Re-imagining Introductory Economics: Developing a Low-Cost Instructional Platform using OpenStax Introductory Economics Textbooks

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The authors previously submitted a proposal on the title "Re-imagining Introductory Economics: Developing a Low-Cost Instructional Platform using OpenStax Introductory Economics Textbooks" for the AEA presentation. But we were informed by the University CITS that the University WordPress system would be migrated to the CampusPress server starting this January 2020. The new CampusPress server will not have some of the plugins used in the current WordPress server and used for the implementation of the website. That is, the current website set up on the University of Massachusetts server will not properly function on the new server. As a result, we have decied to resume the website development on a new server after the migration. Thank you very much for understandings.

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Teaching Producer Theory and Perfect Competition Using a Real-World Example of Trucking Industry and the Autonomous Vehicle Technology

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Abstract

Producer theory and perfect competition are topics most difficult to teach in the Introductory Microeconomics course. The crucial novelty of this project is a novel teaching material that students can learn these topics using a real-world example of the trucking industry (the most popular occupation in 29 of the 50 states) and the impact of a (hypothetical) entry of autonomous vehicles based on actual industry data. We study how the new Autonomous Vehicle technology ("AV" hereafter) will affect the industry profits, employment, and consumer welfare and the policies that the government should take to deal with unemployment due to AV. First, we develop a realistic model of a representative trucking firm and derive production and short-term cost functions. Second, assuming a linear demand, we calculate a short-run market equilibrium that turns out to match the current key market statistics. Third, we introduce AV that has higher fixed costs from initial investments but leads to lower marginal costs. Fourth, we derive a long-term equilibrium with AV that reduces the load rate by 45%, increases the truckload by 22%, and reduces the number of firms by 40%, consistent with CEA estimates. Fifth, we conduct a back-of-the-envelope estimation of the impact of a robot tax, universal basic income, AV subsidy, and a new business creation (MAAS, "mobility as a service"). The material only requires the knowledge of the Introductory Microeconomics textbook and can be used as a course supplement or an assignment.

JEL Classification: A22, D63, E22, E23, E24, J24, O33

Keywords: economics education, project-based approach, producer theory, perfect competition, trucking industry, automation, labor market, economic policy

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"*How can I motivate children? How can I get children to think about what they are doing, not just focus on getting it done? How can I get children to really understand the material, not just pass tests?*" (Blumberfeld et al. (1991), p. 369.)

"*The second question we shall have to try to answer is how to bring engineers and other applied scientists closer to their real world of application. It is not enough for them to remember exactly how to use the formula, providing that the situation is not exactly the same as the situation was in the engineering school when the professor dictated the lecture. We must do something to make the applied engineer more flexible, so that he is effective in a wide range of applications.*" (Feynman (1963))

"*Recommendation: Emphasize the application of a limited number of important concepts and theoretical tools to a variety of problems, at the expense of some of the existing formal and detailed elaboration of theoretical constructs or the extent of coverage of the vast array of topics contained in most textbooks.*" (Siegfried et al. (1991), p.21.)

1. Introduction

1.1. Research Question. Producer theory and theory of perfect competition are important for students to understand the production side of the economy, market equilibrium, and the long-run behavior of the market. Producer theory studies the profit-maximizing behavior of a firm that takes price as given using production functions and cost functions. In a perfectly competitive market, the firm produces as long as the price covers the marginal cost if the price is above the average total cost. The short-term equilibrium price is determined to equate demand and supply. If a firm is profitable at the short-term equilibrium price, the firm enters the market, and the equilibrium price will decrease. The long-run equilibrium price is the one where a firm makes a zero profit.

Nevertheless, producer theory and perfect competition are very difficult to teach to college students. They have little experience in the production side of the economy and knowledge in the long-run behavior of the market. Furthermore, current textbooks illustrate the theory with artificial unrealistic examples that do not make sense for students. For example, one popular textbook uses examples of a law firm, a pizza shop, tree cutting (for lumber) with a two-person crosscut saw, production of widgets, a barbershop called "Clip Joint", a secretarial firm for typing, local governments hiring a private firm to clean up public parks, and production of an alarm clock, all with artificial numbers in one chapter of producer theory. Another popular textbook's typical question is about the "market for paper"(see below). Such examples will not help students to apply economics to the real-world problems.

The top table shows the market demand schedule for paper.

The market is perfectly competitive and there are 1,000 firms that produce paper. Each firm has the costs shown in the bottom table when it uses its least-cost plant.

Some firms ______ the market in the long run.

In the long run, the market price is ______ a box.

- A. exit; $10.00
- B. enter; $7.00
- C. exit; $11.60
- D. enter; $6.40

The number of firms in the long run is ______.
In the long run, the equilibrium quantity is ______ boxes a week.

- A. 500; 250,000
- B. 2,000; a little more than 400,000
- C. 1,600; a little less than 400,000
- D. 750; 300,000

In the long run, firms make an economic profit.

- A. True
- B. False

Price (dollars per box)	Quantity demanded (thousands of boxes per week)
3.65	500
5.20	450
6.80	400
8.40	350
10.00	300
11.60	250
13.20	200

Quantity (boxes per week)	Marginal cost (dollars per additional box)	Average variable cost (dollars per box)	Average total cost
200	6.40	7.80	12.80
250	7.00	7.00	11.00
300	7.65	7.10	10.43
350	8.40	7.20	10.06
400	10.00	7.50	10.00
450	12.40	8.00	10.22
500	20.70	9.00	11.00

Figure 1. A Typical Textbook Question

Then, at least some of the current teaching of producer theory and prefect competition still "tend to be encyclopedic, and all too often oriented toward formalism of theory at the expense of application" as noted by Siegfried et al. (1991) about three decades ago. Then, as Siegfried et al. (1991) recommended, there is a need to "emphasize the application of a limited number of important concepts and theoretical tools to a variety of problems, at the expense of some of the existing formal and detailed elaboration of theoretical constructs or the extent of coverage of the vast array of topics contained in most textbooks."

Then, the research question of the paper is, following Siegfried et al. (1991), to develop a novel teaching material about producer theory and perfect competition that focuses on applications that will help students' learning on these topics.

1.2. Previous Research. Previous researches did not answer the above research question. First, there have been recent significant progresses in applying novel "instructional strategies" such as deliberate practice, interleaving, retrieval practice, spacing, metacognition, desirable difficulties, limited working memory, the curse of knowledge, schema generation, and constructivism to economics education (Boyle and Goffe (2018), for example). But most of these innovations take the course material as given. Thus these innovations do not directly deal with the above problem that requires a new material development that students themselves would be willing to actively learn.

Second, recently developed teaching materials in the area of producer theory and perfect competition are computer simulation and excel spreadsheet (Nicholson and Westhoff (2008) and Mitchell (2009)), estimation of numerical elasticity values for the two-input, two-time period case (Casler (2013)), and others that focus on quantiative calculations. They have significant contributions in their own rights. But they do not offer teaching materials with real-world applications that address Siegfried et al. (1991)' recommendations.

1.3. The Crucial Novelty of the Paper. The crucial novelty of the paper is to address the above question by developing a case study ("case-based approach") of the trucking industry and autonomous vehicle technology to teach producer theory and perfect competition.

This "case-based approach" (and related "project-based approach") has been considered in STEM educations for the past several decades. An example of the engineering case/project is the NASA rocket project (NASA (2011a) and NASA (2011b), for example). For example, NASA (2011a) notes "the purpose of this project is to add engineering rigor in a team-based environment to a project that many students already have exposure to as a youth: launch of a model rocket." According to Blumberfeld et al. (1991), "proponents of project-based learning claim that as students investigate and seek resolutions to problems, they acquire an understanding of key principles and concepts. Project-based learning also places students in realistic, contextualized problem-solving environments. In so doing, projects can serve to build bridges between phenomena in the classroom and real-life experiences; the questions and answers that arise in their daily enterprise are given value and are shown to be open to systematic inquiry, rather than a narrow view of the subject matter."

Regarding the effectiveness of the case-based approach, as an example, Fawcett (2017) investigates how the use of real-life, discipline-specific case study material in Statistics service courses affects student learning and finds that the subgroup who learned from the cases outperformed their peers in terms of their grades in both homework exercises and open-ended projects (see also Boyle (1999), Bradstreet (1996), and Singer and Willett (1990)).

But the above case/project-based approach has not been systematically introduced to economics education yet. Then the crucial novelty of this paper is to introduce the case/project-based approach to economics education and develop teaching materials for producer theory and perfect competition.

1.4. Case Study of Trucking Industry. This paper develops a case study of the trucking industry and the autonomous vehicles technology.[2] The reason that we consider the trucking industry is that the industry is central to the U.S. economy. The industry provides transportation services for companies to haul heavy things. Trucks move roughly 71.4% of the nation's freight by weight and 11.49 B tons of freight per year.[3] 7.8 M people are employed throughout the economy in jobs that relate to trucking activity in 2018.[4] Truck driving is the most popular occupation in 29 of the 50 states.[5]

Economically, trucking lacks asset specificity: the capital investments required for

[2]This paper focuses on the development of the case material. The development of "project" format that students work together would have to be a topic of future research.

Another possible case study for perfect competition could be the effect of entry of peer-to-peer short-term rentals on accomodation markets (Farronato and Fradkin (2018)).

Many institutional and technological details in this paper are based on American Transportation Research Institute (2018), American Trucking Associaton, Anderson et al. (2016), Badue (2019), Freedman (2017), Fridman (2019), The Executive Office of the President (2016), Viscelli (2016), and Viscelli (2018).

[3]http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[4]https://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[5]https://www.rtsinc.com/articles/why-trucking-still-america-s-number-one-job

trucking are not generally tailored to narrow or specific product markets, and trucks are commodities. Thus the barriers to entry into the industry are low, so when trucking is profitable new firms are able to enter the market and existing firms can increase capacity quickly. Thus we consider the trucking industry to be perfectly competitive.

Furthermore, one of the most exciting technological developments to students is taking place in the trucking industry. “Autonomous” vehicles can sense their surroundings and guide themselves without human intervention. The technology was developed with the DARPA Grand Challenge (2004-13). In October 2016, the Uber-owned Otto made its first delivery from Fort Collins. Co to Colorado Springs. Today, AV technology is being developed by dozens of major firms in the tech sector as well as numerous vehicle manufacturers and suppliers, including Apple, Waymo, Uber, Lyft, and Tesla—and major automakers, including Daimler, Audi, BMW, Volkswagen, Volvo, GM, Ford, Honda, and Toyota.

Students intuitively understand that AI and robotics will cause disruptions in the economy as it adapts to new paradigms and there are interested in understanding how they impact their lives. This project responds to students' interests and asks students to use the knowledge of Introductory Microeconomics to understand how the AV technology will change the trucking firm's production, costs, market price, industry employment, consumer surplus, producer surplus, and social surplus and also study the effective government policy to deal with potential unemployment due to AV.[6]

In other words, this case study complements the current textbooks by following Siegfried et al. (1991)'s recommendation to “emphasize the application of a limited number of important concepts and theoretical tools to a variety of problems, at the expense of some of the existing formal and detailed elaboration of theoretical constructs or the extent of coverage of the vast array of topics contained in most textbooks.”

1.5. Analysis Using the Empirical Data. In this case study, we first present the back-

[6] This analysis can be used to study the effect of other automation technologies such as computer software (Acemoglu and Restrepo (2018b)).

ground of the trucking industry such as basic statistics, trucking firms and industry structure, capital (truck), labor (drivers), regulations (Hours of Service), truckloads, load rates, and industry operating expense.

We develop a simple model of a representative trucking firm and derive the production functions and cost functions. An increasing marginal cost curve intersects a U-shaped average cost curve at the latter's minimum, after which the average cost curve begins to slope upward.

We derive the short-run market equilibrium of the trucking industry. We first define a perfectly competitive market and price-taking behavior. We then discuss the firm's profit-maximizing behavior and derive the firm's supply function and the industry supply function. We next construct a linear demand function using an empirically estimated price elasticity of demand. The short-run market equilibrium is the price where the demand equals supply. We then calculate the consumer surplus, the producer surplus, and the social surplus. The model provides industry employment of 7.2 million, consistent with the industry data.

We now introduce AV. After the overview of AV, we focus on a scenario ("Level 4 autopilot") that allows drivers to deliver more truckloads using a technology.[7] We then consider production functions and short-run cost functions with AV. AV will require an initial investment to equip the current truck with sensors and navigators. Then AV will reduce the marginal cost. We compare AV production and cost functions with the current ones.

We are now able to derive the long-run equilibrium with AV. We derive the equilibrium price from the zero profit condition. In the long-run equilibrium, load rates are lower,[8], demand is higher, the consumer surplus is higher, the producer surplus is lower, and the social surplus is higher. The model shows that the AV technology displaces 2.8 million

[7] That is, we consider factor-augumenting technological progress that increases the labor productivity. Level 4 autopilot still requires a driver in the truck. Thus Level 4 does not displace a human driver. (Level 5 would not need the presence of a driver thus replace a driver from the truck.)

We also would like to note that this is a hypothetical exercise to understand the economic effect of new technology. This paper does not take a position whether the Level 4 autopilot AV would be widely adopted in the near future. Fridman (2019) and Badue (2019) provide reviews of the AV technology as of 2019.

[8] What can happen to the driver's income? In a likely case that a driver will be paid for the miles that the driver actually drives to deliver the load, the driver's income will also significantly decrease.

employment, consistent with the estimate by The Executive Office of the President (2016).[9]

We finally consider various policy options to deal with unemployment displaced by AV. We use the above model to analyze the effect of robot tax, Universal Basic Income Taxes that affect the labor demand, subsidy for the further development of AV technology, and the MaasS ("Mobility-as-a-Service") such as ride-sharing service with autonomous vehicles. A robot tax, the Universal Basic Income, and AV subsidy will not recoup the unemployment. The effective labor market policy is a creation of new industry that takes advantage of AV.[10]

1.6. Contribution of the Paper. The contribution of this paper is that this is the first paper to develop a case to teach producer theory and perfect competition using an example of the trucking industry and autonomous vehicles technology familiar and interesting to students. This crucial novelty of this paper in comparison with previous papers is that this paper addresses Siegfried et al. (1991)'s criticism and recommendations.

2. Trucking Service Industry Overview

We first study the current state of the trucking industry and present basic facts about the industry, the firm business model, capital (trucks), labor (workers), regulation ("Hours of Service regulation"), truckloads, and the load rate.

[9]We note that this is not a simple displacement effect considered in Acemoglu and Restrepo (2018a), Acemoglu and Restrepo (2018b), and Acemoglu and Restrepo (2019) that considers a technology that directly replaces a human. In our set up, the Level 4 AV does not replace a human since the truck still needs a driver to supervise the AV. But Level 4 AV still significantly increases worker productivity constrained by HOS regulation. Furthermore, a relatively inelastic demand implies that the trucking demand will not increase much with lower load rates. Thus, even if the Level 4 AV does not directly replace a human, the labor demand still decreases. That is, this paper presents an example of displacement effect and decreasing labor income even with labor-augumenting technological progress. This is also consistent with Autor (2019)'s finding that automation (as embodied in TFP growth) has been employment-augmenting yet labor share-displacing over the last four decades.

[10]This is an example of "new tasks" considered in Acemoglu and Restrepo (2018a) and Acemoglu and Restrepo (2018b) where the new AV technology serves as a platform of a new business such as ridesharing and displaced workers create a greater pool of labor that could be employed in new tasks. Bessen (2015) documents a case that the introduction of ATM machines increased the banking service demand thus increased the demand for bank tellers. The importance of new tasks is also illustrated in Autor (2019).

2.1. Overview. Trucking service transports large quantities of goods such as moving goods from manufacturing plants to retail distribution centers and moving large amounts of building materials used in construction. The trucking industry as a whole traveled 279.1 billion miles in 2014.[11] Trucking industry revenues were $676.2 billion in 2016.[12]

2.2. Trucking Firm. A trucking firm inputs trucks (capital) and drivers (labor) to produce and sell freight services. There are about 1.2 million trucking service companies in the U.S.[13] The 50 largest companies account for less than 30 percent of the market.[14] Consistent with the above fact, truckload operating ratio (a company's operating expenses as a percentage of revenue) is 91 and LTL ("Less Than Truckload") operating ratio is 97.[15] Based on above facts, we assume that trucking industry is perfectly competitive.

2.3. Capital Equipment (Truck). The US DOT puts trucks into classes by "Gross Vehicle Weight Rating" (GVWR) ranked from 1 to 8 (smallest to largest).[16] The Class 8 truck is a vehicle with a GVWR exceeding 33000 lb. There are 3.4 million Class 8 trucks in the industry.[17] 91.3% of firms operate 6 or fewer trucks and 97.4% operate fewer than 20 trucks.[18]

2.4. Labor (Drivers). There are various types of drivers. Long-distance drivers move goods from factories to distribution centers or retail stores or between distribution centers. The large majority are local delivery drivers who perform a wide range of assignments, delivering anything from express packages to flowers. 88% of drivers are male.[19] Most of them have high school and some college degrees.[20] This paper focuses on long-distance drivers but the

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[11] http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[12] http://www.trucking.org/article/ATA-American-Trucking-Trends-2017

[13] http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[14] http://www.dot.ca.gov

[15] https://www.joc.com/trucking-logistics/ltl-shipping/average-ltl-truckload-operating-ratios-rise_20130522.html

[16] GVWR refers to the maximum operating weight a truck can possibly carry while driving including the truck itself.

[17] http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[18] https://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

[19] http://www.esa.doc.gov/sites/default/files/Employment%20Impact%20Autonomous%20Vehicles_0.pdf

[20] http://www.esa.doc.gov/sites/default/files/Employment%20Impact%20Autonomous%20Vehicles_0.pdf

analysis carries over to local drivers since both types of drivers are subject to the HOS regulation explained below. [21]

2.5. Regulation. Most drivers must obtain a commercial driver's license (CDL). Federal Motor Carrier Safety Administration decides the basic nationwide Hours of Service (HOS) regulations for truckers' safety. HOS requires truckers to record their work in a logbook and drivers can work no more than 60 hours in seven days or 70 hours in eight days.[22]

2.6. A Typical Day of Drivers. Long-haul, over-the-road truck drivers' average daily run is nearly 500 miles.[23] A driver's yearly run is 100,000 miles.[24] Viscelli (2016) documents a life of a long-distance driver based on his own experiences:

> "Yesterday, June 27th, I arrived at my truck at 8:00 a.m. and received a series of text messages on my satellite-linked computer. As the text messages instructed, yesterday I drove to a Wal-Mart distribution center (DC) in Marcy, New York, twelve miles away from my home parking location. I waited in a line of trucks for the security guard to record my truck number and reason for entering the DC. After a brief inspection, I coupled up to it, signed out at the guard shack, and hauled W32475 to a paper mill about 106 miles away. By 4:30, W32475 had been loaded with six giant paper rolls that were due in Neenah, Wisconsin, by noon on Wednesday.." (p. 59)

We will study how AV technology affects such driver.

2.7. Truck Load. The average haul length is about 500 miles.[25] Since the trucking industry has 279.1B miles in 2014 as noted above, we estimate that there will be around 540M loads per year. Among them, 25% of loads are local pickup and deliveries (<100 miles), 37% are regional pickups (between 100 and 500 miles), 19% are inter-regional pickups (between 500 and 1000 miles), and 19% are National (>1000 miles).[26]

[21] We also assume that labor is inelastically supplied.
[22] https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Drivers%20Guide%20to%20HOS%202015_508.pdf
[23] http://www.trucking.org/article/Professional-Truck-Drivers-and-the-Trucking-Industry
[24] http://www.trucking.org/article/Professional-Truck-Drivers-and-the-Trucking-Industry
[25] http://atri-online.org/wp-content/uploads/2016/10/ATRI-Operational-Costs-of-Trucking-2016-09-2016.pdf
[26] https://truckingresearch.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf

2.8. Load Rates. Deregulation led to de-unionization of much of the industry. Many drivers are compensated on a per-mile basis rather than a per-hour basis. The average rate is $1.6 per mile.[27] Thus we estimate the average load rate to be about $800.

3. Trucking Firm Short-Term Cost Functions

Given the data in the previous section, we begin with a model of a representative trucking service operators. We derive the production function, the marginal product function, and the average product function. We then calculate the fixed cost function, the variable cost function, and the total cost function. We derive the marginal cost function, the average fixed cost function, the average variable cost function, and the average total cost function.

3.1. A Simple Model of a Trucking Service Operator. A trucking firm inputs trucks (capital) and drivers (labor) to produce and sell freight services. In the short-term, trucks are fixed inputs and drivers are variable inputs.

Regarding capital equipment, as seen, there are about 1.2M trucking service companies in the U.S. and there are 3.4M Class 8 trucks in the industry.[28] Thus we assume that a typical trucking company has 3 trucks. We assume that each truck costs $30K.

Regarding the labor input, a driver is needed to be assigned to one truck. We have seen that the average haul length is about 500 miles (one-way) and a driver's yearly run is 100,000 miles. It means a driver takes 2 loads per week, which does make sense given the Hours of Service regulation. Thus, on average, a driver can deliver up to 100 loads (one-way 50,000 miles and return 50,000 miles) per year.

3.2. The Trucking Firm Production Function. The short-term production function describes the relationship between the number of drivers and the number of deliveries fixing the number of trucks.

[27] https://www.dat.com/blog/post/rates-hit-multi-year-highs-whats-next1

[28] http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx

We consider a following simple load delivery process. When the firm hires 0 drivers, the firm cannot deliver any loads. When the firm hires 1 driver, the firm assigns the driver to the first truck. The driver and the first truck deliver 2 loads per week. A driver works 4 days a week. So the driver will deliver 100 loads for a year. Similarly, the second and the third driver will deliver 100 loads a year. Now consider the fourth driver. The fourth driver will be assigned to the first truck. But the first driver has already used the first truck for four days. Thus the fourth driver can use the first truck only for one load (for two days). Thus the fourth driver can only deliver 50 loads per year. For the fifth and sixth driver, the same reasoning holds. Consider the seventh driver. We assume that the firm assigns the seventh driver to the first truck. But the first driver uses the first truck for four days and the fourth driver uses the truck for the two days. Thus the seventh driver can use the truck only for a day. Thus the seventh driver can deliver only 25 loads per year. That is, as the firm hires more drivers, the output increases, but the output is eventually restricted by the availability of trucks.

	#Drivers	Output (#loads)
	0	0
First driver for each car	1	100
	2	200
	3	300
Second driver for each car	4	350
	5	400
	6	450
Third driver for each car	7	475
	8	500
	9	525

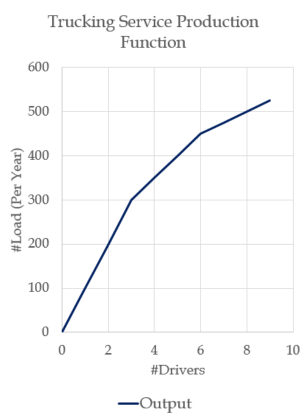


Figure 2. Trucking Firm Production Function

3.3. The Marginal Product Function and the Average Product Function. The marginal product function describes the relationship between the change in output (loads) from one more unit of labor (driver) for each driver. The marginal product of the first to the third driver is 100. The marginal product of the fourth to the sixth goes down to 50. The marginal product of the seventh to the ninth driver is 25. The marginal product function satisfies "the law of diminishing marginal return." That is, as the # of drivers is increased driver productivity decreases since # of trucks is fixed.

The average product is the average output (loads) for one input (driver). For example, the first driver, the average product is 100/1=100. For the second and the third driver, the average product is also 100. For the fourth driver, the average product is 350/4=87.5. For the fifth driver, the average product is 400/5=80. The average product function is decreasing due to the law of diminishing marginal return.

Driver	Marginal Product
0	0
1	100
2	100
3	100
4	50
5	50
6	50
7	25
8	25
9	25

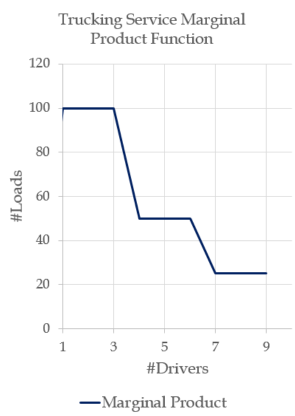


Figure 3. Marginal Product Function

Driver	Loads	Average Product
0	0	0
1	100	100
2	200	100
3	300	100
4	350	87.5
5	400	80
6	450	75
7	475	67.9
8	500	62.5
9	525	58.3

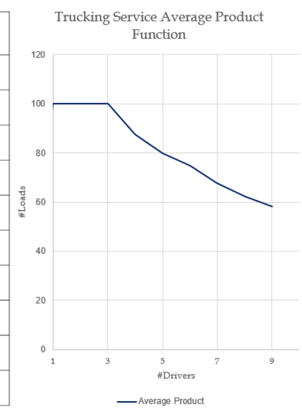
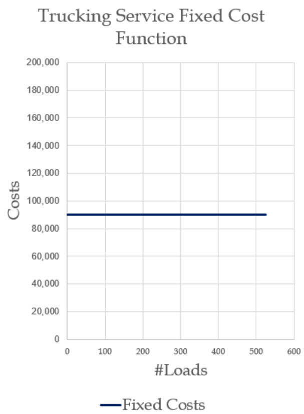


Figure 4. Average Product Function

3.4. The Fixed Cost Function and the Variable Cost Function. We begin the study of the cost structure. The fixed cost function describes the relation between output and the cost of capital and is a constant function. The variable cost function describes the relationship between output and variable inputs costs (wages). Since the firm needs to pay $40K for each driver, multiplying the number of drivers with $40K will give the variable cost for each output. Since more loads require more workers, the variable cost function is an increasing function. Furthermore, the rate of increase accelerates as the firm hits the trucks capacity constraints.

Loads	Fixed Costs
0	90,000
100	90,000
200	90,000
300	90,000
350	90,000
400	90,000
450	90,000
475	90,000
500	90,000
525	90,000



Loads	Variable Costs
0	0
100	40,000
200	80,000
300	120,000
350	160,000
400	200,000
450	240,000
475	280,000
500	320,000
525	360,000

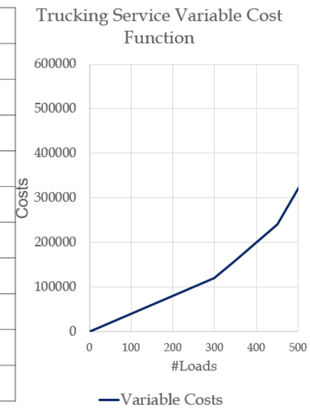


Figure 5. Fixed Cost Function

Figure 6. Variable Cost Function

3.5. The Total Cost Function. The total cost function describes the total cost to deliver given number of loads. The total cost is the sum of the fixed cost and the variable cost. As the output increases, the variable cost increases, thus the total cost increases.

Driver	Loads	Fixed Costs	Variable Costs	Total Cost
0	0	90,000	0	90,000
1	100	90,000	40,000	130,000
2	200	90,000	80,000	170,000
3	300	90,000	120,000	210,000
4	350	90,000	160,000	250,000
5	400	90,000	200,000	290,000
6	450	90,000	240,000	330,000
7	475	90,000	280,000	370,000
8	500	90,000	320,000	410,000
9	525	90,000	360,000	450,000

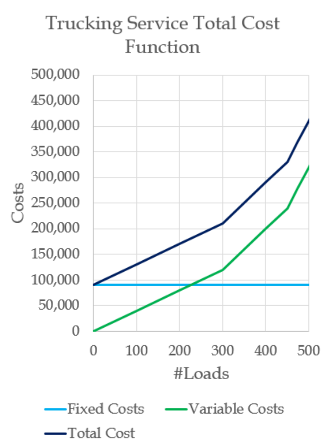


Figure 7. Total Cost Function

3.6. The Marginal Cost Function. The marginal cost is the increase in the total cost from a one-unit increase in output. For example, the marginal cost of delivering the 200th load is (170,000-130,000)/100=400. As the firm delivers more loads, the firm needs to deal with the truck capacity constraints, thus, the marginal cost increases.

Driver	Loads	Marginal Cost
0	0	NA
1	100	400
2	200	400
3	300	400
4	350	800
5	400	800
6	450	800
7	475	1,600
8	500	1,600
9	525	1,600

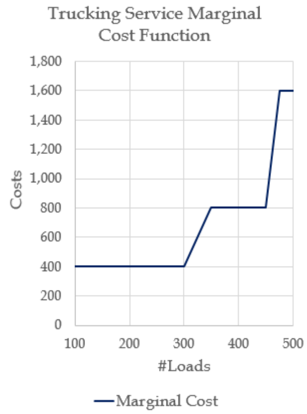


Figure 8. Marginal Cost Function

3.7. The Average Fixed Cost (AFC) Function and the Average Variable Cost (AVC) Function. The average fixed cost function describes the relationship between the output and the fixed costs per unit of producing that output. For example, the average fixed cost for the 200th unit is the total fixed cost \$90,000 divided by 200=450. Since the number of trucks is fixed, the average fixed cost function is a decreasing function. The average variable cost function is the variable cost per unit. For example, the average variable cost for the 200th delivery is the variable cost for the 200 units (\$80,000) divided by 200 that is \$400. Since increasing the output requires more drivers to deal with the truck capacity constraint, the average variable cost function is an increasing function.

Loads	Average Fixed Costs
0	NA
100	900
200	450
300	300
350	257
400	225
450	200
475	189
500	180
525	171

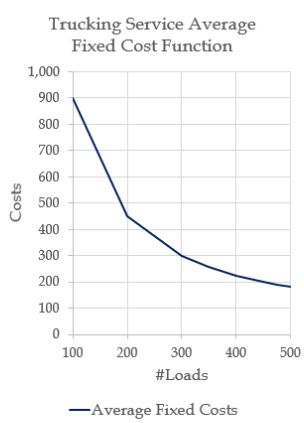


Figure 9. Average Fixed Cost Function

Loads	AVC
0	0
100	400
200	400
300	400
350	457
400	500
450	533
475	589
500	640
525	686

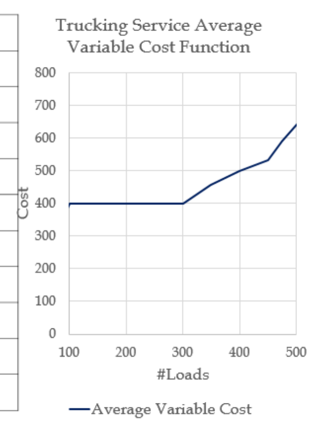


Figure 10. Average Variable Cost Function

3.8. The Average Total Cost (ATC) Function. The average total cost is the total cost per unit. The ATC curve is U-shaped because (1) spreading total fixed cost over a larger output—AFC curve slopes downward as output increases and (2) eventually diminishing returns—the AVC curve slopes upward and AVC increases more quickly than AFC is decreasing. We note that ATC takes a minimum value of $714 when the firm delivers 350 loads.

Loads	AFC	AVC	ATC
0	NA	NA	NA
100	900	400	1300
200	450	400	850
300	300	400	700
350	257	457	714
400	225	500	725
450	200	533	733
475	189	589	779
500	180	640	820
525	171	686	857

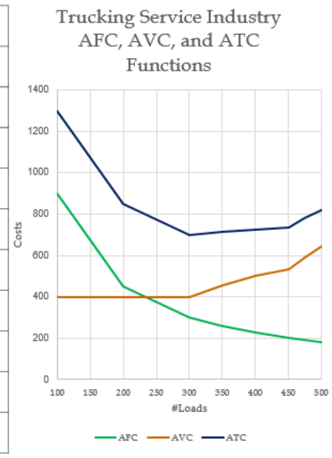


Figure 11. Average Total Cost Function

4. Short-Run Market Equilibrium of the Trucking Industry

We now characterize the short-run market equilibrium of the industry. We first formulate the firm's profit maximization behavior and derive the firm and the market supply function. We then construct the market demand function and derive the short-run market equilibrium to calculate consumer surplus, producer surplus, social surplus, and the equilibrium industry employment.

4.1. Perfectly Competitive Market and Price Taking Behavior. A perfectly competitive market is a situation where many firms sell identical products to many buyers. The trucking industry has a large number of firms (1.2M). Trucking lacks asset specificity. The operating ratio is high. Thus we assume that the industry os perfectly competitive. **I**n a perfectly competitive market, firms are price takers. That is, a firm does not have the power to negotiate the price and a firm accepts the market price as given. Indeed, one firm says "If all you're doing is arguing rates, you'll only get so far... You hit the point of diminishing return."[29]

4.2. Profit Maximization Behavior and Supply Functions. The firm's objective is profit maximization**.** A firm produces as long as the marginal cost is less than the price when the price is above the average total cost. Recall that ATC takes a minimum value of $714 when the firm delivers 350 loads. Thus if the price of a load is less than $714, the firm will not deliver any load. If the price is more than $714, the firm will deliver the load as long as the marginal cost of a load is less than the price. The market supply function is obtained by multiplying the individual supply function by the number of firms in the market (1.2M).

Price	Supply
0	0
200	0
400	0
600	0
800	350
1000	453
1200	456
1400	459

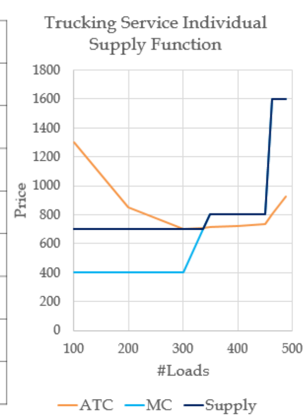


Figure 12. Individual Supply Function

Price	Individual Supply	Industry Supply (millions)
0	0	0
200	0	0
400	0	0
600	0	0
800	350	420
1000	453	544
1200	456	548
1400	459	551

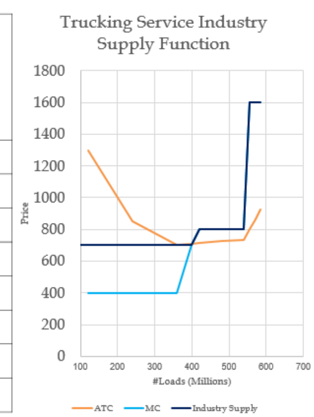


Figure 13. Industry Supply Function

4.3. Market Demand Function and The Short-Run Market Equilibrium. The current market has the load rate $800 and 540 million yearly loads. We extrapolate this data point by assuming linear demand. We follow West (2005) to assume that the demand is inelastic with price elasticity -0.46. The demand is inelastic because we do not have much alternative means of transportation in many situations.[30] The short-run equilibrium is the

[29]https://www.transplace.com/2017/01/31/joc_us_shippers_rethink_truck_contract_pricing-2/
[30]It is also broadly consistent with the Uber demand elasticity -0.36 (Cohen et al. (2018)).

shipping rate that the demand equals supply. We find that the equilibrium load rate is $800 and the number of load is 540M.

Loads	Industry Demand
0	2600
120	2200
240	1800
360	1400
420	1200
480	1000
540	800
555	750
570	700
585	650

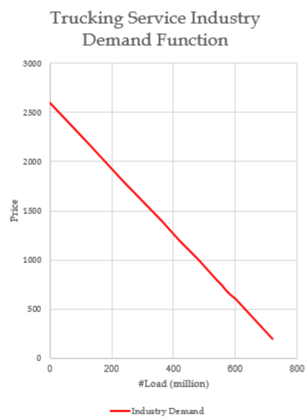


Figure 14. Industry Demand Function

Loads	Industry Supply	Industry Demand
0	700	2600
120	700	2200
240	700	1800
360	700	1400
420	800	1200
480	800	1000
540	800	800
555	3200	750
570	3200	700
585	3200	650
600	3200	600
720	3200	200

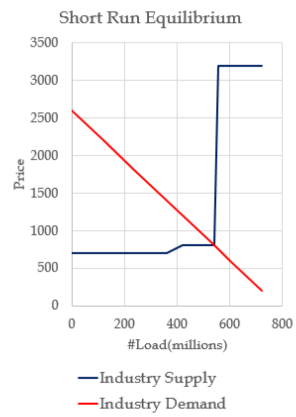


Figure 15. Short-Run Market Equilibrium

4.4. Consumer Surplus (CS), Producer Surplus (PS), and Social Surplus. Consumer surplus is an economic measurement of consumer benefits. Consumer surplus happens when the price that consumers pay for a product or service is less than the price they're willing to pay. Consumer surplus is the sum of consumer marginal benefits minus price summed over quantities. Then CS =(1/2)*($2600-$800)*540M= $486 Billion.

Producer surplus is the total amount that a producer benefits from producing and selling a quantity of a good at the market price. Producer surplus is the price minus marginal cost summed over the quantities. Then Producer Surplus =(1/2)*(360M+450M)*$100=$45 Billion. The sum of consumer surplus and producer surplus is social surplus, also referred to as economic surplus. Thus Social surplus = $486 Billion+$45 Billion= $531 Billion. This result is broadly consistent with the assumption of perfect competition.

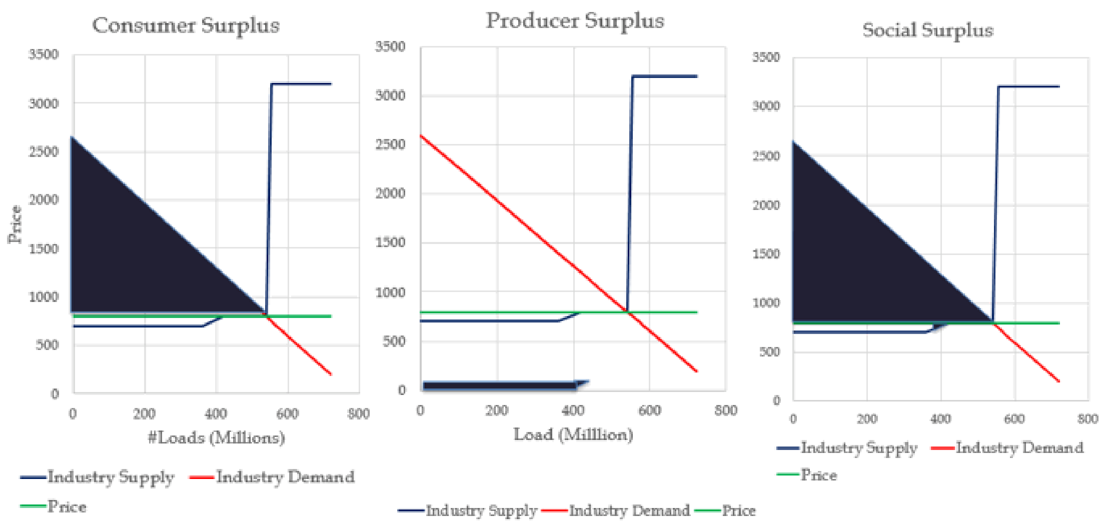


Figure 16. Consumer Surplus, Producer Surplus, and Social Surplus

4.5. Industry Employment. In equilibrium, each firm will deliver 450 loads per year. It implies that each firm will hire two drivers for each truck, thus six drivers in total. This will lead to the employment of 7.2 million people. It also means that trucking business operates close to full capacity. The result is consistent with the industry statistics that 7.3 million people employed in the trucking activity.

5. Autonomous Vehicle Technology

We have so far constructed a model of the trucking industry that matches the key statistics of the industry. Our goal is to study the effect of autonomous vehicles technology on the trucking industry. We now study its economic benefits and costs of AV.

5.1. Autonomous Vehicles Technology. An autonomous vehicle is capable of sensing its environment and navigating without human input. Over the past 15 years, this technology has advanced rapidly, bolstered by Defense Advanced Research Project Agency (DARPA) initiatives that encouraged university research through autonomous vehicle competitions.

The Society of Automotive Engineers (SAE) International published a classification system based on the amount of human driver intervention and attentiveness required by them. Level 0 is traditional large trucks. Level 1 is "driver assistance" with safety and convenience technologies such as electronic stability control and adaptive cruise control. Level 2 is "partial automation" with collision mitigation systems. Level 3 is "conditional automation" such as the Freightliner Inspiration Truck, which can operate autonomously with a close driver oversight. Level 4 is "high automation" that would only be authorized to travel on certain highways that are certified for L4 use, and the driver would need to operate the vehicle on all other roads. Level 5 vehicle allows for full driving automation on any roadway. A driver is not required for an L5 truck to move from an origin to a destination.

5.2. Mechanics of AV technology. The AV technology is typically organized into the perception system and the decision-making system (Badue (2019)). AV combine a variety of sensors to perceive their surroundings, such as radar, lidar, sonar, GPS, odometry and inertial measurement units. The sensor system uses a pulsed laser to amass detailed data about the truck's surroundings. Then advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Computers feed the sensor data into algorithms to adjust braking and steering. There are various scenarios about how the AV technology can change the Trucking industry (Viscelli (2018)).

- Platooning: a single human driver would lead a platoon of autonomous trucks.
- Exit-to-exit autonomous trucks with drone operation: Human operators would remotely control trucks.
- Autopilot: a human would handle loading and local driving, then sleep in the back of the truck while the computer drove on the highway.
- Exit-to-exit cabless autonomous trucks: Human drivers would navigate complicated local streets, then swap trailers with self-driving trucks at the highway.
- Facilities-to-facilities autonomous trucks: Autonomous trucks drive directly from origin to destination.

In this paper, we consider what happens if the Level 4 autopilot technology that was demonstrated by Otto in 2016 becomes widely available. [31]

5.3. Economic Benefit and Costs of AV Technology. The economic benefit of AV is that autonomous trucks could double the productivity of long-haul trucks for highway segments. In the above Otto example,

> "In fact, Otto insists it has no plans to release products intended to operate trucks without a driver in the cab. But Otto does expect to free up the driver during highway cruising to remain in the back of the cab. And therein lies the strongest part of the economic case for self-driving trucks. Drivers are legally restricted to 11 hours of driving a day and 60 hours a week. Given that a new big rig goes for about $150,000, and taking into account the vast delays that pulling over to rest injects into the movement of goods, trucks that can cruise nearly 24/7 could dramatically lower freight costs." (Freedman (2017))

Any tractor built after 2013 with automated transmissions can be modified or retrofitted into an autonomous truck. According to one study, the cost of converting the current truck into AV is about $20K.[32]

6. Autonomous Vehicles Technology Production Functions and Cost Functions

We now study how AV technology will change and cost functions of the trucking firm and compare with the traditional technology studied in Section 3.

6.1. A Model of AV Trucking Service Operators. Consider a trucking company with 3 trucks. But now its truck is updated with the AV technology with the cost of 20K for each truck. We assume that, with AV technology, a driver can deliver twice as many loads as the driver used to be able to. AV technology enables each driver to operate a vehicle more efficiently, so the output increases compared with the previous technology. This will lead to

[31] In this sense, Level 4 AV is not "industrial robots" defined as "fully autonomous machines that do not need a human operator and can be programmed to perform several manual tasks such as welding, painting, assembly, handling materials and packaging" in Acemoglu and Restrepo (2019).

As explained, this paper does not take a position that Level 4 AV technology will soon become reality (Fridman (2019) and Badue (2019)).

[32] https://www.rolandberger.com/en/press/Automated-Trucks-%E2%80%93-The-next-big-disrupter-in-the-automotive-industry.html

an upward shift in the production function.

Driver	Previous-Output	AV Output
0	0	0
1	100	200
2	200	400
3	300	600
4	350	700
5	400	800
6	450	900
7	475	950
8	500	1000
9	525	1050

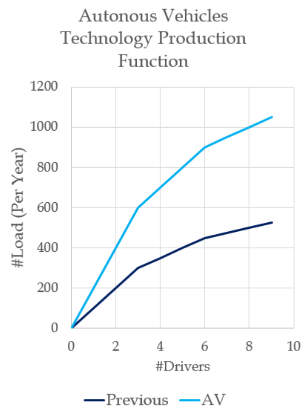
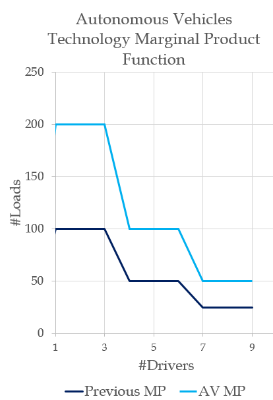


Figure 17. AV Production Function

6.2. AV Marginal Production Function and Average Product Function. AV increases the driver productivity thus marginal product and average product.

Driver	Previous MP	AV MP
0	0	0
1	100	200
2	100	200
3	100	200
4	50	100
5	50	100
6	50	100
7	25	50
8	25	50
9	25	50



Loads	Average Products	AV Average Products
0	0	0
100	100	200
200	100	200
300	100	200
350	88	175
400	80	160
450	75	150
475	68	136
500	63	125
525	58	117

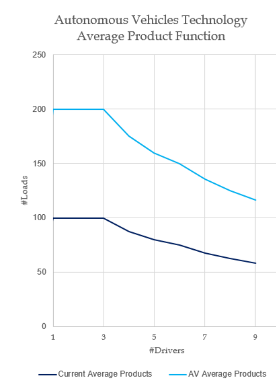


Figure 18. AV Marginal Product Function

Figure 19. AV Average Product Function

6.3. AV Fixed Cost and Variable Cost Function. AV technology requires higher initial capital improvements for hardware and software upgrades. Thus the firm pays a higher fixed cost with AV in comparison with the current technology. The variable cost is the cost of the firm's variable inputs. With the AV technology, a driver can deliver more loads thus the average costs go down. The AV variable cost is less than half of the current variable cost because AV delivers the load with fewer drivers.

Loads	Current Fixed Costs	AV Fixed Costs
0	90,000	150,000
100	90,000	150,000
150	90,000	150,000
200	90,000	150,000
300	90,000	150,000
350	90,000	150,000
400	90,000	150,000
450	90,000	150,000
475	90,000	150,000
500	90,000	150,000
525	90,000	150,000

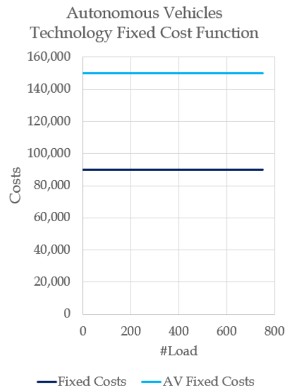


Figure 20. AV Fixed Cost Function

Loads	Current Variable Costs	AV Variable Costs
0	0	0
100	40,000	20,000
200	60,000	40,000
300	120,000	60,000
350	160,000	70,000
400	200,000	80,000
450	240,000	90,000
475	280,000	95,000
500	320,000	100,000
525	360,000	105,000

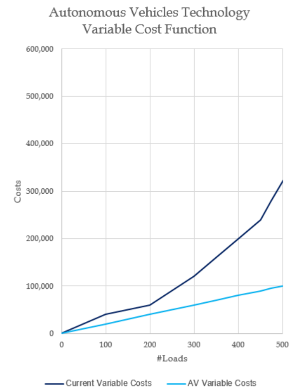


Figure 21. AV Variable Cost Function

6.4. The AV Total Cost Function. The total cost is the sum of the fixed cost and the variable cost. Due to a higher capital investment, the AV total cost would be initially higher. But as the load increases, the productivity improvement kicks in and the AV technology will have a cost advantage.

Loads	Current Total Costs	AV Total Costs
0	90,000	150,000
100	130,000	170,000
200	170,000	190,000
300	210,000	210,000
350	250,000	220,000
400	290,000	230,000
450	330,000	240,000
475	370,000	245,000
500	410,000	250,000
525	450,000	255,000

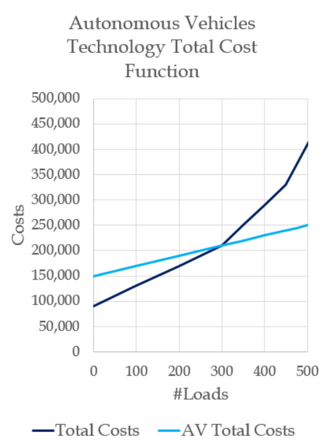


Figure 22. AV Total Cost Function

6.5. The AV Marginal Cost Function. The marginal cost is the increase in the total cost from a one-unit increase in output. With AV technology, a driver can deliver more loads. Thus the AV technology reduces marginal costs. (The capacity constraint of the current technology is much tighter than that of AV.)

Loads	Currnet Marginal Costs	AV Marginal Costs
0	NA	NA
100	400	200
200	400	200
300	400	200
350	800	200
400	800	200
450	800	200
475	1,600	200
500	1,600	200
525	1,600	200

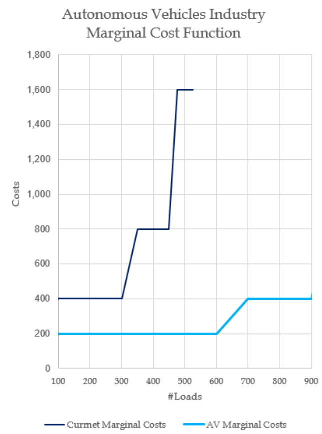


Figure 23. AV Marginal Cost Function

6.6. The AV Average Fixed Cost Function and the AV Average Variable Cost Function. The average fixed cost is the fixed cost per unit of output. Due to higher capital investment, AV would have a higher AFC. The average variable cost is the variable cost per unit. Due to higher driver productivity, AV has lower average variable costs.

Loads	Average Fixed Costs	AV Average Fixed Costs
0	0	0
100	900	1500
200	450	750
300	300	500
350	257	429
400	225	375
450	200	333
475	189	316
500	180	300
525	171	286

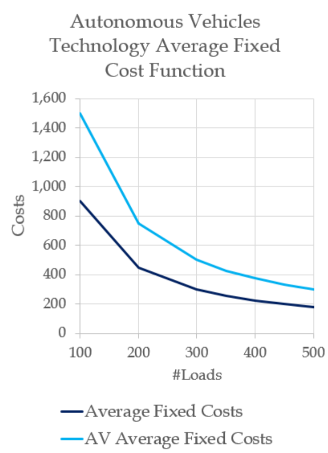


Figure 24. AV Average Fixed Cost Function

Loads	Current Average Variable Costs	AV Average Variable Costs
0	NA	NA
100	400	200
200	400	200
300	400	200
350	457	200
400	500	200
450	533	200
475	589	200
500	640	200
525	686	200

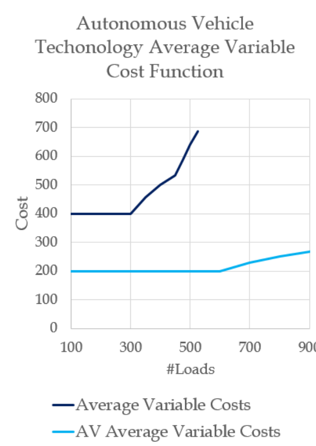


Figure 25. AV Average Variable Cost Function

6.7 The AV Average Total Cost Function. AV technology would have a higher ATC initially due to capital investment in AV technology. AV technology will lead to a lower ATC. Thus AV firms will enter the market over traditional firms.

Loads	ATC	AV-ATC
0	0	0
100	1300	1700
200	850	950
300	700	700
350	714	629
400	725	575
450	733	533
475	779	516
500	820	500
525	857	486
600		450
700		443
800		438
900		433
950		453
1000		470
1050		486

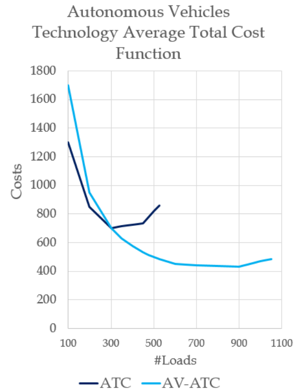


Figure 26. AV Average Total Cost Function

7. Long-Run Industry Equilibrium With AV

We can now study the long-run market equilibrium where no firm in the industry wants to leave and no potential firm wants to enter after the entry of AV trucking firms. Every firm's profit is zero and the price is equal to the minimum average total cost.

7.1. The AV Firm Supply Functions. AV technology will allow the driver to deliver more loads. In equilibrium the firm can deliver more loads with lower prices.

Loads	AV-ATC	AV MC	AV Supply
0	0	0	0
100	1700	200	433
200	950	200	433
300	700	200	433
350	629	200	433
400	575	200	433
450	533	200	433
475	516	200	433
500	500	200	433
525	486	200	433
600	450	200	433
700	443	400	433
800	438	400	433
900	433	400	433
950	453	800	800
1000	470	800	800
1050	486	800	800

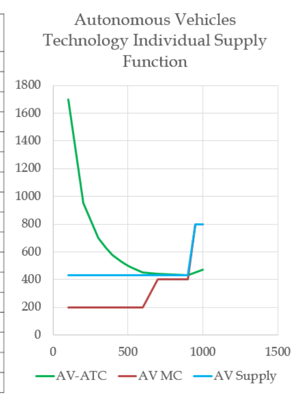


Figure 27. AV Individual Supply Function

Loads	Supply	AV Supply
0		
100	700	433
200	700	433
300	700	433
350	800	433
400	800	433
450	800	433
475	3200	433
500	3200	433
525		433
600		433
700		433
800		433
900		433
950		800
1000		800

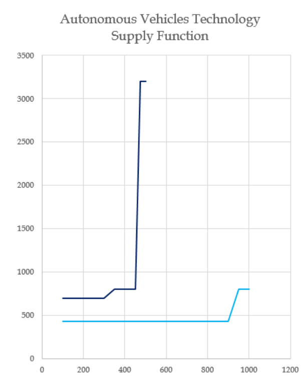
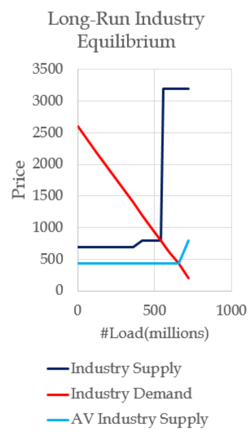


Figure 28. Comparison

7.2. Long-Run Market Equilibrium Prices. From the zero profit condition, the AV equilibrium price has to be \$433 (previously \$800) and each firm supplies 900 loads (previously

450 loads) per year. Thus, an AV technology firm will be able to supply more services but their price will be lower. From the industry demand function, the demand is about 660M, up from 540M in the current equilibrium. That is, AV reduces the load rate by 45%, increases the load by 22%, and reduces the number of firms by 40%.

Loads	Industry Demand	Industry Supply	AV Industry Supply
0	2600	700	433
120	2200	700	433
240	1800	700	433
360	1400	700	433
420	1200	800	433
480	1000	800	433
540	800	800	433
555	750	3200	433
570	700	3200	433
585	650	3200	433
600	600	3200	433
660	433	3200	433
720	200	3200	800



	Current	AV
Load Rate	800	443
#Loads	540M	660M
CS	486M	714B
#Firms	1.2M	0.73M
#Employees	7.2M	4.4M

Figure 29. Long-Run Equilibrium

7.3. AV Consumer Surplus, Producer Surplus, and Social Surplus. Consumers will benefit from the AV technology because AV lowers costs. AV Consumer Surplus=(1/2)*($2600-$433)*660M= $714B, a significant increase from the current consumer surplus $486B For the producer surplus, in the long-run equilibrium, the firms will earn zero profits. Thus AV producer surplus is 0. The AV Social Surplus is $714B, again a significant increase from the previous social surplus $531B.

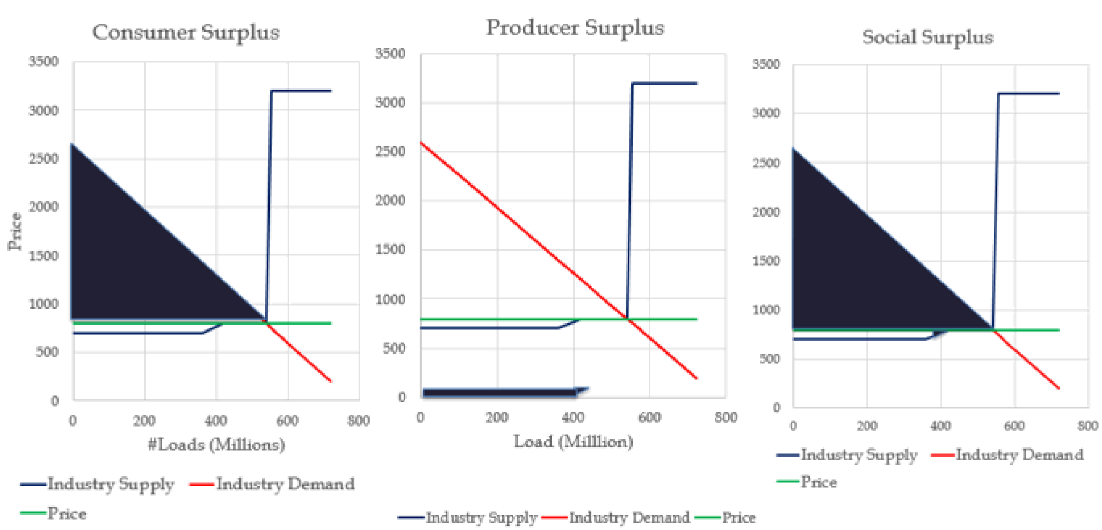


Figure 30. Consumer Surplus, Producer Surplus, and Social Surplus

7.4. Industry Employment with AV Technology. In the long-run equilibrium with the AV technology, each firm will employ 6 drivers and there are 733,000 firms. Thus the total industry employee is 733,000*6=4.4M. Thus the AV technology will lead to 7.2M-4.4M=2.8M loss of employment. The result is consistent with the CEA estimate of 2.2 to 3.1M jobs.(The Executive Office of the President (2016))

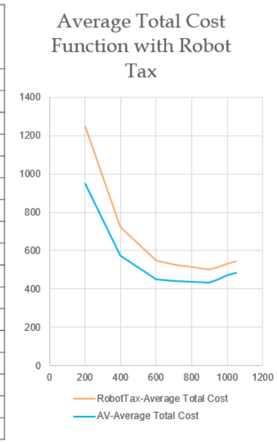
8. Policy Analysis

We have seen that the AV technology can have significant impacts on the labor market. We consider four policy options: robot tax, Universal Basic Income (UBI), subsidy for the further development of AV technology, and new businesses that enhances transportation demand.

8.1. Robot Tax. Robot tax implies that owners should pay taxes for employing a robot instead of workers. New York mayor Bill de Blasio proposed a law that when a company introduces labor-saving automation, it would have to pay the federal government five years' worth of payroll taxes for each worker that the innovation displaces. What will be the effect of such robot tax on the industry?

Assume that there will be 100% robot tax to the AV manufacturer and the manufacturer shifts 100% of taxes to the AV price. AV introduction now costs 40K instead of 20K. But it will not affect the marginal cost. Thus the firm average total cost will shift upward. With the robot tax, the minimum ATC is $500. Thus this will be a new equilibrium price. From the demand curve, the number of loads will be 636M. Since each firm will deliver 900 loads per year, it will mean that there will be 0.71M firms. Thus the robot tax leads to higher load rates, lower CS, lower # of firms, and lower employment. Thus the robot tax lowers the adoption of AV and leads to distortion.

Loads	AV-ATC	Robet Tax-ATC
0	0	0
100	1700	2300
200	950	1250
300	700	900
350	629	800
400	575	725
450	533	667
475	516	642
500	500	620
525	486	600
600	450	550
700	443	529
800	438	513
900	433	500
950	453	516
1000	470	530
1050	486	543

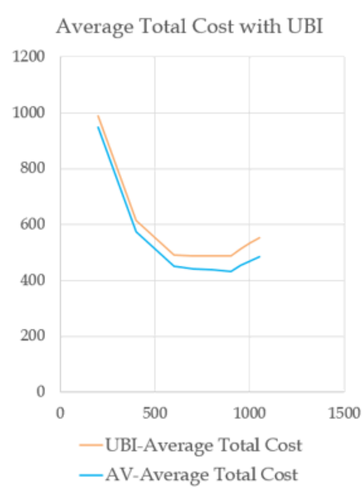


	Current	AV	Robot Tax
Load Rate	800	443	500
#Loads	540M	660M	636M
CS	486M	714B	668M
#Firms	1.2M	0.73M	0.71M
#Employees	7.2M	4.4M	4.2M

Figure 31. Effect of Robot Tax

8.2. Universal Basic Income. Universal basic income (UBI) is that everyone will receive a regular unconditional amount as a social safety net. A research found that "the results provide fairly clear evidence to policymakers that unconditional cash transfer programs in developed countries will likely reduce aggregate labor supply by a meaningful amount."[33] Consider a scenario that UBI increases the wage 20% from 40K to 48K. With the robot tax, the minimum ATC is $487. From the demand curve, the number of loads will be 640M. Since each firm will deliver 900 loads per year, there will be 0.71M firms. Thus UBI leads to lower AV adoption, higher rates, lower loads, lower CS, lower # of firms. and lower employment.

Loads	AV-ATC	UBI-ATC
0	0	0
100	1700	1740
200	950	990
300	700	740
350	629	669
400	575	615
450	533	573
475	516	556
500	500	540
525	486	526
600	450	490
700	443	489
800	438	488
900	433	487
950	453	512
1000	470	534
1050	486	554



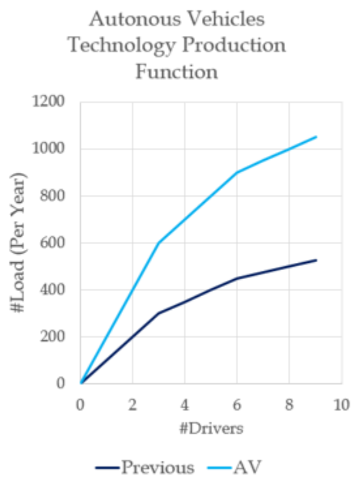
	Current	AV	AV+UBI
Load Rate	800	443	487
#Loads	540M	660M	640M
CS	486M	714B	677B
#Firms	1.2M	0.73M	0.71M
#Employees	7.2M	4.4M	4.3M

Figure 32. Effect of Universal Basic Income

[33] http://voxeu.org/article/labour-supply-responses-lottery-winners

8.3. Subsidy for the Development of AV. The Idea is to provide a subsidy to increase a driver productivity with AV technology. Suppose that AV subsidy increases the driver productivity by 50%. We find that AV subsidy leads to lower rate, higher #load, and higher CS. There will be new work but lower #firms and #employees existing firms will take all the new work. Thus, the effect of mere productivity improvement is limited without new direct demand creation.

Driver	Previous-Output	AV Output
0	0	0
1	100	200
2	200	400
3	300	600
4	350	700
5	400	800
6	450	900
7	475	950
8	500	1000
9	525	1050



	Current	AV	AV+AV Subsidy
Load Rate	$800	$443	$361
#Loads	540M	660M	678M
CS	486B	714B	759B
#Firms	1.2M	0.73M	0.63M
#Employ ees	7.2M	4.4M	3.8M

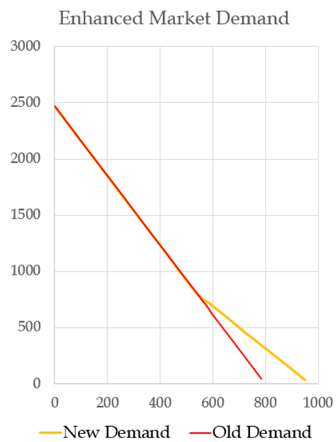
Figure 33. Effect of Subsidy for AV Development

8.4. MaasS: "Mobility-as-a-Service". As we have seen, the main obstacle for job creation is inelastic demand for transportation service that does not increase demand even with lower rates. Thus we now consider the effect of MaasS ("Mobility-as-a-Service"), entrepreneurship to enhance demand for transportation service using AV. For example, with lower cost by AV, consumers could prefer ride sharing with autonomous vehicles rather than driving by themselves. Intel wrote "self-driving cars are poised to open up a whole new economic chapter in what Intel and research firm Strategy Analytics are calling the Passenger Economy, valued at $7 trillion in revenue by 2050."[34]

To consider this effect, suppose that the transportation demand elasticity below the current price $800 is now -0.8. That is, there are higher demand for transportation service

[34] https://newsroom.intel.com/news-releases/intel-predicts-autonomous-driving-will-spur-new-passenger-economy-worth-7-trillion/

due to new business of ride sharing services. This demand enhancement leads to a lower load rate, higher loads, higher CS, more firms, and more employment because displaced truck drivers now work for new ridesharing services. Creating a new business (“new tasks” according to Acemoglu and Restrepo (2018a) and Autor (2019)) is the best policy to deal with the job loss due to AV.



	Current	AV	AV+MaaS
Load Rate	800	443	443
#Loads	540M	660M	678M
CS	486M	714B	740B
#Firms	1.2M	0.73M	0.81M
#Employees	7.2M	4.4M	4.9M

Figure 34. Effect of New Business Creation

9. Conclusion

Producer theory and perfect competition are some of the most difficult topics to teach in Introductory Economics. The crucial novelty of the paper is a new teaching material to teach these topics using an example of trucking industry and autonomous vehicles technology. The material complements the current textbooks by emphasizing the applications according to Siegfried et al. (1991). In other words, the contribution is that this paper is the first paper in economic education that applies a case/project-based approach to improve teaching of producer theory and perfect competition. Hopefully this paper will lead to further development of case/project-based approaches in economics that benefit instructors and students.

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