

Fig. 5.1 Employment by transportation sub-industries

Source: Data are from the Bureau of Labor Statistics Current Employment Statistics survey (BLS CES).

transportation sub-industry, as a fraction of national GDP. We see that all transportation/warehousing industries make up an increasing share of aggregate economic activity, increasing from 2.8 percent in 2005 to 3.2 percent in 2018. Figure 5.3, using data from BLS CES, provides real average weekly earnings from 2006 onward,[4] by transportation sub-industry. On average, wages in the industry appear relatively flat over this entire period. However, there is some heterogeneity across sub-industries. These data suggest that as demand for transportation services increases, the industry is able to adjust relatively quickly at the margin by employing more individuals, such that wages do not rise much.

Figure 5.4 plots labor productivity by transportation sub-industry, mea-

4. The BLS CES only publishes wage estimates at the industry level from 2006 onward.

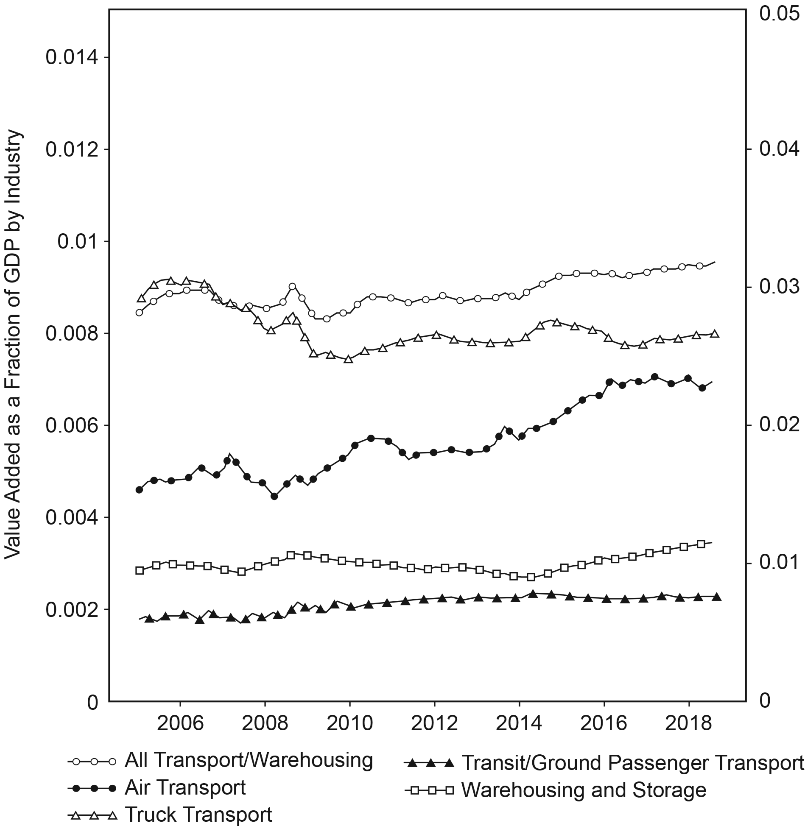

Fig. 5.2 Value added as a fraction of GDP
Source: Data are from the Bureau of Economic Analysis (BEA).

sured with BLS's Annual Index of Labor Productivity. The figure shows changes in output per hour relative to 2007 levels. Most sub-industries appear to have relatively flat productivity, although air transport has increased steadily over the almost 30-year times series between 1990 and 2018. As such, the employment growth in the sector appears not to be a result of changes in labor productivity and instead may stem from broader changes in market structure (Combes and Lafourcade 2005).

Figure 5.5 plots trends in the relative number of establishments by transportation sub-industry. The data come from the BLS Quarterly Census of Employment and Wages. The series is normalized to show establishment levels relative to 1990. While the number of establishments has increased in all sub-sectors, we find that growth in the Couriers and Messengers sub-industry outpaces that of all other sub-industries, followed by Warehousing and Storage.

Next we study two measures of innovative activity—patenting and ven-

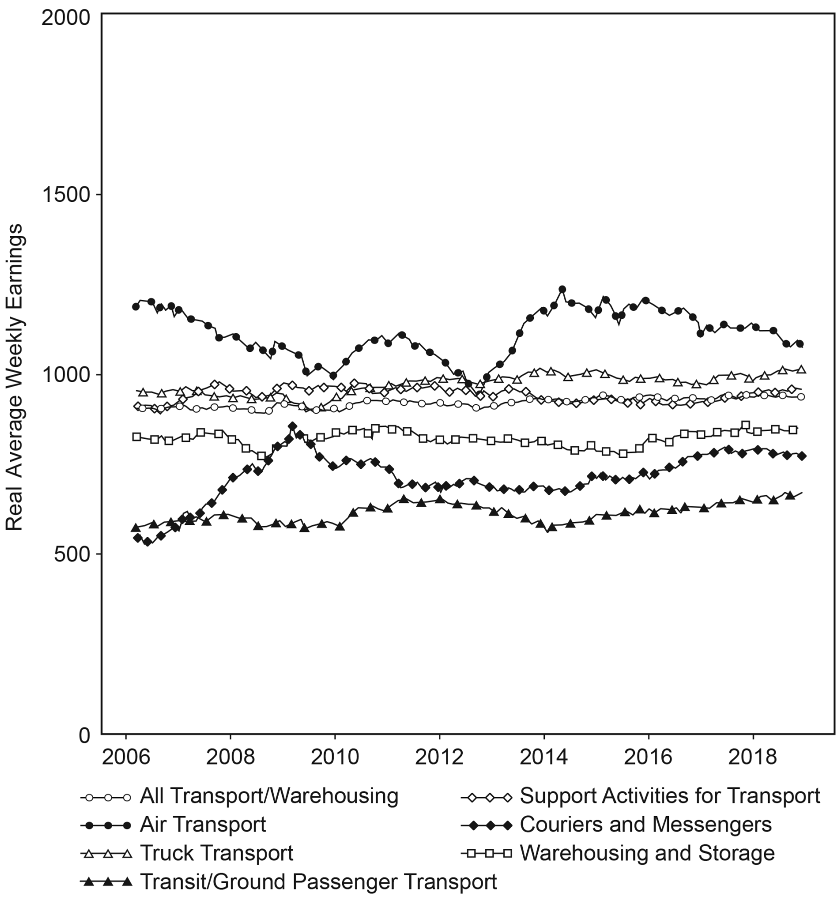

Fig. 5.3 Real average weekly earnings by transportation sub-industry

Source: Data are from BLS CES.

Note: Average weekly earnings are plotted by transportation sub-industry, adjusted for inflation using the CPI-U.

ture capital investment. Figures 5.6 and 5.7 compare patent activity by transportation sub-industry over time. The data come from PatentsView. We find that from 1980 onward, the number of vehicle-related patents outpaces the number of conveying, packing, storing, and other warehousing-related patents. Additionally, among less frequently patented codes, non-rail land vehicle and aircraft-related patents outpace other categories, including those for ships and railways.

Figure 5.8 plots transportation-related funding over time (in US dollars). The data come from CrunchBase. We find that relative to other activities, funding for warehousing companies shows dramatic growth later in our timeframe. Whereas funding for AVs, shipping, and general transportation-

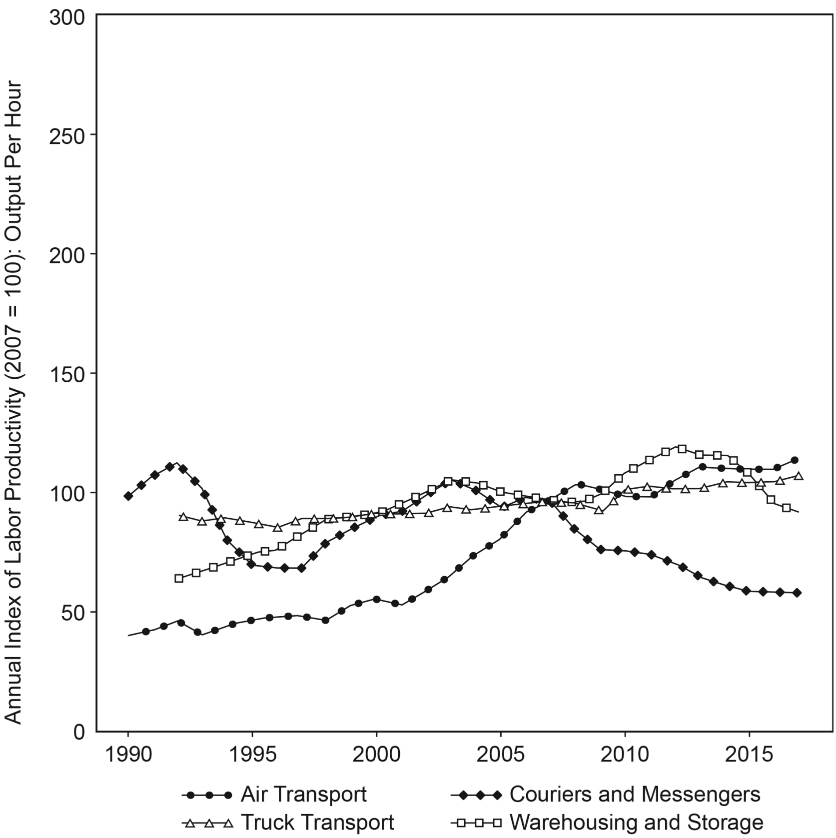

Fig. 5.4 Labor productivity by transportation sub-industry

Source: Data are from the BLS's Annual Index of Labor Productivity.

Note: These figures show changes in output per hour relative to 2007 levels.

related companies increases beginning in 2012, warehousing funding picks up in 2015 in our sample.

Finally, we consider adoption patterns from automotive technologies in the past. In figure 5.9, we plot technology adoption s-curves for various automobile transmission technologies. Our data come from the United States Environmental Protection Agency (EPA). We define advanced transmission as having six or more gears. These data show that advanced transmissions were adopted by the majority of manufacturers faster than automatic transmissions with lockup.

Figure 5.10 plots technology adoption s-curves for various engine technologies. These data come from the EPA. Variable valve timing (VVT) and gasoline direct injection (GDI) demonstrate considerable growth in production share. Multi-valve engines demonstrate a longer period of adoption, reaching around 90 percent of production share over 37 years. Stop/start and

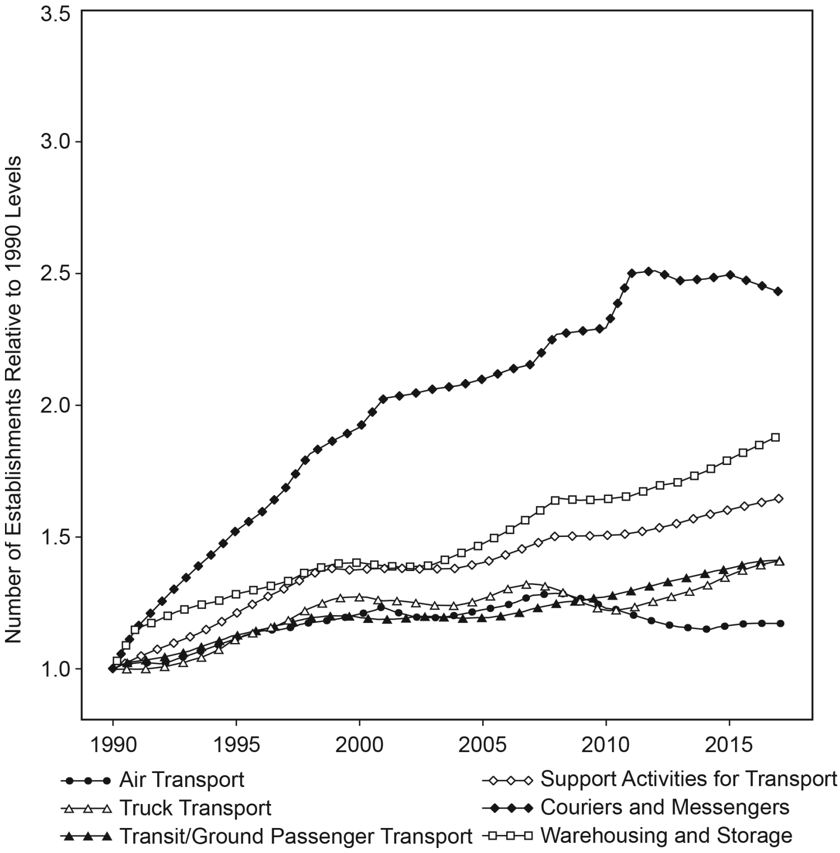

Fig. 5.5 Growth in establishments by transportation sub-industry

Note: These data come from the BLS Quarterly Census of Employment and Wages. The series are normalized to show establishment levels relative to 1990.

turbocharged engines do not yet make up a majority of engine production in our timeline. The broad takeaway from figures 5.9 and 5.10 is that new technologies can take many years before achieving widespread use, and there is heterogeneity across technologies. We keep these patterns in mind as we consider the potential effects of new technologies.

5.3 Moving and Storing Physical Goods

5.3.1 Literature

As noted, transportation's most aggregate industry classification (NAICS code 48–49) includes both transportation and warehousing-related activities. While transportation has received considerable interest from econo-

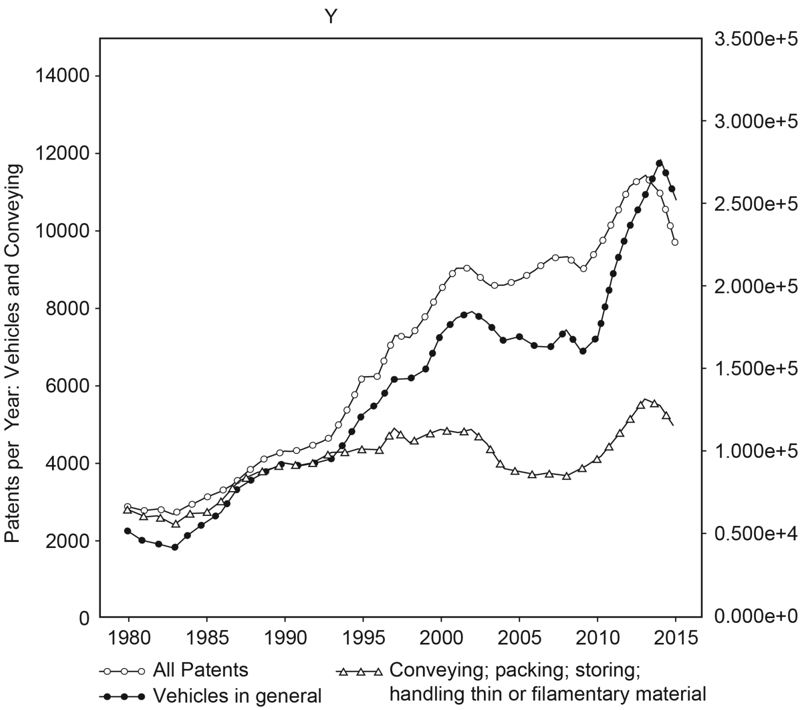

Fig. 5.6 Patenting activity: Vehicles in general and conveying

Source: Data are from PatentsView.

Note: We plot total patents per year for CPC codes B60 (vehicles in general) and B65 (conveying, packing, storing, etc.), as well as all patents.

mists, warehousing has received less attention. One reason for this may be the larger impact that air and truck transport have in contributing to GDP (see figure 5.1) relative to warehousing and storage. Yet over the past 5 years, growth in employment and in new establishments has been markedly higher in the warehousing sector than the overall transportation sector (see table 5.1). In this section, we examine this trend more deeply by exploring the changing role of warehousing, its interface with transportation, and its relationship with the economy at large.

The effects of transportation on economic growth have been extensively documented in the economics literature and well summarized in Redding and Turner (2015). Much less has been written on the role of warehousing in the transport supply chain. One exception is a recent paper by Chava et al. (2019); the authors find that when Amazon opens a fulfillment center in a county, employment levels at transportation and warehousing establishments in the same county grow by 2.1 percent, while worker wages at transportation and warehousing establishments in the same county grow by

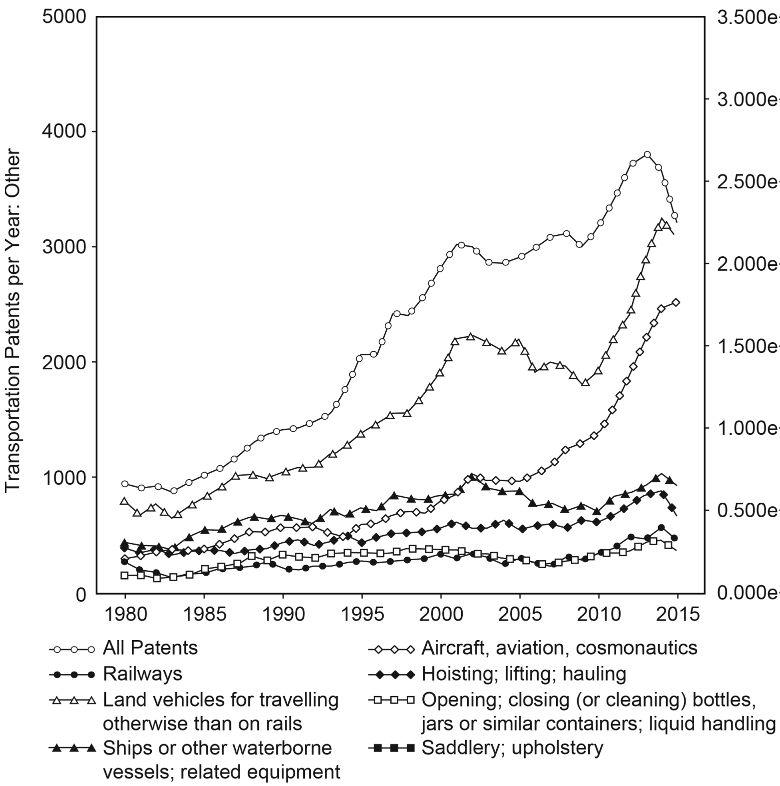

Fig. 5.7 All other transportation patents

Source: Data are from PatentsView.

Note: We plot patents per year for the remaining transportation CPC codes (B60–B68), excluding vehicles in general and conveying/packing.

1.7 percent. These numbers provide suggestive evidence of the complements that may exist between geographic co-location of warehousing/fulfillment centers of e-commerce players and local demand for additional transportation and warehousing services. It is unlikely, however, that the significant growth in warehousing employment is entirely attributable to the changing nature of retail. Figure 5.11 presents the warehousing employment plot first shown in figure 5.1 alongside retail employment growth.

More broadly, as others have noted, there may have been a shift in consumer purchase behavior. For example, Lafontaine and Sividasan (this volume, chapter 6) find marked growth in restaurant establishments and employment, which they attribute to an increase in consumer expenditure share for restaurant food. The authors also note that DoorDash and Instacart, two of the top delivery businesses, received substantial venture capital investments ($2.1 billion and $1.8 billion, respectively). As we indicate

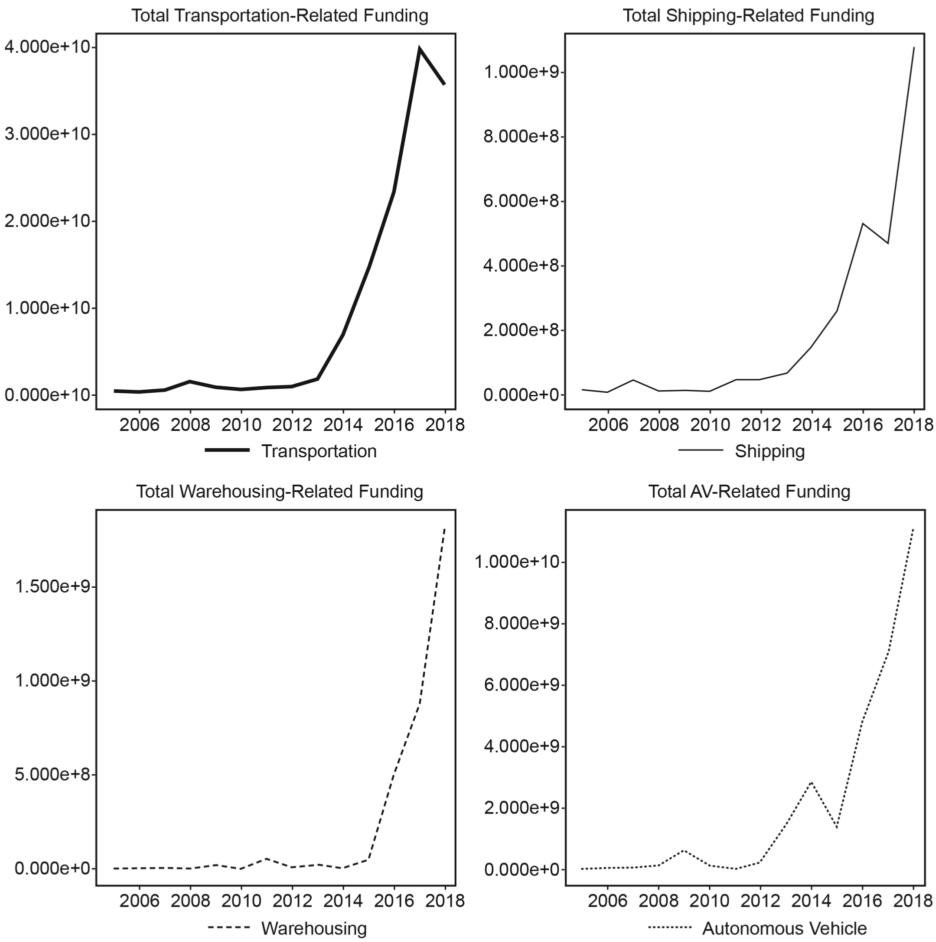

Fig. 5.8 Venture funding, by transportation sub-industry
Source: Data are from CrunchBase.
Note: Figures report annual funding by company type; amounts are reported in US dollars.

below, Instacart was the top hiring firm in the "transit and ground passenger" sector in 2017 and 2018 (see table 5.3 below). As another example, Relihan (2020) shows that consumers using online grocery delivery platforms change their consumption patterns by shifting time away from grocery shopping and toward visits to coffee shops. Relihan finds that early adopters of online grocery platforms reduce spending at grocery stores by 4.5 percent and increase spending at coffee shops by 7.6 percent.

Mandel (2020) points out that the shift from offline retail purchases to online purchases requires a substantial change in the architecture of supply chains. Notably, firms like Amazon and Walmart that want to engage with

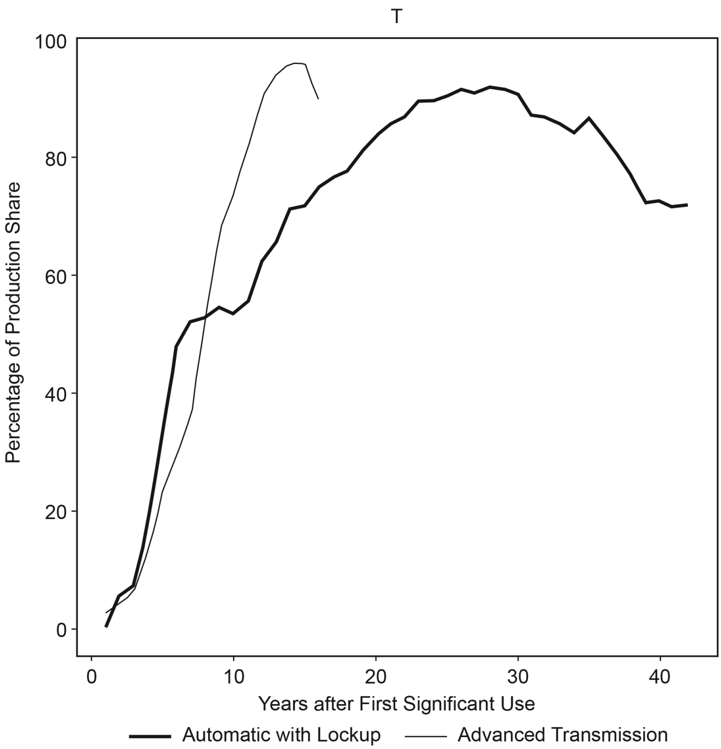

Fig. 5.9 Automobile transmission technology adoption

Note: Data are from the United States Environmental Protection Agency (EPA). We define advanced transmission as having six or more gears.

consumers on a large-scale basis need to invest in warehousing to hold merchandise, fulfilment systems to organize and pack orders, delivery infrastructure to ship packages to customers, and a complementary returns infrastructure to handle orders that are sent back or dropped off at physical locations. Some of these functions need to be available at local levels to serve customers quickly and efficiently, and others can be located far from customers.

5.3.2 Geography

The changes in employment documented in table 5.1 vary by geography. The majority of warehousing employment growth has come in rural counties, which have employment levels seven times higher than in 1990 (figure 5.12). However, growth in warehousing employment is not solely a rural phenomenon. Urban counties have not grown at the same pace as rural ones, but employment levels are 3.5 times higher than they were in 1990. Indeed, Chava et al. (2019) note that Amazon opens fulfillment centers in

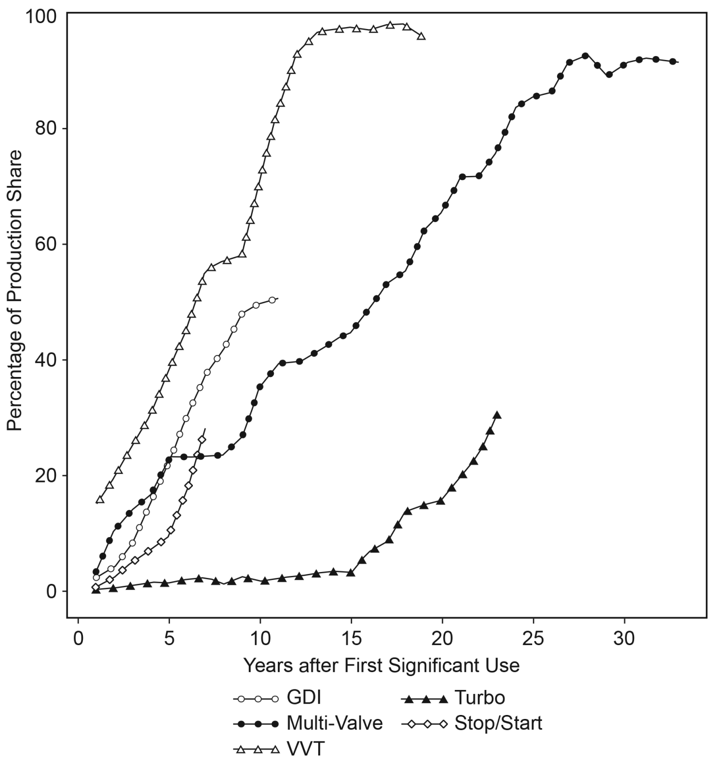

Fig. 5.10 Automobile engine technology adoption
Source: Data are from EPA.
Note: GDI, gasoline direct injection; VVT, variable valve timing.

counties with population densities 2.5 times higher than the average across all US counties. This trend is also in line with growth of transportation companies, in particular, truck transport. Figure 5.13 decomposes truck transport growth for establishments in urban and rural counties. As can be seen, truck transport employment growth follows similar patterns to those observed in figure 5.12 but at a much smaller scale. Rural truck transport has increased by 40 percent from 1990 levels, while urban truck transport has increased by 25 percent from 1990 levels. The extent to which this increase in warehousing activity is a complement or substitute for long- and short-haul trucking is difficult to fully assess, but time series data provide some suggestive relationships.

Figure 5.14 presents time series of warehousing and trucking employment relative to total US employment scaled to 1990 levels. As can be seen, general warehousing has increased the most—it has taken a 3.5 times larger share of US employment since 1990. Employment shares of used household and office goods moving as well as general freight trucking are unchanged since

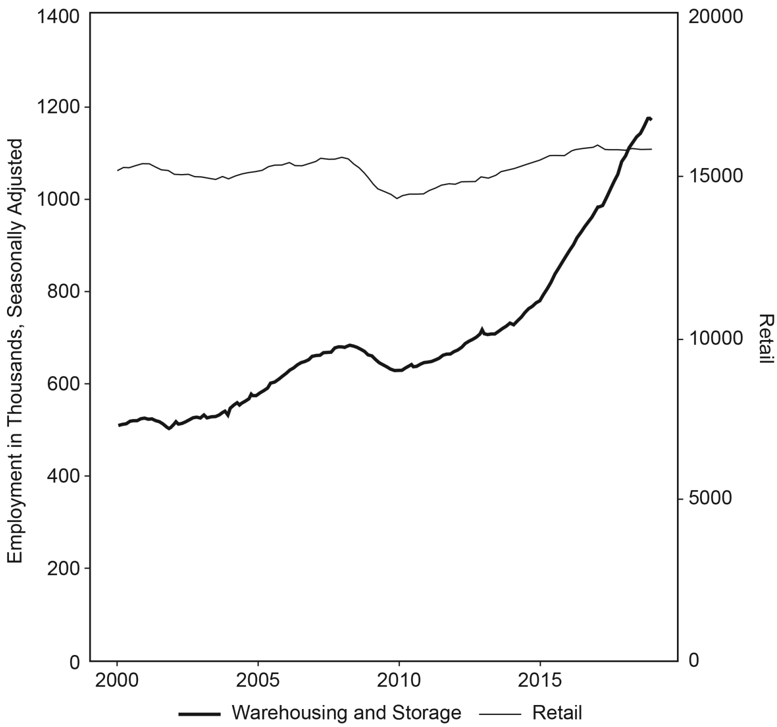

Fig. 5.11 Retail and warehousing employment over time
Note: Data are from the BLS Current Employment Statistics.

1990. In contrast, couriers and express delivery services, and local messengers and local delivery employment are both up, with local messengers up significantly since 2015—a possible reflection of the increasingly important role that e-commerce is playing in the retail industry. It may seem strange for us to observe such large increases in both urban-focused warehousing and transportation, given the higher real estate costs of urban areas compared to rural ones. Yet urban dwellers disproportionately make use of e-commerce retail, and this demand pull has strongly affected the way in which technology is deployed and the impact it has had on entrepreneurial activity.

Figure 5.15 plots the changes in rank of the top counties employing warehouse and storage workers. There have been some notable shifts between 2007 and 2017, with Cook County (IL), Franklin County (OH), and Harris County (TX) experiencing drops in their ranks, and San Bernardino County (CA), Riverside County (CA), San Joaquin County (CA), and Dallas County (TX) experiencing rises in their ranks. The results in figure 5.15 mirror, at a broad level, an observation made by Michael Mandel (2020) that California and Texas have been among the biggest gainers in the shift to what he

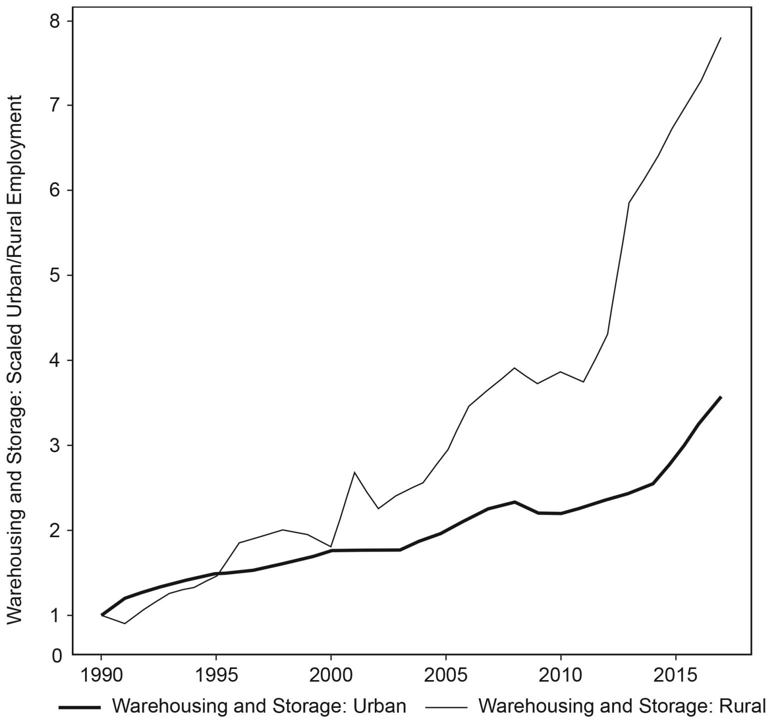

Fig. 5.12 Warehouse employment growth: Urban vs. rural

Source: Data are from BLS QCEW.

Note: Rural counties are defined as counties with more than half of their population living in rural areas as designated by the Census Bureau.

calls "consumer distribution" (e-commerce and brick and mortar retail).[5] Future research could investigate the causes and consequences of this shift.

5.3.3 Role of Incumbents and Entrants

Accompanying the change in economic activity for transportation and warehousing is an increase in startup activity. Much of this startup activity has been in logistics-focused firms attempting to reduce transport frictions and solving problems associated with delivering goods the "last-mile." One example is Fourkite, an e-commerce logistics company headquartered in Chicago that has received over $100 million in venture backed funding through a Series C round of funding. Fourkite has built a supply chain platform alongside a predictive shipment arrival time algorithm to lower shipping times and costs. Technologies like these are enabling new forms of warehousing to develop in urban areas, often referred to as "micro-fulfillment

5. https://www.progressivepolicy.org/blog/the-geography-of-ecommerce-industries/.

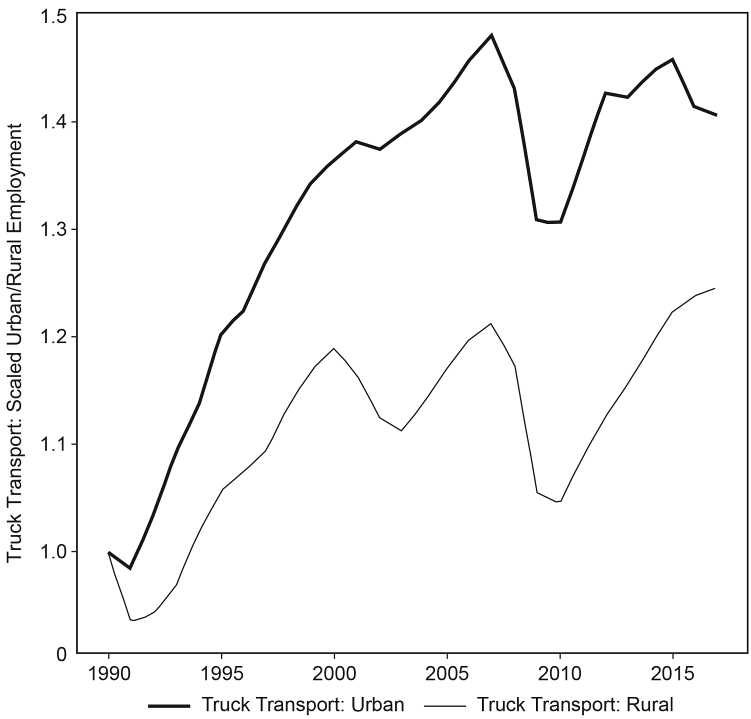

Fig. 5.13 Truck transport employment growth: Urban vs. rural
Source: Data are from BLS QCEW.
Note: Rural counties are defined as counties with more than half of their population living in rural areas as designated by the Census Bureau.

centers," that allow quicker delivery to urban customers. Another company that is working in the space of micro-fulfillment centers is Fabric. Founded in 2015, Fabric makes heavy use of robotics and small fulfillment centers in urban areas to fulfill order requests within an hour of purchase. They have raised $136 million through a Series B venture round and are growing rapidly.

As Fabric has demonstrated, technology—both in the form of AI predictive algorithms and robotics—is playing a critical role in the development of these new warehousing forms. The company Nuro is focused on developing AVs for the explicit purpose of delivering local goods and aiming to reduce the costs of the aforementioned last-mile delivery. They recently received $940 million in financing from Softbank. While Nuro is one of the most high-profile startups in this space, other startups also exist, including Startship Technologies, Marble, Boxbot, Robby Technologies, Kiwi Campus, Dispatch, and Unsupervised AI.[6] These technology trends may have

6. https://news.crunchbase.com/news/robot-couriers-scoop-up-early-stage-cash/.

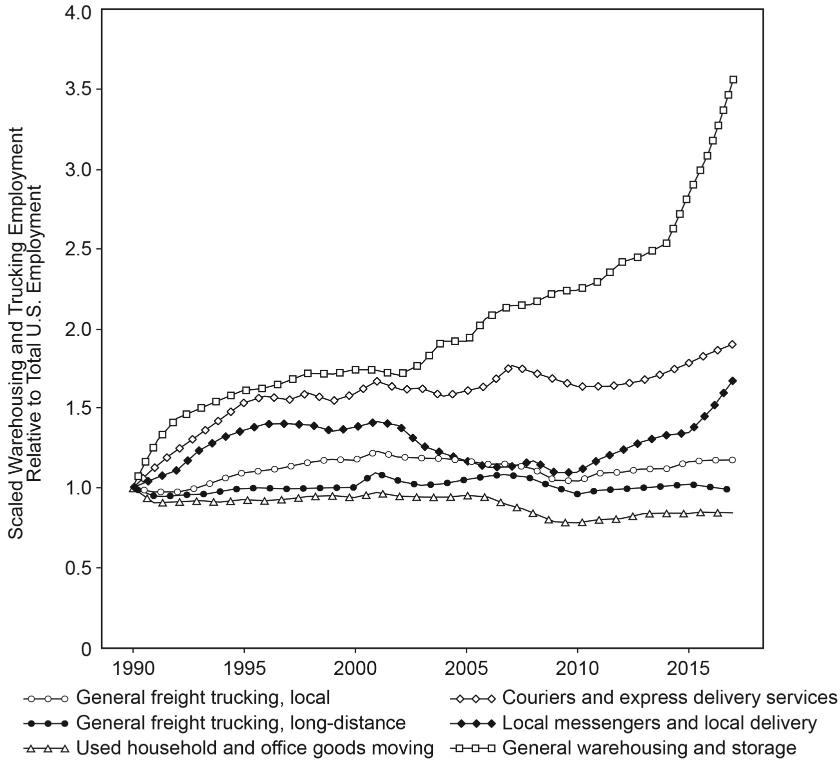

Fig. 5.14 Increasing importance of warehousing employment in the US

Source: Data are from BLS QCEW.

Note: Employment shares are plotted by transportation sub-industry (5-digit NAICS), normalized to 1990 levels.

divergent effects both for larger retailers continuing to vertically integrate into warehousing by operating ever-more efficient fulfillment centers and the arrival of technology-enabled specialized micro-warehouses lowering the cost of developing viable e-commerce business models for fledging direct-to-consumer startups.

Another technology that has the potential to impact last-mile delivery is that of unmanned aerial vehicles, also sometimes referred to as "drones." According to the CrunchBase database, there were at least 329 drone startups operating in late 2019.[7] While some of these startups will undoubtedly not focus on logistics and transportation (and focus more on leisure applications, military, etc.), this figure may also undercount numerous companies that are still in "dark mode." Apart from startups, many incumbents are also increasingly thinking about the impact of drones on their businesses, and growing numbers of transportation companies have received clearance

7. https://www.crunchbase.com/hub/drones-startups.

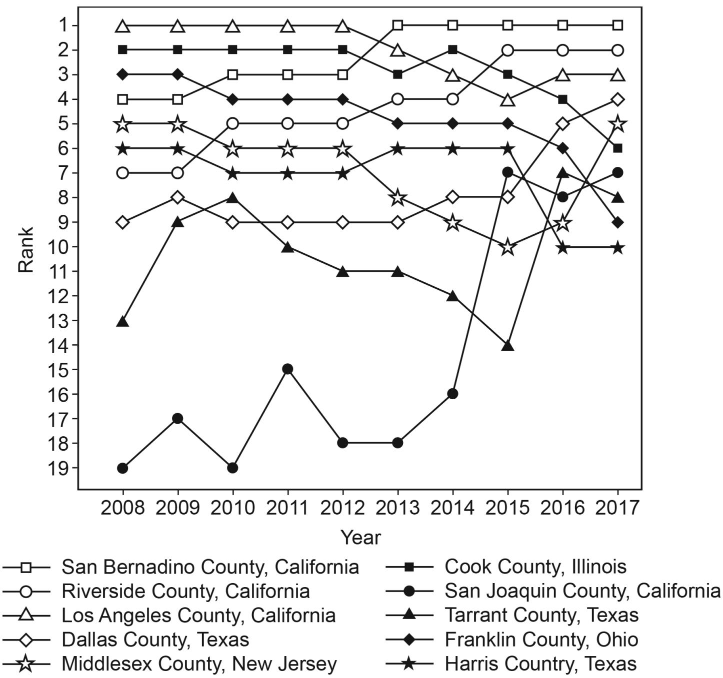

Fig. 5.15 Top county-level employers: Warehousing and storage
Source: Data are from BLS QCEW.
Note: Shown is a bump chart plotting the county ranks in terms of raw (not per capita) warehousing and storage employment. We include the top 10 counties in 2017 over a 10-year period (2008–2017).

from the Federal Aviation Administration (FAA) to run pilot programs. As an example, in October 2019, UPS's subsidiary UPS Flight Forward, Inc., was granted approval by the FAA to deliver medical packages by unmanned drone.[8] Not to be outdone, Amazon has launched a program named "Prime Air" with the express intent of delivering items in under 30 minutes from purchase. In both instances, the geographic location of warehouses will continue to be critical, as will advances in AV technologies. We next examine the implications of improvements in the viability of AVs on the transportation and warehousing sector.

Despite all the excitement about new firms and technologies, it appears that most of the employment activity by firms in this sector is by established, incumbent firms. Table 5.2 uses data from job postings, collected by Burning Glass, to list the top five "courier and messenger" firms by year. The top three in each year are UPS, FedEx, and DHL Express—which is no surprise,

8. https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=15699339654.76–404.

as these are currently the dominant firms in the sector. Table 5.3, again using job posting data from Burning Glass, lists the top five "transit and ground passenger" firms by year. While most of the firms are engaged in transportation of people (covered in the next section), it is notable that in 2017 and 2018, the firm with the most listings was Instacart, a rapidly growing startup that specializes in same-day grocery store delivery.

Table 5.4 uses Burning Glass data to list the top five "warehouse and storage" firms by year. While the rank changes from year to year, it is interesting to note that most of the top firms are the same each year. For example, Exel is in the top five each year except 2018. Exel is a subsidiary of DHL, one of the world's largest courier and messenger firms. As another example, Americold, the owner and operator of a network of temperature-controlled warehouses used for storage of fruits, vegetables, meats, dairy, and other perishable products, is the top employer in 6 out of 9 years. Americold owned 160 such warehouses in the US in 2019.[9]

5.4 Entrepreneurship and Innovation in the Movement of People

5.4.1 Introduction

As section 5.3 demonstrates, the way in which physical goods are moved and stored has changed significantly over the past three decades. Yet media focus and public attention have centered disproportionately on the movement of people. Figure 5.16 presents Google Trends data of Internet search activity over the past two decades for the terms "Uber" and "Warehouse." As can be seen, warehousing has done little to change the attention (or Internet query interest) of Internet users, while interest in Uber and related ridesharing firms has grown significantly since the arrival of these services over the past 10 years. This section focuses on the movement of people with an emphasis on personal mobility and the implications for AVs, and it provides a brief discussion on the externalities that will arise as a result of the increased movement of people due to entrepreneurship and innovation in the transportation sector.

5.4.2 Personal Mobility

One of the biggest changes to personal mobility has been the rise of ride sharing firms such as Lyft and Uber, particularly in certain urban areas. These firms differ from standard taxi firms in at least two ways. First, unlike a traditional taxi company that manages a fleet of taxicabs which either search for passengers on city streets or wait for a dispatcher to tell them where to go, ride sharing firms rely on a digital application interface to manage the

9. Americold Annual Report 2019, Form 10-K. Available at: https://ir.americold.com/financials/sec-filings/sec-filings-details/default.aspx?FilingId=13971750.

Table 5.2 **Top courier and messenger companies by job postings**

	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	UPS	UPS	UPS	UPS	UPS	UPS	UPS	UPS	UPS
2	FedEx	FedEx	FedEx	FedEx	FedEx	FedEx	FedEx	FedEx	FedEx
3	DHL Express	DHL Express	DHL Express	DHL Express	DHL Express	DHL Express	DHL Express	DHL Express	DHL Express
4	Republic Beverage	Republic Beverage	Midnite Express	Publisher's Circulation	Xpo Last Mile Inc	Spee Dee Delivery	Spee Dee Delivery	Spee Dee Delivery	Shipt
5	Courier	Courier	Republic Beverage	Ameriflight Incorporated	Spee Dee Delivery	Midnite Express	Midnite Express	Midnite Express	Ameriflight Incorporated

Note: These data come from Burning Glass. We report the top five companies by number of job postings (NAICS 492). Burning Glass does not report employer data for every single job posting.

Table 5.3 **Top transit/ground passenger transport companies by job postings**

	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	MV Trans., Inc.	Firstgroup Plc	MV Trans., Inc.	MV Trans., Inc.	MV Trans., Inc.	Durham School Services	MV Trans., Inc.	Instacart	Instacart
2	Firstgroup Plc	MV Trans., Inc.	Firstgroup Plc	Veolia Trans.	Durham School Services	Uber	Amtrak	MV Trans., Inc.	MV Trans., Inc.
3	Veolia Trans.	Veolia Trans.	Westours Motor Coaches	First Student	Amtrak	Amtrak	Veolia Trans.	First Transit	Uber
4	Coach America	First Transit	Veolia Trans.	Firstgroup Plc	Veolia Trans.	MV Trans., Inc.	First Transit	Uber	First Transit
5	First Transit	Coach America	First Transit	Durham School Services	Firstgroup Plc	Veolia Trans.	Uber	Stock Trans.	Stock Trans.

Note: These data come from Burning Glass. We report the top five companies by number of job postings (NAICS 485). Burning Glass does not report employer data for every single job posting.

Table 5.4 **Top warehousing and storage companies by job postings**

	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Americold Logistics	Americold Logistics	Americold Logistics	Americold Logistics	Americold Logistics	Americold Logistics	Diversified Transfer Storage	Dematic	Dematic
2	Exel	Dematic	Dematic	Dematic	Exel	Exel	Americold Logistics	Americold Logistics	All My Sons Moving Storage
3	Dematic	Exel	After-market Tech. Corp,	Exel	Versacold Int. Corp.	Dematic	Dematic	Pure Storage, Inc	Life Storage, Inc
4	Document Storage Systems Inc.	After-market Tech. Corp.	Exel	After-market Tech. Corp.	Dematic	Diversified Transfer Storage	Exel	All My Sons Moving Storage	Pure Storage, Inc
5	Jk Moving Storage Inc.	Jk Moving Storage Inc.	Es3 Llc	Versacold Int. Corp.	Es3 Llc	Versacold Int. Corp,	Pure Storage, Inc	Exel	Americold Logistics

Note: These data come from Burning Glass. We report the top five companies by number of job postings (NAICS 493). Burning Glass does not report employer data for every single job posting.

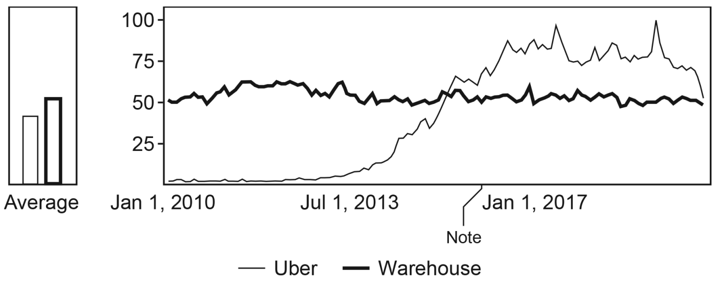

Fig. 5.16 Google trends: Uber vs. Warehouse

interaction between drivers and riders. Perhaps not surprisingly, ride sharing is more popular among younger generations. According to the Department of Transportation's National Household Travel Survey (2019), Millennials are almost twice as likely to use ride sharing services than Generation X or Baby Boomers.[10] In addition, ride sharing firms rely on complex, dynamic pricing models to "manage" the number of drivers and riders. As such, the interactions between drivers and riders are similar to those in other two-sided market settings (Parker and Van Allstyne 2005; Rochet and Tirole 2006). Second, ride sharing firms have argued that they should be regulated as technology firms instead of taxi firms, citing the prominent role that technology plays in providing their services. This regulatory arbitrage has led to the seeming proliferation of ride sharing services in various cities, arguably to the detriment of taxi companies. In some cases, cities have responded by banning ride sharing altogether (Paik, Kang, and Seamans 2019).

Recent research has sought to understand various economic and societal effects of these changes in personal mobility. To start, ride sharing apps provide efficiency benefits. Cramer and Krueger (2016) attribute Uber drivers' capacity utilization rate premiums of 30–50 percent to the company's matching rates, larger scale, freedom from inefficient regulation, and flexible labor and pricing models. These technologies also show social benefits. For example, Greenwood and Wattal (2017) find evidence that ride sharing has led to a decrease in vehicular fatalities associated with drunk driving. Burtch, Carnahan, and Greenwood (2018) provide evidence that driving for ride sharing firms may substitute for low-quality entrepreneurial activity. Gorback (2020) provides evidence that ridesharing's entry is associated with a doubling of net restaurant entry and an increase in housing prices. Some papers use incredibly rich and detailed data from ride sharing firms to study other economic issues. For example, Cook et al. (2018) use ride-level data from a ride sharing platform to study the determinants of gender earnings gap, and Liu, Brynjolfsson, and Dowlatabadi (2018) compare taxi and ride

10. https://nhts.ornl.gov/assets/FHWA_NHTS_Report_3E_Final_021119.pdf.

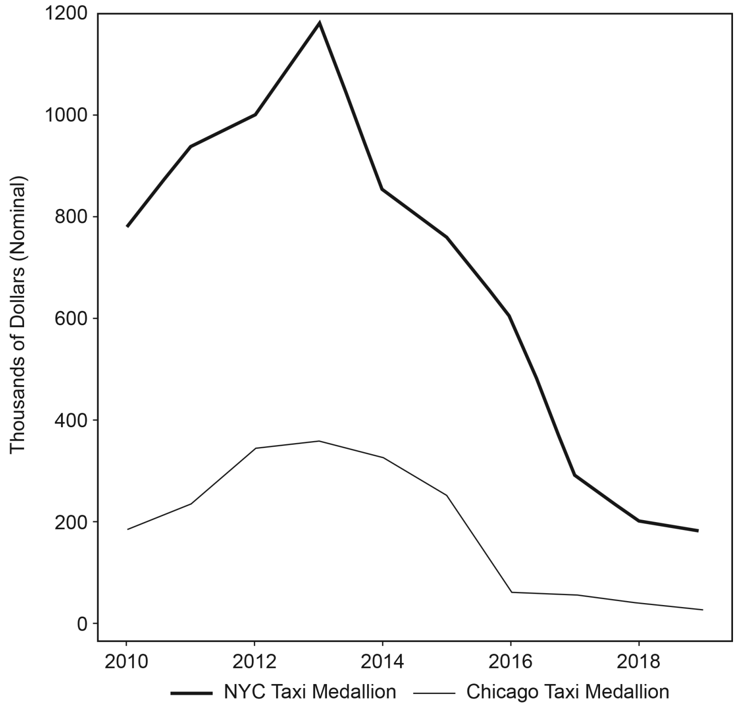

Fig. 5.17 New York and Chicago taxi medallion prices

Source: Data are from the NYC Taxi and Limousine Commission, as well as the Chicago Department of Business Affairs and Consumer Protection.

sharing ride-level data to study the extent to which digital monitoring via the ride sharing platform reduces moral hazard on the part of drivers.

To study competitive effects of ride sharing on traditional taxi businesses, we consider how ride sharing may affect taxi medallion sales. The 2016 *Economic Report of the President* (CEA 2016) shows that taxi medallion sales prices peaked in New York City in 2013 at over $1 million and in Chicago in 2013 at over $350,000. In figure 5.17, we extend this analysis with updated data through 2018 and find that medallion prices in both cities have continued a dramatic decline. In New York, medallions are now below $200,000 and in Chicago below $50,000. These dramatic changes provide suggestive evidence that ridesharing has substituted for traditional taxi service in many cities. Berger, Chen, and Frey (2018) decompose the resulting labor market effects; they find that Uber's entry coincides with a 10 percent decrease in relative taxi earnings. However, the authors note that the supply and composition of the taxi labor market has remained largely the same. Additionally, research suggests that ridesharing may have spurred adaptive changes in

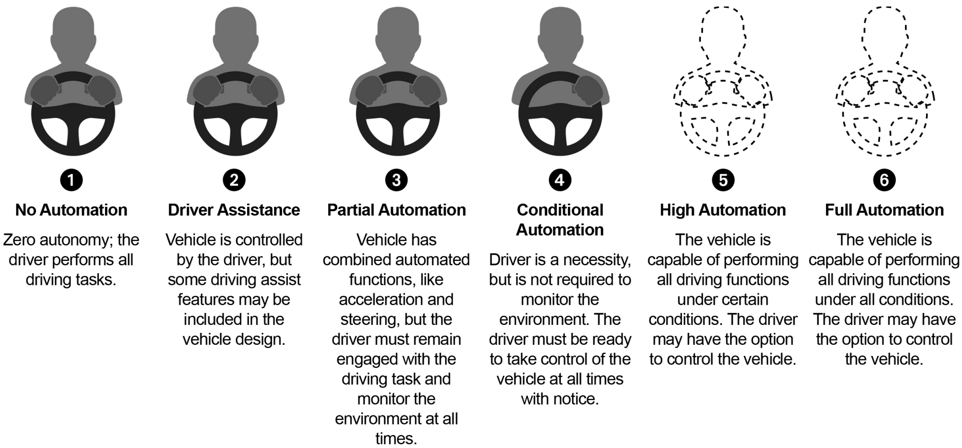

Fig. 5.18 Society of Automotive Engineers (SAE) automation levels

product quality among taxi drivers; Wallsten (2015) finds that increases in Uber's popularity are associated with decreases in taxi customer complaints in New York and Chicago.

5.4.3 Autonomous Vehicles

Automation of driving can take multiple forms. The current standards for autonomous driving were developed by the Society of Automotive Engineers (SAE International). According to the standards, autonomous driving ranges from Level 0, with no autonomy, to Level 6, which is full automation (see figure 5.18). Many vehicles sold today have features that would qualify as Level 1, including park assist, lane assist, and adaptive cruise control. A few vehicles claim to qualify as Level 2 or 3, including Tesla's vehicles, the Nissan Leaf, and Audi A8.[11] Google's Waymo would be considered Level 4 or 5. No Level 4 or 5 cars are certified for use on regular roads.[12]

Autonomous vehicles have generated a great deal of excitement. Some observers have referred to AVs as the "AI killer app."[13] However, a lot of disagreement exists around how long it will take for AVs to become widespread, and there is great uncertainty about the ultimate effect of AVs on the

11. https://www.pocket-lint.com/cars/news/143955-sae-autonomous-driving-levels-explained; https://techcrunch.com/2019/04/22/teslas-computer-is-now-in-all-new-cars-and-a-next-gen-chip-is-already-halfway-done/; https://www.forbes.com/sites/lanceeliot/2019/08/01/eyes-on-hands-off-for-nissans-propilot-2–0-rouses-level-3-self-driving-tech-misgivings/#60e628627558; https://www.wired.com/story/audi-self-driving-traffic-jam-pilot-a8–2019-availablility/.

12. https://crsreports.congress.gov/product/pdf/R/R45985.

13. https://www.forbes.com/sites/chunkamui/2013/08/23/google-car-uber-killer-app/#2620f33d600a.

economy. On one hand, in 2018 Elon Musk predicted that there would be a Tesla driverless taxi fleet by 2020.[14] On the other hand, Chris Urmson, who was a DARPA challenge winner, head of Google's Waymo AV unit, and is now CEO of a self-driving vehicle software company, argues it may take up to 30–50 years before widespread adoption of AVs.[15] To put these predictions into perspective, recall from figures 5.8 and 5.9 that historically, widespread adoption of new innovations in the auto sector can take several decades, as automobiles are long-lived, durable assets. Ultimately, several factors will affect the timing of adoption, including technological development, consumer preferences and tastes, and the regulatory landscape.

Researchers have begun to explore the economic and behavioral outcomes that may result from these technologies. Gelauff, Ossokina, and Teulings (2019) model two components of automation that lead to differing outcomes on population distribution: improved use of time during car trips, which lowers the cost of living at a distance from cities, and improved door-to-door public transit, which has the countervailing effect of lowering the costs of living in urban environments and may lead to increased population clustering in cities. Finding considerable welfare benefits resulting from these technologies, the authors suggest that these effects may lead to overall population shifts toward large, attractive cities at the expense of smaller urban as well as non-urban areas. Additionally, Kröger, Kuhnimhof, and Trommer (2019) project the adoption of AV technologies in the US and Germany. They estimate that the introduction of AVs will increase vehicle traffic by 2–9 percent, as a result of new automobile user groups, as well as lower generalized costs of car travel. However, others have argued that the conversion of all drivers into passengers may result in a substantial reduction in travel costs and thus substantially increase vehicle traffic (Duranton 2016).

5.4.4 Regulation

The speed of adoption of new technologies such as AVs will depend in large part on federal rules and regulations. We highlight two notable developments in this section. One notable development on the regulatory landscape is the US House and Senate nearing compromise language on legislation that would provide the National Highway Traffic Safety Administration (NHTSA) with the authority to regulate AVs. This is significant, as it would allow NHTSA to develop nationwide federal regulations for AVs, rather than allowing a patchwork of state-level AV regulations, which could slow down mass adoption. Federal regulation would provide clarity for various stakeholders, including car manufacturers and insurance companies, which

14. https://www.theverge.com/2019/4/22/18510828/tesla-elon-musk-autonomy-day-investor-comments-self-driving-cars-predictions.

15. https://www.theverge.com/2019/4/23/18512618/how-long-will-it-take-to-phase-in-driverless-cars.

should then lead to the development of AV vehicles and other technologies, and insurance products to complement these vehicles.

Another notable development is the Federal Communications Commission's (FCC) recent announcement of its plan to split the use of the 5.9 GHz spectrum between unlicensed Wi-Fi and vehicle-to-vehicle (V2V) communications standards.[16] This spectrum, a 75 Mhz band, had initially been set aside for use for vehicle-to-vehicle communications in 1999, and NHTSA, car manufacturers, and device manufacturers spent the ensuing two decades working on a standard for V2V communications. However, the standard that emerged, called "DSRC," faced lots of resistance, including from a competing standard called "C-V2V." Separately, Wi-Fi demands were growing, and the 5.9 GHz spectrum was increasingly used for unlicensed Wi-Fi. A recent study by Rand Corporation estimates the value of the consumer and producer surplus from using the entire band for Wi-Fi to be between \$82.2 billion and \$189.9 billion.[17] The FCC announced that 45 Mhz at the lower end of the band will be for Wi-Fi, the next 20 Mhz for C-V2V, and the top 10 Mhz potentially for C-V2V or DSRC. While it is too early to predict the ultimate outcome, the FCC's announcement seems to throw a lot of weight behind the C-V2V standard. The upshot is that this may hasten the resolution of what has been a battle over standards. Resolving this uncertainty over standards should then lead to the development of AV vehicles and other technologies.

In addition, the federal government will also play a role in addressing any externalities that may arise from these new technologies. We discuss some of these externalities, and the potential role for government to address them, in the next subsection.

5.4.5 Spillovers

Sections 5.4.2 and 5.4.3 highlight just two advances spurred by entrepreneurial entry and technological innovation, and while ride sharing and AVs certainly provide numerous benefits, they may, too, usher in costs and unintended consequences. These spillovers are discussed in more detail below, starting with the effect of AVs on jobs, followed by a broader discussion of ancillary spillovers that are unlikely to be properly priced.

5.4.5.1 Jobs

Scholars and pundits have speculated on a range of outcomes from AVs, including lower transport costs due to fewer drivers, better fuel efficiency, and better safety. The effect on driving jobs has garnered lots of attention. For example, the *Guardian* reports that autonomous driving puts 2 million

16. https://www.reuters.com/article/us-usa-spectrum/u-s-regulator-proposes-splitting-auto-safety-spectrum-to-boost-wi-fi-idUSKBN1XU2BJ.

17. https://www.rand.org/content/dam/rand/pubs/research_reports/RR2700/RR2720/RAND_RR2720.pdf.

US truck drivers at risk of losing their jobs.[18] However, as Gittleman and Monaco (2017) point out, there are a variety of types of drivers, and autonomous driving will affect some more than others. The use of AVs is more likely for heavy and tractor trailer truck drivers (aka "long haul") rather than local delivery, given how difficult it would be to automate driving in a local or urban environment, and given all the other tasks associated with local delivery. According to analysis by Gittleman and Monaco, some of the other tasks performed by drivers include freight handling, paperwork, and customer service. Gittleman and Monaco estimate that Level 4 automation may ultimately displace 300,000 to 400,000 drivers. But the authors highlight that there are many practical limitations to automation. For example, they stress that one of the important functions of a truck driver is to serve as a security guard for the freight.[19]

Expected benefits stemming from autonomous trucking may need to be tempered in the event that the most likely application for autonomous trucking is in long haul and not local delivery. For example, most emissions and most accidents occur in urban environments (where local delivery is more common). Gately, Hutyra, and Wing (2015) report that urban vehicle emissions account for 60 percent of total emission and for 80 percent of growth in emissions since 1980. In other words, the most polluted areas are potentially the very areas where there will be little penetration of AVs. The Insurance Institute for Highway Safety reports that most accidents occur in urban and local roads, not rural interstates, and that 67 percent of fatalities occur outside the interstate system.[20] Again, the most dangerous areas are potentially the very areas where there will be little penetration of AVs.

Ultimately the costs and benefits of autonomous trucking will likely depend on the characteristics of government regulation. For example, one could imagine that consumer fear of AVs leads to regulations requiring humans to be in the cab of any AV, just in case the vehicle encounters unforeseen problems (in fact, in a 2018 survey, 71 percent of US drivers said they don't trust self-driving vehicles).[21] Such a regulation would attenuate any cost savings from replacing drivers. While the job displacement risk stemming from the arrival of AVs is but one of the many consequences of the changes in transportation arising from new products and services, numerous other spillovers also arise as result.[22]

18. https://www.theguardian.com/technology/2017/oct/10/american-trucker-automation-jobs.

19. The authors also cite an estimate of $175 million in losses to truck theft per year. https://www.trucks.com/2016/01/29/truck-thefts-result-in-large-losses/.

20. https://www.iihs.org/topics/fatality-statistics/detail/large-trucks.

21. https://www.theverge.com/2018/5/22/17380374/self-driving-car-crash-consumer-trust-poll-aaa.

22. We thank our discussant, Gilles Duranton, for articulating many of these.

5.4.5.2 Congestion and Vehicular Accidents

The effect of increased vehicle traffic on congestion, pollution, and the rate of accidents will depend on the source of increased vehicle usage. On one hand, ride sharing has been shown to lead to an increase in congestion[23] (and in turn pollution), in addition to an increase in accidents (Barrios, Hochberg, and Yi 2020). On the other hand, AVs may overcome these negative externalities as AVs with improved response times (compared to humans) can more safely drive close together.[24] These safety improvements should, in turn, reduce fatalities, and assuming the increase in capacity is greater than the reduction in transport costs, they should reduce congestion as well (Duranton and Turner 2011). Technologies that facilitate this vehicle-to-vehicle coordination, solutions that spread usage to off-peak hours, or improve passenger safety will all be important areas of both innovation and entrepreneurship. Policymakers will also need to strike the appropriate balance between usage patterns and how to allocate public space for various transportation modes.

5.4.6 Long-Run Effects

Ultimately, the successful proliferation of new transportation technologies will affect the geographic distribution of economic activity, but the impacts are likely to be heterogenous. As previously discussed, AVs will reduce the costs of transport, which in turn may reduce the need to live in proximity to one's place of work. This will have implications not only for the location of offices but also of domiciles, with commuters potentially moving to cheaper areas far from city centers. However, the wide adoption of electric vehicles may reduce the costs associated with living in urban areas (e.g., pollution) as well as heighten the value of face-to-face interactions and thus may lead to more densification/urbanization. Surely many other changes will emerge from the unanticipated interactions between individuals and new transportation technologies. These long-run effects are sure to be large, but at present, it is difficult to anticipate what equilibrium-level outcomes will look like, especially given the role that will be played by government regulators discussed in this chapter.

5.5 Conclusion

The transportation sector, which includes warehousing, plays a critical role in economic activity. In this chapter, we describe economic, entrepre-

23. As acknowledged by Chris Pangilinan, Uber's Head of Global Policy for Public Transportation, https://medium.com/uber-under-the-hood/learning-more-about-how-our-roads-are-used-today-bde9e352e92c.

24. https://www.economist.com/finance-and-economics/2018/01/20/why-driverless-cars-may-mean-jams-tomorrow.

neurial, and innovative activities in this area of the US economy. Recent trends suggest a shift emerging in this sector, with warehousing playing an increasingly important role. Prior economic research has focused primarily on innovations affecting the movement of goods (e.g., building new roads or railways), and there has been comparatively little research on innovations in storing goods. Thus, one takeaway from this chapter is for economists to conduct more research on the role of warehousing in the economy.

We also highlight several new transportation technologies, including ride sharing and AVs. There is much speculation about how these technologies will affect the sector, and eventually the economy as a whole. We note that prior innovations in this sector experienced heterogeneous rates of adoption. We believe this lesson from history suggests that we exercise much caution when speculating about the speed of adoption and impact of any new technology. Ultimately, the rate of adoption will depend on a range of factors, including technological development, consumer preferences and tastes, and regulatory landscape.

We believe there are areas for follow-on research, including addressing the following questions:

- Which firms are adopting new technologies in this sector, what are the barriers to adoption (if any), and what are the implications for the industrial organization of the sector?
- What accounts for the recent, rapid rise of employment in the warehousing sector? How much of this shift is attributable to online purchasing behavior or other shifts in consumer behavior?
- What is driving the rapid growth in warehousing employment in certain geographies of the US? What are the implications of this for the economic vitality of those regions that are gaining or losing employment in the sector?
- How much growth in the warehousing sector is coming from new firms vs. established incumbents? If, as appears to be the case, most growth is from established firms, what entry barriers are new firms facing?
- How will AVs affect employment and the economic geography of jobs?
- What are the implications of AVs for congestion, pollution, safety, and other by-products?
- How will transportation technologies interact with existing information technologies and the existing digital infrastructure?

On the first point, we note that the US statistical agencies can play a critical role in measuring the adoption and use of new technologies. The US Census Bureau has started to collect data on firm-level adoption of robots (Buffington, Miranda, and Seamans 2018) and other new technologies, such as machine learning, computer vision, and autonomous-guided vehicles. It appears that these technologies are primarily used by larger firms (Beede et al. 2020). This US data will soon be available for researchers to study the impact of these technologies on workers, firms, communities, and industries, including warehousing and transport. Consequently, the improved collection and increased availability of these data will play a critical role in answering many of the questions outlined in this chapter.

References

Agrawal, A., A. Galasso, and A. Oettl. 2017. "Roads and Innovation." *Review of Economics and Statistics* 99(3): 417–34. https://doi.org/10.1162/REST.

Banerjee, A., E. Duflo, and N. Qian. 2012. "On the Road: Access to Transportation Infrastructure and Economic." NBER Working Paper No. 17897. Cambridge, MA: National Bureau of Economic Research.

Barrios, J. M., Y. Hochberg, and H. Yi. 2020. "The Cost of Convenience: Ridehailing and Traffic Fatalities." NBER Working Paper No. 26783. Cambridge, MA: National Bureau of Economic Research.

Baum-Snow, N. 2007. "Did Highways Cause Suburbanization?" *Quarterly Journal of Economics* 122(2): 775–805.

Baum-Snow, N., J. V. Henderson, M. A. Turner, Q. Zhang, and L. Brandt. 2017. "Does Investment in National Highways Help or Hurt Hinterland City Growth?" *Journal of Urban Economics* 115 (September): 103124. https://doi.org/10.1016/j.jue.2018.05.001.

Beede, D., E. Brynjolfsson, C. Buffington, E. Dinlersoz, L. Foster, N. Goldschlag, K. McElheran, and N. Zolas. 2020. "Measuring Technology Adoption in Enterprise-Level Surveys: The Annual Business Survey." Washington, DC: US Census Bureau working paper.

Berger, T., C. Chen, and C. B. Frey. 2018. "Drivers of Disruption? Estimating the Uber Effect." *European Economic Review* 110: 197–210. https://doi.org/10.1016/j.euroecorev.2018.05.006.

Billings, S. B. 2011. "Estimating the Value of a New Transit Option." *Regional Science and Urban Economics* 41(6): 525–36. https://doi.org/10.1016/j.regsciurbeco.2011.03.013.

Bleakley, H., and J. Lin. 2012. "Portage and Path Dependence." *Quarterly Journal of Economics* 127(2): 587–644. https://doi.org/10.1093/qje/qjs011.

Buffington, C., J. Miranda, and R. Seamans. 2018. "Development of Survey Questions on Robotics Expenditures and Use in US Manufacturing Establishments." Working Paper No. 18-44. Washington, DC: US Census Bureau, Center for Economic Studies. https://ideas.repec.org/p/cen/wpaper/18-44.html.

Burtch, G., S. Carnahan, and B. N. Greenwood. 2018. "Can You Gig It? An Empirical Examination of the Gig Economy and Entrepreneurial Activity." *Management Science* 64(12): 5497–5520.

CEA (Council of Economic Advisers). 2016. "Economic Report of the President." https://obamawhitehouse.archives.gov/administration/eop/cea/economic-report-of-the-President/2016.

Chava, S., A. Oettl, M. Singh, and L. Zhang. 2019. "Creative Destruction? Assessing the Impact of E-Commerce on Employees at Brick-and-Mortar Retailers." Working paper, Georgia Tech Scheller College of Business.

Combes, P.-P., and M. Lafourcade. 2005. "Transport Costs: Measures, Determinants, and Regional Policy Implications for France." *Journal of Economic Geography* 5(3): 319–49.
Cook, C., R. Diamond, J. Hall, J. A. List, and P. Oyer. 2018. "The Gender Earnings Gap in the Gig Economy: Evidence from Over a Million Rideshare Drivers." NBER Working Paper No. 24732. Cambridge, MA: National Bureau of Economic Research.
Cramer, J., and A. B. Krueger. 2016. "Disruptive Change in the Taxi Business: The Case of Uber." *American Economic Review* 106(5): 177–82. https://doi.org/10.1257/aer.p20161002.
Donaldson, D. 2018. "Railroads of the Raj." *American Economic Review* 108(4–5): 899–934. https://doi.org/10.2307/1251838.
Duranton, G. 2016. "Transitioning to Driverless Cars." *Cityscape* 18(3): 193–96.
Duranton, G., and M. A. Turner. 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities." *American Economic Review* 101(6): 2616–52.
———. 2012. "Urban Growth and Transportation." *Review of Economic Studies* 79(4): 1407–40. https://doi.org/10.1093/restud/rds010.
Gately, C. K., L. R. Hutyra, and I. S. Wing. 2015. "Cities, Traffic, and CO_2: A Multidecadal Assessment of Trends, Drivers, and Scaling Relationships." *Proceedings of the National Academy of Sciences* 112(16): 4999–5004.
Gelauff, G., I. Ossokina, and C. Teulings. 2019. "Spatial and Welfare Effects of Automated Driving: Will Cities Grow, Decline or Both?" *Transportation Research Part A: Policy and Practice* 121 (March): 277–94. https://doi.org/10.1016/j.tra.2019.01.013.
Gibbons, S., and S. Machin. 2005. "Valuing Rail Access Using Transport Innovations." *Journal of Urban Economics* 57(1): 148–69. https://doi.org/10.1016/j.jue.2004.10.002.
Gibbons, S., T. Lyytikäinen, H. G. Overman, and R. Sanchis-Guarner. 2019. "New Road Infrastructure: The Effects on Firms." *Journal of Urban Economics* 110 (January): 35–50. https://doi.org/10.1016/j.jue.2019.01.002.
Gittleman, M., and K. Monaco. 2017. "Truck-Driving Jobs: Are They Headed for Rapid Elimination?" *ILR Review*. https://doi.org/10.1177/0019793919858079.
Glaeser, E. L., and J. E. Kohlhase. 2004. "Cities, Regions and the Decline of Transport Costs." In *Fifty Years of Regional Science*, 197–228. Berlin and Heidelberg: Springer.
Gorback, C. 2020. "Your Uber Has Arrived: Ridesharing and the Redistribution of Economic Activity." Wharton working paper, Wharton School of the University of Pennsylvania, PA.
Greenwood, B. N., and S. Wattal. 2017. "Show Me the Way to Go Home: An Empirical Investigation of Ride-Sharing and Alcohol Related Motor Vehicle Fatalities." *MIS Quarterly* 41(1): 163–87.
Kröger, L., T. Kuhnimhof, and S. Trommer. 2019. "Does Context Matter? A Comparative Study Modelling Autonomous Vehicle Impact on Travel Behaviour for Germany and the USA." *Transportation Research Part A: Policy and Practice* 122 (April): 146–61. https://doi.org/10.1016/j.tra.2018.03.033.
Liu, M., E. Brynjolfsson, and J. Dowlatabadi. 2018. "Do Digital Platforms Reduce Moral Hazard? The Case of Uber and Taxis." NBER Working Paper No. 25015. Cambridge, MA: National Bureau of Economic Research.
Mandel, M. 2020. "Pre-Pandemic Retail and Warehouse Productivity and Hours Growth, and Post-Pandemic Implications." Washington, DC: Brookings Institution working paper.
Paik, Y., S. Kang, and R. Seamans. 2019. "Entrepreneurship, Innovation, and

Political Competition: How the Public Sector Helps the Sharing Economy Create Value." *Strategic Management Journal* 40(4): 503–32.
Parker, G. G., and M. W. Van Alstyne. 2005. "Two-Sided Network Effects: A Theory of Information Product Design." *Management Science* 51(10): 1494–1504.
Perlman, E. 2016. *Connecting the Periphery: Three Papers on the Developments Caused by Spreading Transportation and Information Networks in the Nineteenth Century United States*. PhD thesis, Boston University, Graduate School of Arts and Sciences.
Redding, S. J., and M. A. Turner. 2015. "Transportation Costs and the Spatial Organization of Economic Activity." In *Handbook of Regional and Urban Economics*, vol. 5, 1339–98. Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-444-59531-7.00020-X.
Relihan, L. 2020. "Is Online Retail Killing Coffee Shops? Estimating the Winners and Losers of Online Retail Using Customer Transaction Microdata." London: London School of Economics working paper.
Roche, M. P. Forthcoming. "Taking Innovation to the Streets: Microgeography, Physical Structure and Innovation." *Review of Economics and Statistics* 102(5): 912–28.
Rochet, J. C., and J. Tirole. 2006. "Two-Sided Markets: A Progress Report." *RAND Journal of Economics* 37(3): 645–67.
Sohn, E., R. Seamans, and D. Sands. 2019. "Technological Opportunity and the Locus of Innovation: Airmail, Aircraft, and Local Capabilities." New York: New York University Stern working paper.
Sokoloff, K. L. 1988. "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790–1846." NBER Working Paper No. 2707. Cambridge, MA: National Bureau of Economic Research.
Wallsten, S. 2015. *The Competitive Effects of the Sharing Economy: How Is Uber Changing Taxis?* Washington, DC: Technology Policy Institute.

Comment Gilles Duranton

In their excellent chapter, Derrick Choe, Alexander Oettl, and Rob Seamans take a deep dive to examine two areas of the transportation sector, warehousing and personal travel with ridesharing services, and the future emergence of self-driving vehicles. Instead of trying to provide even more nuance to these thorough explorations, I would like to step back and draw some more general lessons, from these two case studies and from my own experience as someone who has been involved in transportation research for nearly 15 years. Doing this, I will highlight four key features of transporta-

Gilles Duranton is the Dean's Chair in Real Estate Professor at the Wharton School, University of Pennsylvania, and a research associate of the National Bureau of Economic Research.
For acknowledgments, sources of research support, and disclosure of the author's material financial relationships, if any, please see https://www.nber.org/books-and-chapters/role-innovation-and-entrepreneurship-economic-growth/comment-whats-driving-entrepreneurship-and-innovation-transport-sector-duranton.