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Macroeconomic Impacts of Automated Long-Haul Trucking

October 24, 2025

NBER

Economics of Transportation in the 21st Century

2025 Context

Macroeconomic Impacts of Automated Driving Systems in Long-Haul Trucking (2021)

- With Robert Waschik of Centre of Policy Studies (CoPS) at Victoria Univ (Melbourne, Australia)
- Research conducted in 2019/2020
  https://rosap.ntl.bts.gov/view/dot/54596
- Understanding of the technology and industry is now 5-6 years old
- Some data is even older

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While contributing to the Report to Congress, notice that were several analyses focusing on potential job losses, but not much looking at the positive economic impacts.

Research Question

Existing literature (*as of 2019*) focused on potential job *losses* resulting from automation of driving. However, driving automation would *increase* productivity for the overall economy.

We focus on L4-L5, where driver can be removed from vehicle

What are the expected macroeconomic impacts from L4-L5 automation of long-haul trucking in the United States? In terms of GDP, total employment, wages, and welfare.

Given that long-haul trucking has a relatively high occupational turnover rate, would one expect lay-offs in the trucking industry due to automation?

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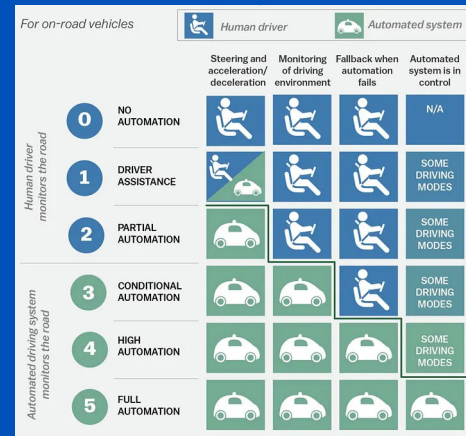
SAE J3016 Levels of Automation (Photo from Vox)

We mean automation where there is no need for a human driver on the vehicle. That is where we expect to see labor cost savings.

Agenda

Literature Review

Key Modeling Assumptions

Results

Recent Developments

You may find this an interesting example of collaboration between USDOT and University researchers. And share some data sources, you might not be aware of.

Literature Review

# Report to Congress: Potential Workforce Impacts

Driving Automation Systems in Long-Haul Trucking and Bus Transit: Preliminary Analysis of Potential Workforce Impacts - Report to Congress, January 2021

https://rosap.ntl.bts.gov/view/dot/54595

Noticed several analyses of potential job loses in trucking, but not much looking at potential for economy-wide benefits. Trucking plays a central part in the US economy and productivity improvements would be expected to ripple through.

Note: Repository & Open Science Access Portal (ROSAP) of the National Transportation Library is a great resource! Where all USDOT reports are archived.

https://rosap.ntl.bts.gov/

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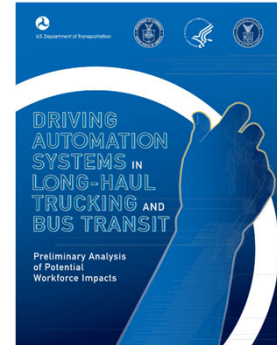
Focus on Long-Haul

Gittleman and Monaco, *Truck Driving Jobs: Are They Headed for Rapid Elimination*
- State automation does not "necessarily imply the wholesale elimination of the truck driver labor market."
- Identify long-haul trucking (particularly the for-hire segment) as the driving job most likely to feel the initial impacts of higher-level automation:
  - Long-haul requires long periods of uninterrupted driving
  - Short-haul requires many other duties

Viscelli, *Driverless? Autonomous Trucks and the Future of the American Trucker*
- Also argues that long-haul truck driving jobs are most vulnerable to displacement from automation.
- Suggests automating long-haul trucking will also create short-haul, local delivery jobs, leading to an uncertain net jobs impact.
- Concludes there are only a few hundred thousand trucking jobs in danger of elimination initially, not millions

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USAGE-Hwy

USAGE-Hwy

- Computable general equilibrium (CGE) model of the US economy
- Developed by Centre of Policy Studies (CoPS) of Victoria University
- USAGE was originally developed for USITC
- USAGE-Hwy was sponsored by Federal Highway Administration (FHWA) in collaboration with USDOT Volpe Center
- USAGE-Hwy has been customized to provide detail on transportation related industries (trucking, rail, air, water) while aggregating other industries
- Covers both "for hire" and "in-house" sectors of transportation industries
  - Depiction of "in-house" is from BTS Transportation Satellite Accounts
- Goal of model is to provide policymakers with more familiar measures of impacts from transportation investments: GDP, wages, employment, etc.

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USAGE-Hwy

- CGE models:
  - Supply and demand for each commodity is the outcome of optimizing behavior of economic agents
  - Industries choose labor, capital, and land to minimize costs subject to technology constraints
  - Households choose bundle of goods using relative prices and income
  - Capital creators assemble, in a cost minimizing manner, units of industry specific-capital for each industry
  - Investment is allocated across industries to maximize rates of return
  - Governments operate with fiscal framework
  - Exports and Imports are accounted for using relative prices and resource constraints
  - <u>Closed system</u>: expansion in one part of the economy "crowds out" activity elsewhere (unlike typical Input-Output models)

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Depicting Impacts of Long-Haul Trucking Automation in USAGE-Hwy

- Productivity shock to trucking industry from:
    - Labor cost savings
    - Fuel cost savings
    - Capital cost savings
- Safety improvements
- Accounting for upfront costs of acquiring technology

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Modeling Assumptions

Size of Trucking Industry (2016)

NAICS Industry	Intermediate inputs	Compensation of employees	Gross operating surplus	Taxes	Value of industry output	Value of commodity sales
484 For-Hire Truck transportation	156,224	90,051	52,920	8,040	307,235	320,016
47OT.484 In-House Truck Transportation	175,978	86,338	50,738	0	313,054	313,054

Source: Bureau Economic Analysis (BEA) and Bureau of Transportation Statistics (BTS) Transportation Satellite Accounts

Trucking (In-House and For-Hire) is 2.1% of GDP in 2017

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This detailed industry level data from 2016 is factored to represent 2019 totals.

Number of Truck Drivers

For Hire: NAICS 48400

(Truck Transportation)

- 880,710 heavy tractor-trailer drivers* employed in NAICS 48400

- 51.52% long-haul from Gittleman and Monaco using 2002 Vehicle Inventory and Use Survey (VIUS)

- 453,773 at-risk long-haul tractor-trailer drivers

In-House: All other NAICS codes

- 919,600 heavy tractor-trailer drivers (remainder of occupation code that are not in NAICS 48400)

- 8.13% long-haul from Gittleman and Monaco using 2002 Vehicle Inventory and Use Survey (VIUS)

- 74,718 at-risk long-haul tractor-trailer drivers

15   *Standard Occupational Classification 53-3032 "Heavy and Tractor-Trailer Truck Drivers"*

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This detailed industry level data from 2016 is factored to represent 2019 totals. 140 million total employment in 2016
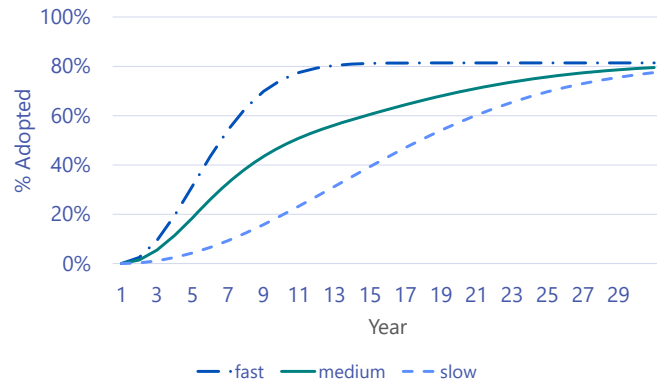
Key Technology Adoption

Adoption (for <u>new</u> truck purchases) after 10 years:

- Fast: 75%
- Medium: 48%
- Slow: 19%

Maximum Automation Potential: 81.4%

(McKinsey Global Institute)

Year 1 refers to the first year technology is commercially available (not specified)

% Adopted (y-axis: 0% to 100%)

Year (x-axis: 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29)

Legend: — · fast   — medium   – – slow

Technology Adoption Rates

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Not all can be automated: border crossings, high value commodities, hazmat

Cost of Adoption (For-Hire)

- Initial investment assumed to be $100,000 (Chottani et al. 2018:4)

- Total investment increases as the industry grows and the adoption rate accelerates

- Total investment declines around year 9 in the fast scenario as adoption rates slow down and cost of technology declines over time (to a minimum of 50% starting price - $50,000)

- Total investment increases again because this is a recurring investment: early adopting trucks will need to be replaced in later years (assumed truck useful life of 9 years).

- In the slow adoption scenario, the uptick due to replacing early adopters occurs later
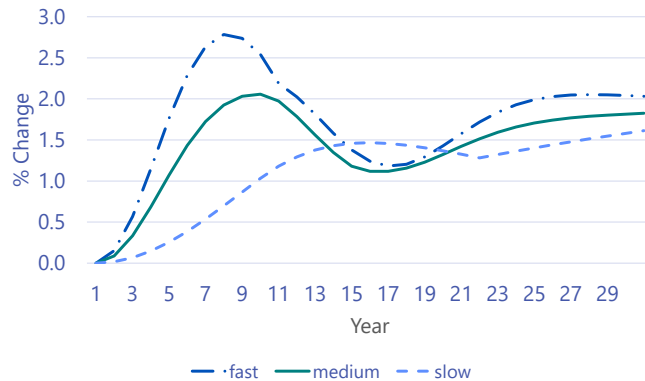
Cost of adopting automation in For-Hire (% Relative to Baseline)

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Labor-Saving Technical Change

- Average wages of $46,230 multiplied by inferred % of drivers associated with technology adoption
  - The 20% floor reflects the ceiling of 81.4% as maximum adoption, factored by 52% that is long haul

Note that labor-saving technical change is measured here as the change in the amount of labor required to produce one unit of output holding other inputs constant. Thus, the productivity shocks are negative because less labor is required to produce the same level of output.
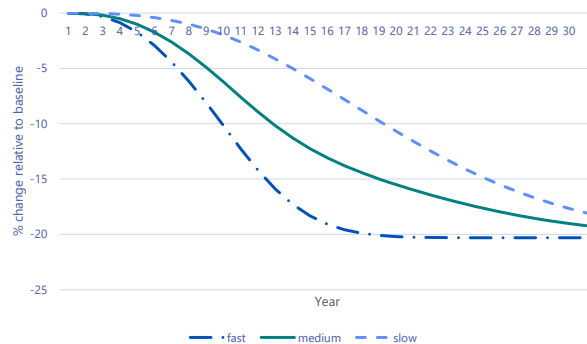

Labor saving technical change in For-Hire (relative to baseline)

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Fuel Saving (For-Hire)

Expect fuel savings due to:

- Optimizing throttle controls
- Maintaining lower speeds than humans choose

Fuel savings assumed to be 5.22% as the central case from analysis of the fuel savings from mandated speed regulators on trucks (FMCSA)

Fuel saving in For-Hire (% relative to baseline)

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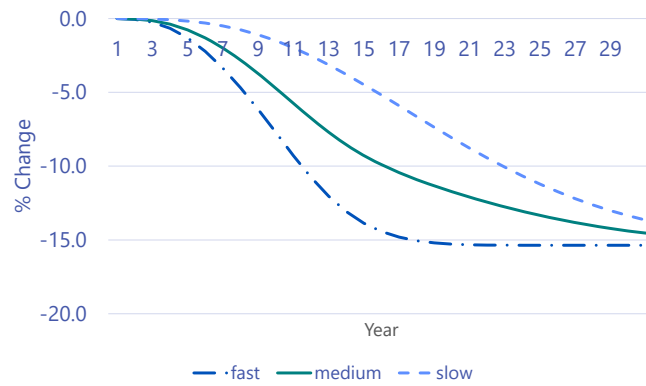**Volpe Center**
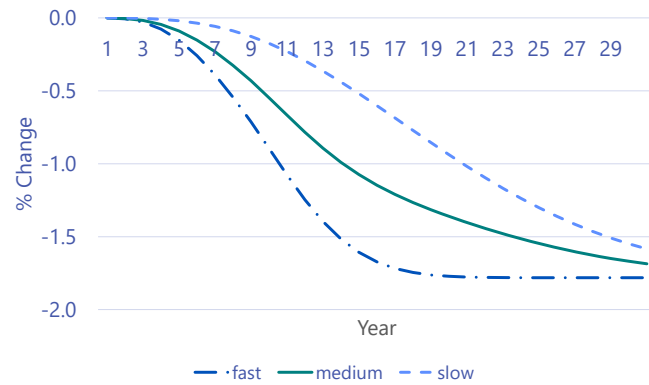
Capital Savings (For-Hire)

Expect more efficient deployment of capital:

- Truck can run 24 hours a day

Assumed to be 45% reduction in total cost of ownership

(McKinsey Global Institute)

Capital saving in For-Hire (% relative to baseline)

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Fatalities and Injuries

- Focus on heavy combination trucks (tractor-trailers)

- Single vehicle crashes and fatalities where driver is at fault (conservative)

- Pro-rate for long-haul

- 155 fatalities and 17,000 injuries in total per year in 2017 (Large Truck and Bus Crash Facts, FMCSA)

- # of fatalities and injuries grows over time with truck VMT

- Welfare enhancement valued at

  - $9.6 million USDOT Value of Statistical Life (VSL)
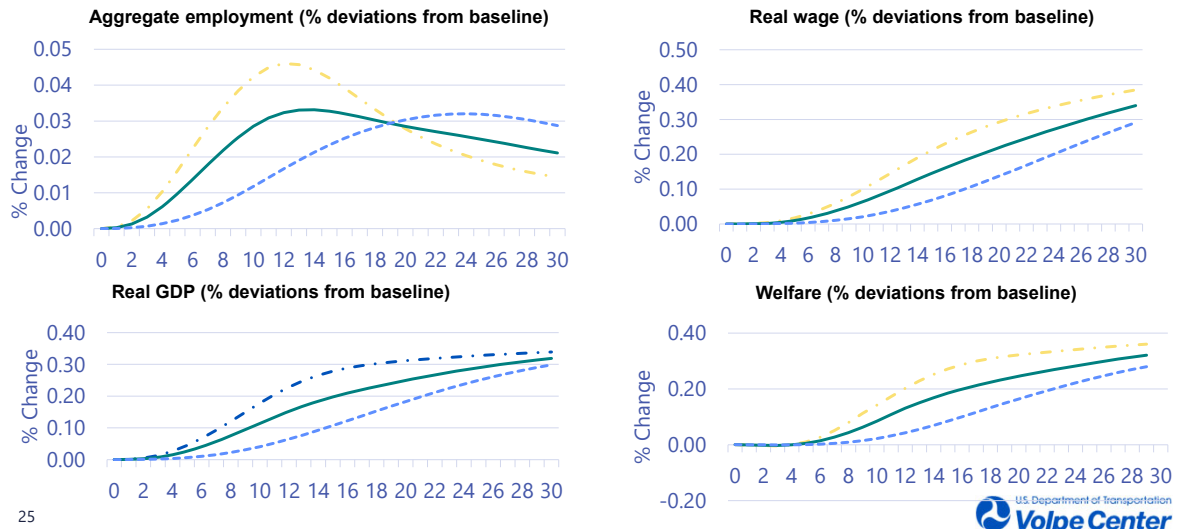
  - $32,800 medical costs per injury

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Reduction in fatalities (# relative to baseline)

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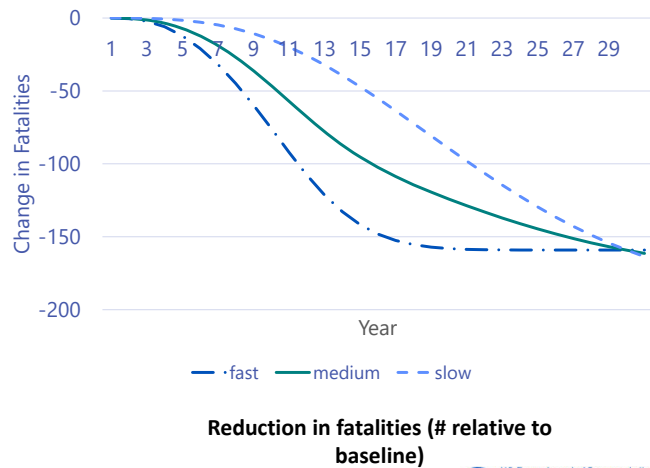
Results

Caveat

- Long-haul trucking *in isolation*
  - *Not countervailing increase in short haul trucking for "last-mile" delivery*

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Macroeconomic Indicators

This analysis finds that SAE Level 4 and Level 5 automation of the long-haul trucking industry would do the following:

- Produce welfare increases ranging from $35 per person in the U.S. per year under the slow adoption scenario to $69 per person per year under the fast adoption scenario.

- Raise average annual earnings for across all U.S. workers by $203 per worker per year under the slow scenario and $267 per worker per year under the fast scenario.

- Increase total U.S. employment by 26,400 to 35,100 jobs per year on average during the analysis period, despite decreases in employment for long-haul truck drivers.

- Increase GDP by at least 0.3 percent by year 30 of the analysis period. (Note: Trucking accounts for 2.1% of GDP)

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Macroeconomic Indicators

Aggregate employment (% deviations from baseline)

Real wage (% deviations from baseline)

Real GDP (% deviations from baseline)

Welfare (% deviations from baseline)

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Fast:

Net Hiring of Long-Haul Truckers

- Assuming current turnover rate (10.5%), employment levels in the long-haul trucking sector will necessarily fall but **will not** force lay-offs in the slow and medium adoption scenarios.

- Lay-offs observed only under the fast adoption scenario and only occur during a 5-year period.
  - Max lay-offs in single year: 11,000 (1.7 percent of the long-haul driver workforce)

Net hiring of Long-haul Truckers

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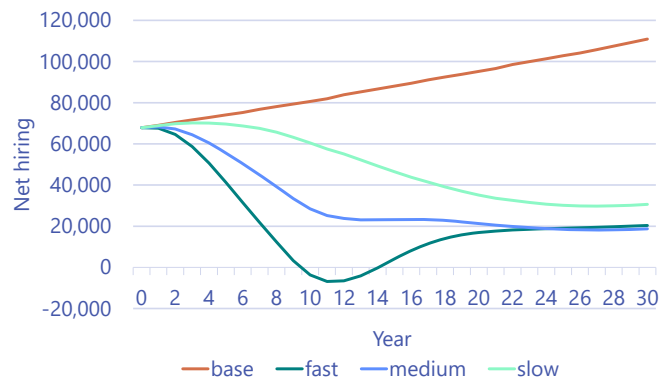
Recent Developments

Technology Milestones: Driverless Trucks (L4)
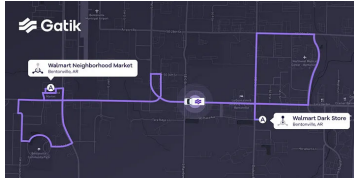
Credit: Gatik.ai

Nov. 2021: Gatik/Walmart "fully autonomous" 7.4 mile route in Bentonville, AR

Credit: Kodiak.ai

Dec. 2024: Kodiak+Roush/Atlas Energy Solutions: Deliver frac sand across Permian Basin on private roads without a safety driver

Credit: Aurora

May 2025: Aurora (for Uber Freight and Hirschbach Motor Lines) operates driverless trucks between Dallas and Houston

Costs of LiDAR systems in passenger cars prices have fallen from $75,000 in 2015 to as low as $500 today (FleetOwner)
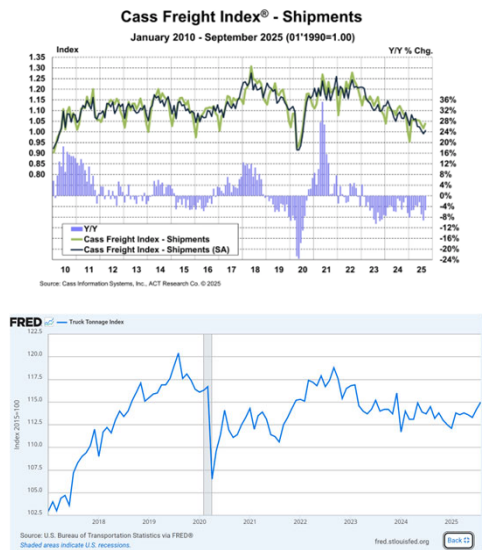
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Source: Volpe colleague Joshua Cregger

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Lidar costs for autonomous trucks are dropping fast | FleetOwner
https://www.fleetowner.com/technology/article/55316670/lidar-costs-for-autonomous-trucks-are-dropping-fast

Great Freight Recession

The Cass shipments index is a measure of the number of intra-continental freight shipments across North America, for everything from raw materials to finished goods. All domestic modes are included, with truckload moves accounting for more than 50% of shipments and LTL about 25%.

https://www.truckingdive.com/news/fmcsa-q3-2025-capacity-data-operating-authority/801876/

DIVE BRIEF
Trucking market exits outweigh entrants in Q3, suggesting possible tightening
September data from the FMCSA showed a significant drop in new carriers entering the market, but a calendar quirk might explain the dip.
Published Oct. 9, 2025

Final Thoughts

- What does "The Great Freight Recession" mean for eventual automation of the long-haul trucking sector?

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