The Influence of Autonomous Vehicles on State Tax Revenue

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Executive summary

Autonomous vehicles (AVs) are one of the foremost areas where artificial intelligence will transform mobility and lifestyles as they offer lower cost, safer mobility and reduced emissions. Transitions in vehicle-related employment and taxes will be important byproducts of changes associated with AVs. This paper focuses on how traditional state tax bases/revenue will likely be reduced but also discusses how employment will be disrupted.

Widely different expectations exist on when and how AVs will be integrated into the economy and everyday life. Key issues include what technology will be used in AVs, how rapidly AVs will be adopted, how many AVs will be necessary to replace the existing stock of internal combustion engine vehicles, and how vehicle miles traveled (VMT) will be affected. This paper presumes that AVs will convert the United States to a regime of electric, shared, fleet-owned vehicles that will initially begin sometime during the 2020s and be achieved through a process that continues over the next three to four decades.

Employment effects are divided into vehicle manufacturing, vehicle support, and motor vehicle-using occupations that together constitute nearly one-sixth of U.S. employment. AVs will change the tasks performed by workers in many of these areas and open the potential for large labor market disruptions. Vehicle manufacturing represents about 0.7 percent of total U.S. employment and includes vehicle assembly and parts manufacturing, with the latter accounting for over 60 percent of manufacturing employment. Shared, fleet-owned AVs will require fewer vehicles compared with today, although VMT will probably rise and moderate the reduction in the number of vehicles. Manufacturing employment will be affected by reductions in the number of vehicles and movement to electric AVs that are composed of relatively more software versus hardware compared with traditional vehicles. Both effects can lower employment and potentially alter where jobs are located.

Vehicle support refers to employment in industries such as vehicle repair, sales, financing, insurance, and so forth, and represents nearly 4 percent of employment. Vehicle-using occupations include motor vehicle operators and other on-the-job drivers, and account for 11.5 percent of employment. Truck and taxi drivers are obvious examples, but other occupations include first responders, delivery workers, and many others. The expected regime of AVs will change the tasks performed in many of these industries, which may increase or decrease the number of workers.

Taxes both directly imposed on transportation and indirectly linked with transportation-related industries will be affected. Direct taxes include those on fuel, number of vehicles, number of drivers, sales of vehicles, purchase of support services, and others. Direct taxes, such as gasoline taxes and sales taxes on the purchase of vehicles, are generally imposed at the destination of transportation services. Indirect taxes are those linked to production and employment in transportation-related industries. Indirect taxes include the personal income, sales, and corporate income taxes associated with earnings and production in the three employment categories described above. Indirect taxes are levied at both the origin and destination of transportation equipment and services. This paper simulates the effects on direct taxes arising from movement to electric, fleet-owned AVs for six states: California, New Hampshire, New York, Ohio, Tennessee and Texas. No attempt is made to estimate the effects on indirect taxes.

Revenue losses vary depending on specific characteristics of AVs and state tax structures. The overall inelasticity of transportation revenues will cause declines in the relative contribution of transportation revenues even prior to AVs. Each feature of AVs—electric, shared, and driverless—causes revenue losses given the tax structures that states have developed. Reductions ranging from 2 percent to more than 9 percent of total revenue and representing more than 60 percent of transportation revenues are estimated in cases where the number of vehicles is significantly reduced. The speed of adoption does not change the ultimate revenue losses, although it does impact how rapidly states feel them. States are affected very differently depending on the role that transportation revenue plays in their overall tax structure. For example, fuel tax revenue (gasoline and motor fuel taxes) will erode much more than vehicle revenue (sales taxes on vehicle sales, registrations, etc.) because the former are entirely eliminated by electric vehicles, so states depending more on the former experience larger declines. Electric vehicle taxes offset some reductions in other taxes.

States should consider reforming their tax systems now before the vested interests develop around the industry and impede development of an efficient structure. Adoption of a reformed tax system will allow producers and consumers to make more efficient choices and permit revenue losses to be moderated. Early development of regulations and taxes will assist the U.S. in becoming a leader in the AV industry. Further, taxpayers will be affected unequally without reform because those moving to AVs first will see their tax burdens fall while those relying on traditional transportation modes will continue to pay. Rural residents, for example, may adopt AVs more slowly than urban residents and, as a result, pay relatively higher taxes without structural changes.

Options for reforming direct taxes on mobility include expanding the sales tax to all forms of mobility (at the general sales tax rate or a selected rate), levying VMT taxes, and imposing congestion charges. These options are not mutually exclusive, so states could adopt a combination, which may be a good direction because the current regime of self-driven, fossil-fuel-powered vehicles is likely to operate next to the new regime of shared, electric, AV vehicles at least for several decades.

Introduction

Autonomous vehicles (AVs) will transform transportation and mobility around the world by enhancing accessibility and safety and ultimately reducing congestion and costs. Several forward-looking papers anticipate the impact of AVs with wide agreement that they will be transformational. However, many particulars remain unclear, including exactly how AVs will be owned, how quickly they will be adopted, and many other specifics of how they will affect both lifestyles and the economy. This paper adds to this discussion in one key area—how AVs and the accompanying changes will affect state government tax revenue. Given the uncertainty about precisely how AVs will develop, the paper begins with a discussion of how AVs could affect the economy, which provides a framework for thinking about the tax implications.

More broadly, AVs should be considered as another example of how new technologies and artificial intelligence (AI) are altering the economy and taxes, rather than as a single event. For example, AI is impacting the supply/value chain for many businesses, which can effect structural economic change and consequently affect tax revenue. Robotics, business analytics, and transportation enhancements are allowing the supply chain to shorten and potentially reducing employment as capital replaces labor. Still, AVs are likely to be one of the foremost places where AI alters lifestyles forever. And, most important for this paper, much of state and local governments' tax systems are built around the current transportation system, so the tax implications could be particularly important. Therefore, while AVs may not be unique from an economic impact perspective, they may be singularly important for state and local governments.

This paper focuses on the direct effects of AVs on state tax revenue, but also discusses indirect effects in cases where they are most likely to arise. Direct effects on the tax system refer to the set of taxes and revenue sources focused specifically on vehicles and transportation, which includes sales taxes on vehicle purchases, registration fees and licenses, fuel taxes, tolls, and so forth. These taxes and charges[1] are mostly determined by where vehicles are *sold* and *used*. For example, the sales tax is generally paid where the vehicle is registered and fuel taxes where vehicles are used.

Virtually all other taxes could be affected indirectly. For example, individual and corporate income taxes could be affected in states where workers and owners in vehicle production industries are located. Sales taxes on business inputs could also be reduced. Much of the indirect effect on taxes arises where AVs are *produced*, but there are also large implications for where vehicles are used. Indirect tax reductions may be transitory as one set of industries declines or closes (for example, manufacturers of mufflers) while another set expands (for example, battery manufacturers). Whole new industries that are not currently available or anticipated may develop

[1] For simplicity, the text generally refers to the revenue sources as taxes, but many may be better regarded as fees or charges.

around AVs, and these could expand tax revenue and offset some losses. Thus, indirect tax effects may ultimately be on the distribution of tax revenue across states and the timing of the revenue more than the overall revenue collected. In any event, large disruptions should be expected.

It is important to recognize that the effects described here are not because AVs harm the overall economy. AVs will improve the quality of life for many people and benefit the economy through lower costs, safer mobility, and reduced emissions. The effects described here arise from transitions in the economy and the specific structure of state tax systems, not because there are mostly underlying negative effects. Lower costs free up resources that people and businesses can use for other purposes, and the ability for riders to use their time in other ways improves the quality of life as consumer surplus grows in many related industries.

Several areas of the economy that are likely to be impacted by AVs are identified to frame the prospective economic and fiscal impacts. Precisely estimating the impacts is currently infeasible given the overall ~~forecasting~~ uncertainty and large number of unknown variables. Rather, the approach in this paper is to describe the risks to state governments by providing potential scenarios and evaluating the impacts of AVs under each one. The extent and pace of AVs' penetration into personal and business mobility will determine the breadth of economic and fiscal effects. Wide disagreement exists on both the expected long-term market share of AVs and the rate at which the economy converges to a steady state. AVs could gain significant market share rather quickly, but heterogeneous rates of adoption can be expected throughout the country, and it is certainly possible that people will fail to adopt AVs rapidly or that governments will be slow in establishing necessary regulations (or fail to extend regulations) in an ultimately fruitless quest to protect existing industries and workers.

The section following this introduction discusses the expected characteristics of AVs and how they could affect employment. The next section addresses direct and indirect ways that transition to AVs will impact tax revenue based on current state tax structures. The third section contains six state case studies to provide perspective on the quantitative effects on individual state tax revenue. Finally, the report provides some policy recommendations for how states can restructure their tax systems to better accommodate the changing mobility throughout the U.S. and the world.

AVs and the economy

Five categories of autonomous vehicles[2] have been delineated, depending on the technical capabilities and the role of the driver, including[3]:

- Category 1: some steering and acceleration/deceleration technologies that require the driver to be fully engaged.
- Category 2: partial automation as it expands the capabilities in Category 1, and requires the driver to be fully engaged.
- Category 3: Category 2 and monitoring of the driving environment. The driver is less engaged, but may be involved in difficult environments.
- Category 4: Category 3, but the vehicle handles difficult environments if the driver does not. Requires limited driver monitoring.
- Category 5: automates all systems and allows the driver to be optional.

This paper refers to categories 4 and 5 when discussing AVs.

Adoption of AVs

Vehicles are widely integrated into every facet of life and the economy, so widespread implications can be expected as the means of mobility evolve. The extent to which the economy changes and tax revenues are affected depends on the characteristics of AVs and their penetration into mobility, including:

- *Development of the key technologies*. Electric vehicle, battery and automation technologies are key aspects of AVs; their continued expansion and development can affect how quickly AVs become the norm. For example, battery costs fell 80 percent between 2010 and 2016 (Ratner, 2018). The importance of battery development diminishes if AVs are delivered through networks rather than private ownership because of the ability to rotate vehicles in the fleet. Some of the effects described here are lessened if internal combustion engines remain the predominant technology.
- *The pace of adoption*. The current U.S. vehicle stock includes approximately 278 million[4] light vehicles, and these will not be automatically or quickly replaced or eliminated by AVs. The rate of adoption depends on the willingness of users to substitute AVs for their current mode of transportation and development of the regulatory structure allowing the substitution. The public domain aspects of the neural net necessary for AVs make the regulatory structure important, but they could also slow its development.

[2] See Society of Automotive Engineers (2018).
[3] Most new cars include category 2 and 3 features with the potential capability to go to higher categories.
[4] Reported from an IHS Markit analysis, https://www.autonews.com/automakers-suppliers/average-age-vehicles-us-roads-hits-118-years

- *Ownership/mode of AVs*. AVs combined with smartphones, apps and related technologies provide a clear opportunity to deliver mobility through transportation networks with fleet ownership as part of the sharing economy. Although fleet ownership may be easily adopted by certain demographic groups, it may be a longer transition for others. Private/individual ownership or other forms of pooling could remain as well, at least in some cases. Consequences for current tax structures grow as the sharing economy plays a larger role.
- *Vehicle miles traveled (VMT).* AVs may allow expansion of mobility and not merely substitution for existing transportation modes and distances. The number of miles that people travel could be significantly increased as AVs ease mobility and lower cost.

These factors (and potentially others) will determine how many AVs are needed and the rate at which they replace person-driven vehicles. The key point is that the simulations below are built around the implications of moving from a regime of internal combustion engine, self-driven and self-owned vehicles to one of electric, autonomously driven, and pooled vehicles. Nonetheless, surveys suggest that many people are not currently ready to accept AVs. For example, J.D. Power and the National Association of Mutual Insurance Companies found that 15 percent of people said AVs will never exist and CNBC reporter Phil LeBeau observed that 42 percent of people indicated that they will never ride in an AV. However, current surveys are likely of little value for predicting penetration rates for a technology that most people have not experienced.

Standard & Poor's (2018) offers a range of penetration from a low scenario with only 2 percent of sales by 2030 to a high of 30 percent by 2030. Eric Meyhofer, CEO of Uber's advanced technology group, said that Uber will operate AVs without safety drivers in limited parts of five to six cities in 2020.[5] Many believe the adoption rate will be faster in China and Europe. For example, Made in China 2025 specifically targets AVs (S&P, 2018). International adoption could affect U.S. production and adoption. Indeed, implementation of AVs outside the country pressures the U.S. to hasten development and implementation of AVs so that the country doesn't fall behind in the technology, production, and usage of AVs and ultimately cede market share to other countries and companies.

A rapid increase in the willingness of users to adopt AVs is possible as riders see the ease, safety, and low cost associated with them. Mobility as a service, more broadly, offers the opportunity to link AVs with bicycles, scooters and other forms of transportation to create an efficient system of mobility for each type of need and to facilitate acceptance of AVs. Several demographic and geographical groups appear to be natural early adopters. Younger generations and urban dwellers, particularly in the largest cities, are inclined to be more open to the use of AVs. Even the elderly, children, and people with disabilities may move quickly in order to gain mobility.

[5] CNBC, "Squawk Box," June 12, 2019.

These groups, combined with expected greater initial acceptability outside the U.S., will provide models for broader adoption in the U.S.

Number of AVs

The number of AVs that will be built and sold each year, the future vehicle stock, and how vehicles are owned are essential determinants of the direct and indirect fiscal effects. Ownership decisions are important to the number of AVs produced and sold each year. AVs could be owned individually or in fleets as part of networks. And related, fleet vehicles could offer pooled or individual rides (and likely both). As mentioned above, movement to a new regime with autonomously driven, pooled vehicles that are owned and operated through fleets is a very possible outcome. In the long term, shared ownership and pooled travel will likely result in fewer new cars being produced. Even individual ownership will likely reduce the number of vehicles that are produced and the size of the U.S. vehicle stock; households will determine they need fewer vehicles because the same AV can take one person on a trip, return home to take a second person, and so forth.[6] Vehicles generally sit unused most of the time, and even at peak times of day, only about 12 percent of vehicles are in use (Clements and Kockelman, 2017).

Fleet ownership of AVs parallels the way in which Uber and Lyft networks operate today, but without drivers and with the capital owned by fleet companies. Uber is seeking to unbundle mobility, according to Dara Khosrowshahi, Uber CEO, and approaches mobility as a service.[7] The unbundling appears to work most effectively with fleet ownership and operation of vehicles, although unbundling is likely to develop first in more urbanized settings, with niche networks more likely in rural places. A key advantage of fleet ownership is that vehicle sharing could reduce the vehicle capital stock more than individual ownership because people can effectively share vehicles with others through apps and similar technologies. Fleet ownership is consistent with peoples' general need for mobility during limited periods of the day and therefore offers the potential to reduce transportation costs through vehicle sharing. Still, only 21 percent of people in large cities use ride sharing today (Clewlow and Mishra, 2017), and most have not reduced their ownership of vehicles yet.[8] As such, large behavioral transitions are needed for sharing to be the major form of mobility and to reduce the number of vehicles.[9]

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[6] Based on a 43 percent reduction in vehicles per household and 2.187 vehicles per household, this equals roughly 0.94 fewer privately owned vehicles per household. See https://tedb.ornl.gov/wp-content/uploads/2019/03/TEDB_37-2.pdf.

[7] Dara Khosrowshahi interview on CNBC "Squawk Box," May 10, 2019.

[8] Standard & Poor's (2018) reports a small decline in the share of households with a vehicle. Jim Edwards (Business Insider, March 3, 2019) noted that vehicle sales are already declining significantly in the European Union, and specifically in countries such as Britain and Turkey, and that car registrations are falling in the U.S. Although there are many causes of these changes, vehicle sharing is presumed to be an important factor.

[9] Keith Naughton and David Welch (Bloomberg Business, Feb. 28, 2019) note that many people in China have adopted ride-sharing rather than car ownership.

Companies will quickly develop effective ways to serve passengers as they pursue profits and grow market share. For example, networks of vehicles will be developed that meet specific rider needs based on rider demographics, and algorithms will be developed that anticipate need in different geographic areas and permit quick access to mobility. Ride pooling (with multiple people in the vehicle) is also likely to continue growing to reduce the costs for those desiring to use this service.

The benefits of shared vehicle use could be partially offset as fleet-owned vehicles are used more intensely during the day and require more rapid replacement. So, the vehicle miles traveled (VMT) combined with the life span of AVs (AVs may depreciate faster because of the greater use) and efficiency of the network determine how many vehicles are needed. For several reasons, average VMT per person is expected to rise with AVs. First, a set of underserved riders, such as children and people with disabilities, could find better mobility options and increase their VMT. Second, AVs make transportation easier (effectively reducing the marginal cost of time spent in traveling) for all riders because time in the vehicles can be safely used for purposes other than driving.[10] Improved comfort and lower transportation costs suggest that people will travel more, increasing the total VMT in the economy.[11] Empty miles as AVs travel to the next rider could also increase VMT. But, ride pooling and efficient transportation algorithms could reduce VMT, at least in some cases. "Mobility as a service"—which includes a variety of ways that mobility can be provided, such as shared bicycles or scooters—could also reduce VMT.

Simple arithmetic can illustrate effects on the number of vehicles. Taxis in large cities drive about 70,000 miles per year and have a life of nearly five to six years (Clements and Kockelman, 2017). This suggests a life of about 350,000-420,000 VMT, which is a reasonable assumption for fleet AVs.[12] The current light vehicle stock has a life of about 12 years and has an average life of about 180,000 VMT (more miles are driven in the early years relative to the later years for the current stock).[13] Thus, only a little more than 40 percent as many vehicles would be needed assuming full replacement of existing vehicles by AVs, the same total VMT per year, and vehicles driven their maximum miles. This should be increased by 20 to 25 percent to account for greater VMT per rider,[14] suggesting that about half as many AVs are required in the steady

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[10] A recent survey found that 59 percent of people between ages 22 and 37 would rather be using their driving time in more productive ways. Forty-five percent of these people regularly use ride sharing. See https://www.lincolninst.edu/publications/articles/driverless-ed.

[11] Savings in the VMT necessary to find a parking place will be one offsetting factor in total travel.

[12] AVs may have a much longer life if they are safer, and fewer are damaged or destroyed, and have relatively simple electric motors that could be replaced if necessary. As discussed below, software will provide relatively more of the value added and the software may be more easily updated than the hardware of current cars.

[13] See Davis, S.C., Williams, S.E., and Boundy, R.G. (2018).

[14] VMT has been growing about 0.7 percent annually. Standard & Poor's (2018) expects a 5 to 20 percent increase in VMT with a 50 percent penetration rate for AVs. Clements and Kockelman cite sources anticipating a 20 percent increase in VMT.

state U.S. light vehicle stock, and a number consistent with this must be produced/sold in the U.S. over time.

The effect of cost/price on mobility will impact VMT.[15] Mobility becomes cheaper if vehicle sharing lowers the transportation cost and AVs allow the marginal cost of time while riding to be reduced.[16] On the other hand, people may currently suffer from an illusion about the "true" cost of transportation as they recognize only out-of-pocket expenses such as gasoline, and fail to recognize other real costs such as vehicle depreciation and maintenance. Fleet owners will reflect the true marginal cost of mobility in the price, and recognition of the actual cost could reduce the willingness to ride, at least until people become comfortable with a system that prices per ride.[17] Fleet owners are also likely to use time-of-day pricing to limit the number of vehicles needed for mobility and to limit congestion costs (which raise the true cost to both fleet owners and riders). Oregon's optional VMT tax program has reduced VMT by 10 to 14 percent, evidencing how the pricing/tax structure can affect VMT (Ratner, 2018), although this is not a causal estimate. Riders' high sensitivity to road tolls and parking fees (see Litman, 2018) provide additional evidence that the pricing mechanism can limit VMT.

Mode shifting from transit vehicles (buses,[18] vans, etc.) could increase the VMT for AVs.[19] The required AV stock and annual production will be greater if ride sharing is significantly substituted for public transit, but little is known about the substitution, particularly in the near term. The BATIC Institute (2018) suggests a 9 percent reduction in local transit ridership nationally. Similarly, air transportation could be reduced as AVs become a good option for certain travel. The extent of substitution may depend on whether AVs carry multiple passengers for many types of trips.

Autonomous trucks, like light vehicles, can be expected to get more intensive usage on a daily basis, and this could reduce the number of overall trucks in the U.S. stock. On the other hand, the relative cost of trucking will fall and could result in substitution for rail shipments (Uber, 2018). AV trucking is likely to be used for long hauls, at least in the nearer term, as the "final mile" continues using drivers. This will limit the ability to reduce the stock of trucks and, particularly, the number of drivers, at least in the short run.

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[15] Moody's anticipates a significant reduction in costs per mile. Savings on parking can also be very important in many cities. See Clements and Kockelman (2017) for discussion of other estimates of cost savings.

[16] Naughton and Welch cite Mark Wakefield stating that AVs can reduce a taxi ride's cost by 60 percent.

[17] The assumption is that rides will be priced on a per trip basis. Other pricing strategies may develop, such as a monthly subscription fee. Pricing could be higher if monopolistic or oligopolistic market structures develop for AV networks.

[18] Of course, bus/van versions of AVs are also very possible.

[19] Graehler, Mucci, and Erhardt (2019) find that public transit ridership falls with access to transportation network companies (TNCs), and bus ridership falls with access to bike sharing. The potential transit decline discussed in this section may depend more on access to the TNCs of any kind than on AVs. This may mean that much of any increase in VMT from reduced transit ridership may take place before AVs are introduced.

Industries affected by transition to AVs[20]

This section discusses a mix of occupations and industries that AVs will affect. These economic disruptions will be the key determinant of indirect effects on state taxes.[21] The economic/employment effects of the transition from driven vehicles to AVs can be divided into those in vehicle-manufacturing industries, vehicle-using industries, and vehicle-support industries.[22] Table 1 shows more than 23 million workers in these three areas during 2017, representing 16 percent of total U.S. employment.[23] About two-thirds of the workers are in vehicle-using industries. Manufacturing workers are concentrated in a modest number of states, and the impacts will likely be focused in these states. But the vehicle-support industries and vehicle-using occupations are spread broadly throughout the country, so every state will feel the effects of the transition.

Table 1: Vehicle-Related Transportation Employment, U.S.

	U.S. employment	Share
Total employment	143,859,855	100.00%
Vehicle manufacturing	1,023,674	0.71%
Vehicle support	5,425,489	3.77%
Motor vehicle operators & other on-the-job drivers	16,571,180	11.52%
Total, vehicle-related	23,020,343	16.00%

Source: Author's calculations using Bureau of Labor Statistics data.

Industries in these three categories will be affected at very different rates; vehicle-manufacturing and vehicle-using industries will feel the effects first. Changes in types of inputs and numbers of

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[20] Clements and Kockelman (2017) discuss a number of industries that could be affected by AVs.

[21] The discussion recognizes that significant employment disruption is likely, but it makes no attempt to estimate net employment effects from AI and other technologies.

[22] The U.S. Department of Commerce (2017) estimated that 15.5 million workers are in occupations that could be affected by AVs, which is about 1 in 9 workers in the U.S. economy (excluding workers involved in vehicle and parts production and vehicle support industries). The Commerce Department study focuses only on workers in occupations that use vehicles intensively. The occupation-based estimates provided here rely on the Commerce Department approach and occupational categories.

[23] Two distinct datasets from the Bureau of Labor Statistics are used here: the Quarterly Census of Employment and Wages (QCEW) and the Occupational Employment Statistics (OES) survey program. QCEW employment data are collected from establishments covered by unemployment insurance programs and are available *by industry*. Employment data for vehicle manufacturing and vehicle support industries are QCEW employment for selected industries. The OES program produces employment and wage estimates *by occupation* for nonfarm establishment workers (employment *by occupation* is not available from QCEW). Some potential for overlap between the two data series exists. The occupations are distinct from each other but could overlap with manufacturing or support workers, but the overlap between vehicle-intense occupations and vehicle-support workers is probably limited. Some overlap with vehicle manufacturing will exist, but it is still small as a share of either category and as a share of U.S. employment.

vehicles will impact the production industries. Vehicle-using industries will be affected as AVs become integral to the production of some services. Vehicle-support industries will be affected much more slowly because driven vehicles will remain a large component of the vehicle stock for many years. Some industries, such as repair, may even see an expansion of activity for a number of years as the life of the existing vehicle stock is extended.

Vehicle manufacturing

As discussed above, it is reasonable to expect the aggregate number of vehicles in the economy to be significantly reduced as fleet owners efficiently manage their capital to earn a profit and households decrease the number of individually owned vehicles.[24] Employment related to current vehicle-producing industries is expected to fall as a result. The length of the transition from the current stock to AVs and the number of AVs necessary relative to the current vehicle stock will determine how large the effects will be and how quickly they occur.

Electric vehicles rely on different production technologies and will differentially impact the economy of automobile-producing states.[25] For example, simple electric motors will replace combustion engines. Perhaps more important, software will become a much larger share in the value added of a vehicle. One estimate is that 60 percent of the value added will be in software relative to 10 percent today (see Clements and Kockelman, 2017), as the hardware component becomes relatively less important.

Thus, employment can be affected both through the number of vehicles manufactured and the vehicle technology. The total effect on vehicle manufacturing employment can be described by equation 1, in which V equals the number of vehicles and L is labor per vehicle:

1. $W_i = L_i * V_i$

The total employment effects through regime change from internal combustion, self-driven, privately owned vehicles (regime 1) to electric, shared, AVs (regime 2) can be seen as a change in employment associated with the number of vehicles produced and associated with the technology (including parts manufacturing) that is employed:

2. $W_2 – W_1 = (L_2 – L_1)V_2 + (V_2 – V_1)L_1$

[24] Ford and General Motors have already announced large employment cutbacks, heavily focused on white-collar jobs, as they begin to right-size employment for movement to AVs and electric vehicles in the future.
[25] Volkswagen recently announced plans to shift radically toward making electric vehicles. General Motors also announced a new electric car plant in Michigan.

Vehicle assembly. Vehicle assembly involves about 379,000 workers in the U.S economy.[26] The change in new vehicle production could be much faster than the change in the vehicle stock as consumers become less willing to purchase new vehicles once they realize that AVs are going to become a reality and anticipated resale values for traditional vehicles begin to fall. Demand by fleet owners for AVs will likely rise faster than demand for mobility in the early days as an appropriate network is established. Then, AV production will lessen to the steady state number to replace fully depreciated vehicles. Ultimately, employment will decline with vehicle production and technological improvements as described in equation 2. The effects on current vehicle-producing states will be larger if manufacturers produce AVs in new assembly plants rather than retooled plants and procure parts from new suppliers.

Vehicle parts. Employment in parts manufacturing is larger than at assembly plants, with 644,000 workers in parts and tire manufacturing. Parts production could be larger during a transition period as people seek to extend the life of driven vehicles. Ultimately, employment will fall as the number of vehicles falls, but it will also be affected by conversions in vehicle components. Manfred Schoch, chairman of the BMW Group Works Council has observed that an eight-cylinder engine has 1,200 parts that need assembly, and an electric motor only 17 parts (Focus Online, 2016). These changes will significantly alter the firms and industries producing parts and could redistribute production across states. A key question is whether much of the technology in AVs will be produced by electronics firms or by traditional vehicle parts suppliers.

Firms supplying parts manufacturers will also be impacted as the number and types of vehicles produced decline. For example, glass production, metals and metal stamping, and many other industries could be affected.

<u>Vehicle-using occupations</u>

Employment in vehicle-using occupations, which include motor vehicle operators and other on-the-job drivers, will also be affected. Motor vehicle operators include taxi drivers, ridesharing drivers, and truck drivers. For example, there are currently 3.8 million motor vehicle operators in the U.S. (U.S. Department of Commerce, 2017). Job losses in these industries may be quick as AVs replace 100 percent of the tasks performed. As noted above, the initial effects in trucking will be fewer long-haul drivers, but more jobs will be lost as AV trucks are better able to navigate the last mile. The specific time depends on the willingness of employers and clients to accept and adopt the technologies.

Other "on-the-job" drivers include ambulance drivers, firefighters, police officers, delivery workers and sanitation workers. Autonomous vehicles will affect these drivers in complicated ways because they generally perform tasks besides driving, such as delivering packages or

[26] U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

putting out fires. The many nondriving tasks that the workers undertake—emergency/first responder services, delivery, etc.—must still be provided even if AVs supply the mobility. The vehicles are complements to labor so AVs can make workers more productive, which can allow the services to be provided more cheaply. On net, jobs will be lost unless demand for the services rises more rapidly in the face of falling service costs than the labor-saving reductions associated with AV technology. [27] The public sector may be slower at implementing the new technologies if they are labor saving, with the private sector much more likely to seek cost savings where possible. Unions could slow the pace of adoption in either the public or private sectors.

Vehicle-support industries

A wide range of industries supports the existing automobile industry, including auto dealers and repair; rental companies; fuel stations; vehicle finance and insurance agencies; and parking lots. Industries/occupations supporting the existing vehicle stock will be necessary for several decades after AVs are introduced as the existing stock of vehicles erodes, but most will be in decline as AVs expand. Declines in demand for vehicle services will be self-reinforcing as fewer driven vehicles will remain as the services become scarcer. Ultimately, almost all employment in existing vehicle-support industries and occupations will be eliminated. Of course, a new set of support industries for AVs will develop, so the net effect on employment depends on the relative size of the changes. But large disruptions will take place even if new jobs are created in other support industries.

Revenue effects

This section describes transportation-related taxes and fees throughout U.S. states and refers specifically to case studies in six states. The discussion focuses on how the expected characteristics of AVs, as described above, will affect revenues. States can limit these effects by reforming their tax structures to better fit new approaches to mobility—so some tax reform options are provided at the end.

Reductions in vehicle-related taxes can lower revenue available to finance earmarked services or general services provided by state governments, depending on the state's institutional structure. States often place much of their tax revenue, such as from the sales tax, in their general fund.[28] Changes in these revenues alter the ability to finance basic government services. The motor fuel and vehicle registration taxes and some other revenue sources are often earmarked in a

[27] Acemoglu and Restrepo (2019) describe the displacement effect of automation in which certain tasks previously performed by workers are replaced by equipment or AI and the productivity effect in which the demand for labor rises because workers are more productive in their new tasks. The overall demand for workers rises only if the productivity effect exceeds the displacement effect.
[28] A few states, such as Kentucky and South Carolina, put taxes on vehicle sales in their transportation funds.

transportation fund for financing road infrastructure services. Of course, revenue is often fungible and can be shifted across funds.

No attempt is made to estimate the net impacts of AVs on overall state fiscal conditions, but AVs will also affect state government expenditures. Effects on the net fiscal position of governments (measured as the change in revenue minus change in expenditures) depends on a wide range of factors that could influence every part of state government, and the key observation is that they could be smaller or larger than the revenue losses described here. Even transportation expenditure categories could increase and some decrease. Expenditures for areas such as the highway patrol may be lowered. Public transportation expenditures will also rise, depending on the extent of infrastructure needs and operational costs, such as monitoring and regulating AVs. More broadly, AVs offer the opportunity to reduce costs of delivering many government public services, including transporting school children, collecting solid waste, delivering fire protection, transporting public officials in pursuit of their duties, and so forth.

AVs will also impact local government revenue, although estimating the effect is beyond the scope of this paper. Local and state government taxes are interconnected in many ways, so local government revenue losses can also place fiscal pressure on states, and vice versa. Some examples of interactions between state and local government revenue sources include: local governments often share in certain state tax collections, state and local governments often impose taxes on the same or similar tax bases, state governments provide many grants to local governments, and so forth.

Governing magazine (2018) estimated that the 25 largest U.S. cities generate $5 billion annually from parking, traffic citations, gas taxes, towing, registration fees, and licensing fees. The survey found that New York City collected almost $1.2 billion and that Chicago received almost $700 million in 2016. AVs eliminate much of the need for parking, and this will significantly reduce related revenue. But parking is the largest land use in central cities, often accounting for 15 to 20 percent of land use, and AVs will free up much of this space for other purposes.[29] Property tax revenue will be significantly impacted as land use and related economic incentives are altered, resulting in dynamic interactions that both change and redistribute property tax revenues.

Six states—California, New Hampshire, New York, Ohio, Tennessee, and Texas—were selected as case studies for how their tax revenues will be affected by AVs. Several criteria were used to identify these states, including diversity in:

- Current state revenue sources.
- Taxes relative to the state economy.

[29] Also, see Clark, Larco, and Mann (2017).

- State population size.
- Importance of vehicle production to the state economy.

Populous states, such as California, New York, and Texas, were studied as well as smaller ones, such as New Hampshire and Tennessee. Direct transportation taxes are normally imposed in market rather than in production states, so vehicle production was a consideration but not the major factor in the selection. Ohio and Tennessee have large manufacturing operations but Michigan, for example, was not included. Case study states generate widely different taxes relative to personal income. (See Table 2.) For example, *state and local* taxes in New York are 15.4 percent of personal income but are only 8.0 percent of personal income in Tennessee. Similar disparities exist for *state* taxes, which range from 7.0 percent of personal income in California to 3.3 percent in New Hampshire.

Table 2: State and Local Taxes as a Percentage of Personal Income

State	State taxes as percentage of personal income (2017)	State and local taxes as percentage of personal income (2016)
California	7.0	11.2
New Hampshire	3.3	8.9
New York	6.8	15.4
Ohio	5.9	10.2
Tennessee	4.8	8.0
Texas	4.2	8.7
U.S. average	**6.0**	**10.3**

Source: Federation of Tax Administrators

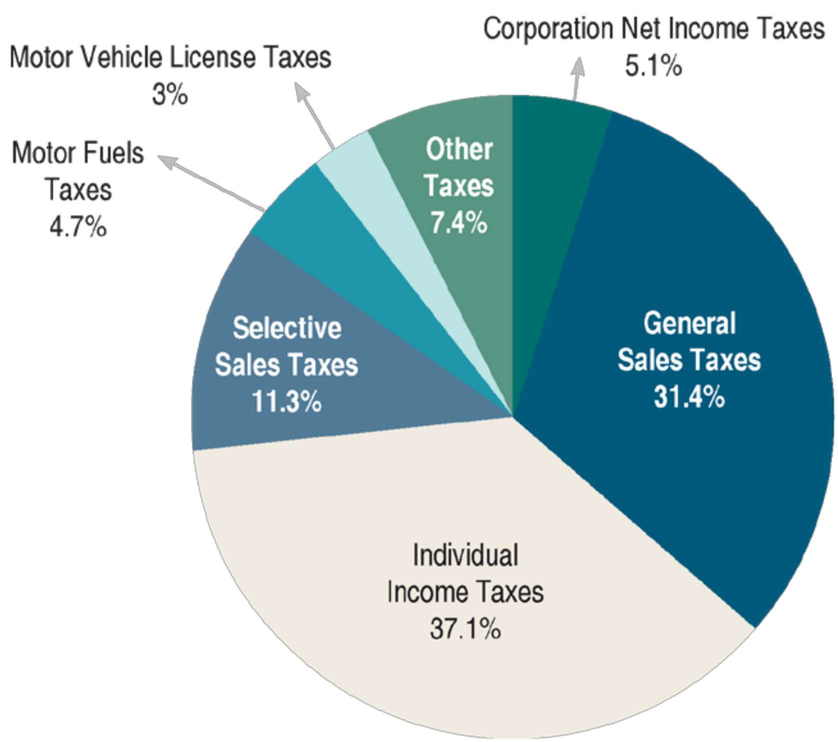
Table 3 illustrates existing state tax structures for the average of all 50 states and the case study states, and the same information is contained in Figures 1-7 associated with discussion of national and state-specific observations. Again, disparity is apparent. Personal income and sales taxes dominate nationally, providing nearly 70 percent of tax revenue.[30] California and New York raise more than 70 percent from these taxes and New Hampshire generates only 3 percent. New York and California focus heavily on income taxes, and Texas and Tennessee rely much more heavily on sales taxes. Motor fuel and vehicle license taxes generate only 7.7 percent of revenue nationally but 11.2 percent in Texas and 3.9 percent in New York.

[30] Sales taxes on vehicle sales were estimated for case study states but are not available for the entire country. Thus, vehicle sales taxes and general sales taxes must be aggregated to get total sales taxes for the case study states and no national average is available for Table 3.

Table 3: Distribution of Taxes by Source							
	State average	California	New Hampshire	New York	Ohio	Tennessee	Texas
Corporations' net income taxes	5.1%	6.4%	26.5%	5.1%	0.1%	11.5%	
General sales taxes	31.4%	20.7%		15.0%	36.6%	44.1%	53.7%
Sales taxes on autos		4.5%		1.6%	6.0%	8.3%	8.0%
Individual income taxes	37.1%	52.0%	3.3%	57.2%	28.5%	2.4%	
Selective sales taxes	11.3%	4.8%	31.7%	11.9%	14.5%	13.4%	20.6%
Motor fuels taxes	4.7%	3.2%	5.5%	2.0%	6.5%	6.7%	6.7%
Motor vehicle license taxes	3.0%	2.8%	4.6%	1.9%	3.0%	2.7%	4.5%
Other taxes	7.4%	5.6%	28.3%	5.4%	4.9%	10.9%	6.5%
Total taxes	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Author's calculations using U.S. Census Bureau data.

Figure 1: U.S. Distribution of State Taxes



The largest direct effects of AVs on state taxes will arise from fuel-related taxes, sales taxes on vehicle transactions, sales taxes on some services provided by support industries, and vehicle taxes and fees. AVs impact fuel tax revenue as electric vehicles replace vehicles that burn fossil fuel. Other taxes are affected as the number of new vehicles sold is reduced, as the vehicle stock falls, and as the purchases of certain vehicle-related services are changed. After a brief description of each tax, a mix of U.S. census, state, and American Petroleum Institute data is used to analyze each below. Utility and sales tax revenue associated with charging electric vehicles could rise, but these revenue gains are not estimated.

<u>Motor fuel excise taxes</u>

Every state collects a range of taxes on gasoline and diesel fuel.[31] (See Table 4.) State gasoline excise taxes average 23.06 cents per gallon and account in most states for much of the fuel and vehicle-related taxes on internal combustion vehicles.[32] States (and in some cases, local governments) average another 11.15 cents per gallon through sales taxes on gasoline, gross receipts taxes, oil inspection fees, county and local taxes, and environmental taxes. New York collects much of its vehicle-related taxes through a petroleum business tax, state sales tax (which varies by population in the region), registration fees and county sales taxes rather than fuel excise taxes. Combined, states impose an average tax of 34.21 cents per gallon. The rates vary from 58.7 cents per gallon in Pennsylvania to 14.73 cents per gallon in Alaska. Western and Mid-Atlantic states generally impose the highest rates, and Southern states the lowest.

Table 4: Gasoline and Diesel Fuel Taxes

	State gasoline excise tax	Other state vehicle taxes	Total	State diesel excise tax	Other state diesel taxes	Total
California	41.7	13.83	55.53	36	51.35	87.35
New Hampshire	22.2	1.63	23.83	22.2	1.63	23.83
New York	8.05	37.57	45.62	8	37.02	45.02
Ohio	28	0.01	28.01	28	0.01	28.01
Tennessee	25	1.4	26.4	24	1.4	25.4
Texas	20	0	20	20	0	20
50-state and D.C. average	**23.06**	**11.15**	**34.21**	**23.04**	**13.24**	**36.27**

Note: All taxes state in cents per gallon.
Source: American Petroleum Institute (2018).

[31] The discussion in this section relies on American Petroleum Institute (2018) data that aggregate a range of taxes linked to vehicles and fuel. These taxes are imposed on various tax bases and have been reported in cents per gallon although the calculations also include taxes such as sales tax on gasoline in some states.
[32] The federal government assesses an 18.4 cents per gallon tax.

States also impose excise taxes on diesel fuel, with an average rate of 23.04 cents per gallon, approximately equal to the gasoline tax rate.[33] (See Table 2.) In addition, states levy a series of other taxes similar to those listed above for gasoline taxes that average 13.24 cents per gallon. Overall, diesel fuel taxes, including these other levies, average 36.27 cents per gallon, somewhat higher than the per gallon tax on gasoline. Again, Western states impose the highest rates (61.89 cents per gallon), in this case by a substantial margin, followed by Mid-Atlantic states. Southern states are the lowest at 20.51 cents per gallon. California has the highest state rate at 87.35 cents per gallon (as with the New York taxes associated with vehicles powered by fossil fuel, much of this revenue comes from taxes other than the diesel fuel excise tax). Alaska is the lowest at 14.69 cents per gallon.

Some states, such as California and Tennessee, have a tax on electric vehicles but it is levied per vehicle rather than per mile, and the effective rate is lower than the fuel tax that would be collected based on average mileage driven.[34] The fee is even lower than the forgone fuel taxes for shared vehicles that are driven much more intensively.

Federal fuel tax revenue will fall concurrently with state fuel taxes. The revenue is generally distributed to states, suggesting another area of loss for state coffers. This revenue loss is not included in the estimates provided below.

Registration fees

States impose a range of license and registration fees that would be reduced as the vehicle stock falls. For example, California imposes a current registration fee, a California Highway Patrol fee, a weight fee (on trucks), a vehicle license fee, a transportation improvement fee, and a series of other small charges and fees. Many of these taxes and fees are included in the calculations that the American Petroleum Institute used to estimate the non-excise taxes accounted for in Table 4.

Sales tax

Forty-five states levy a general sales tax, but sales tax laws vary widely across states, making generalities somewhat difficult. The sales tax is levied on the sale of many vehicles and also on selected services. The case studies account for taxes on vehicle sales but do not account for sales tax on related services because estimates of the tax bases are unavailable for the specific

[33] These revenues are often distributed through the International Fuel Tax Agreement (IFTA). Revenue distribution issues during the transition of trucks to autonomous/electric and to using new operational approaches will surely begin to arise.

[34] Based on fuel tax rates in the states, average miles per gallon, and 12,000 miles per year. At least 19 other states have some type of charge for electric vehicles. See http://www.ncsl.org/research/energy/new-fees-on-hybrid-and-electric-vehicles.aspx.

services. On the other hand, the estimates of sales tax on vehicle sales may include related items sold by vehicle dealers, so they may overestimate the sales tax on vehicles alone.

Vehicle sales. Every sales-taxing state imposes a sales tax on light vehicle sales, although most states tax the differential between the purchase price and any trade-in value (particularly if the trade-in is of like goods). In some states the legal mechanism for taxing vehicle sales is similar but different from the general sales tax. A number of states also impose differential sales tax rates (generally lower) on motor vehicle sales versus other transactions. Some intermediate transactions are taxed in the production, distribution, and sale of vehicles. Revenue losses from fewer intermediate transactions are not included here. Many states also impose sales taxes on trucks, although some do not levy the tax on trucks used in interstate commerce.

Sales tax revenue depends on the value of vehicle sales, unlike the fuel taxes discussed above that are generally levied on quantity rather than value. So, a significant reduction in sales volume would generally lower sales tax revenue, but this could be offset to some extent if the average value of an AV is higher than for existing vehicles. States relying heavily on the sales tax, such as Texas and Tennessee, are at risk of losing significant revenue if total vehicle volume diminishes.

Vehicle-related services. States levy the sales tax on a range of vehicle-related services, and this revenue could also be impacted by declines in the number of vehicles, how these services are delivered, or by changes in travel. Examples of taxed services are provided in Table 5, but the effects on revenue are not estimated here. Table 5 also provides the total number of states that tax the service.[35] None of the case study states taxes all of the services, although New York exempts only one and Ohio exempts only two of these services. States generally tax repair materials, auto service, and waxing and washing.

Table 5: Sales Tax Rates on Selected Services

	Standard sales tax rate	Local transit	Taxis	Automotive washing and waxing	Road service and towing	Auto service except repair	Parking lots & garages	Rustproofing and undercoating	Labor charges for motor vehicles	Repair materials, generally	Limousine service
California	7.25	E	E	E	E	7.25	E	E	E	7.25	E
New Hampshire	0										
New York	4	E	E	4	4	4	4	4	4	4	4
Ohio	5.75	E	5.75	5.75	5.75	5.75	E	5.75	5.75	5.75	5.75
Tennessee	7	E	E	7	7	7	7	7	7	7	E
Texas	6.25	E	E	E	E	E	6.25	E	E	6.25	E

[35] Note that the state counts include states such as Delaware, which impose low-rate gross receipts taxes rather than a general sales tax, and the District of Columbia.

Number of states that impose the tax	46	6	10	24	20	25	21	26	23	47	17

Note: "E" indicates exempt from tax
Source: Federation of Tax Administrators 2017 Services Taxation Survey, https://www.statetaxissues.org/services/2017/.

Transportation services, including local transit, taxis and limousines, are taxed by a limited number of states. Thus, modest additional revenue will be gained if AV fleet services are treated under existing statutes covering these transportation services. Similarly, vertical integration within fleet/network mobility providers could result in services such as repairs and cleaning being provided intra-firm, and sales taxes are generally imposed only if a transaction occurs. A little less than half of states tax parking lots, which means many will see no revenue loss as parking diminishes.

Indirect tax effects

Significant economic transitions such as those discussed in the employment section above can impact the range of general taxes levied by states, including the individual income tax, sales tax, and corporate income taxes. The indirect effects of employment/production transitions are not estimated here. Still, a few general points can be made. Changes in the extent and geographic location of vehicle production could have large indirect effects on both the level and distribution of income, sales, and corporate income taxes. For example, declines in wage income associated with production of fewer vehicles or replacement of workers with technology will lower state income taxes. Of course, these revenue losses will be replaced if the workers can transition to other similarly paying jobs in the economy. Reduced expenditures for transportation could lower sales tax revenue as described above, but they also allow consumers to spend the money on other goods and services, and sales tax revenue could rise over time depending on how worker incomes are affected. Corporate income taxes could also be impacted to the extent that overall corporate profitability goes up or down.

Case studies[36]

Static, state-specific models are used to estimate the revenue implications of AVs separately for each case study state based on the linkages with state's tax bases.[37] Effects of explicit and implicit prices on the extent of mobility and the mode adopted are key dynamic effects that are not addressed here. The simulations use current state tax structures, and no attempt is made to anticipate how state tax policy evolves as AVs develop. The process begins by calculating the

[36] A more detailed description of the simulation methodology is available from the author.
[37] U.S. Census Bureau motor vehicle license taxes and motor fuel excise taxes were a key data source. Some additional data were collected as possible, including several cases in which the tax revenue is estimated. For example, sales tax on vehicle sales are estimated for several states. The breadth of coverage for the case study states depends on the ability to locate desired data.

compound annual growth rate in each tax's revenue from 2000-16.[38] Each tax is then assumed to grow at this trend rate through 2025. *The 2025 estimates serve as a baseline/jumping-off point for assessing the effects of AVs on tax structures.* Effects of AVs on tax revenue are simulated for 2030 and 2040 and are compared to a non-AV environment for the same years.[39]

Simulations on how taxes will be affected are developed using assumptions about the adoption rate,[40] which equals the number of years required for AVs to replace self-driven vehicles, and the number of AVs relative to self-owned vehicles required to meet the demanded mobility.[41] Four scenarios are modeled for each state to provide a range of possible outcomes. The first is a quick adoption scenario, with a substantial reduction in the number of vehicles needed to provide demanded mobility. Thus, AVs are fully adopted in 15 years (from 2025 to 2040) with only half as many vehicles needed and all fossil fuel vehicles eliminated.[42] This scenario is the most aggressive in terms of adoption rate and fewest vehicles required. Scenario 2 is less aggressive and assumes a 30-year phase-in of AVs with 60 percent as many vehicles required. Scenario 3 assumes a 30-year phase-in but includes no reduction in the number of vehicles relative to the population. Scenario 4 assumes a 50-year phase-in with 60 percent as many vehicles. The latter two scenarios attempt to separate the relative importance of these two metrics—how many vehicles will be needed and how long the phase-in period lasts.

Fuel-based revenue (such as gasoline and diesel fuel taxes) is assumed to decline as electric AVs replace internal combustion vehicles. The fuel revenue losses depend on the rate at which AVs are adopted, as internal combustion engine vehicles are presumed to decline inversely to electric AV adoption. Vehicle-based revenue (such as registration fees and sales tax on motor vehicles) depends on either the number of vehicles sold[43] or the vehicle stock. These estimates are linked to both the rate at which AVs are adopted and the required number of AVs.

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[38] It was necessary to use a shorter time period in cases in which earlier data were unavailable or the tax was new.

[39] The analysis is generally conducted by calculating the proportion of each revenue source that is decreased or increased by AVs and not on the basis of actual gallons of fuel sales or the stock of vehicles. Taxes on electric cars in California and Tennessee are exceptions in which the actual number of vehicles is estimated.

[40] Adoption of AVs is assumed to occur at a straight-line rate given the period of full adoption.

[41] Vehicle purchases are determined based on the assumed phase-in period and the assumed replacement rate. The simulations effectively assume that some internal combustion engine vehicles will continue to be purchased after 2025 and within the phase-in period to ensure that sufficient vehicles are available to meet mobility demands. It is possible that the simulation approach allows a stock of internal combustion engine vehicles to remain when sufficient AVs exist to provide mobility. No revenue estimate is linked to these remaining internal combustion engine vehicles. This problem is most likely to arise for simulations based on very short AV adoption periods.

[42] This scenario requires that internal combustion engine vehicles be abandoned at twice the rate that AVs are acquired and effectively that no internal combustion engine vehicles are in use by 2040. Any potential manufacturing constraints are presumed to be accounted for by the length of the adoption period. Short adoption periods are less likely if production capacity is limited.

[43] No adjustment is made for the price of AVs versus internal combustion engine vehicles. AVs could be more expensive because of the value added in technology, but they will be purchased in fleets or potentially delivered through vertically integrated companies, and these factors could help keep the taxable cost/price down.

California[44] and Tennessee impose a $100 per vehicle tax on electric cars. These taxes are presumed to apply to all AVs, so the simulated tax revenue depends on the rate at which AVs are adopted and the replacement rate of AVs for internal combustion engine vehicles.[45] The calculation requires estimating the actual stock of vehicles. The baseline stock of vehicles is assumed to equal the 2016 vehicles per person in each state (0.77 per person in California and 0.86 per person in Tennessee).[46] Each state's population is assumed to rise from the 2018 census population estimate at the compound annual growth rate of census population estimates from 2010 to 2018, and the vehicles per person decline proportionately in scenarios in which fewer AVs are needed relative to the number of vehicles with internal combustion engines.

Overall simulation findings

Comparison of the simulation results, which are provided in detail for each state below, lead to several generalizations. First, aggregate vehicle-related tax revenue is generally less elastic than total tax revenue, so the vehicle share of tax revenue is usually declining between 2016 and 2025, before AVs become part of the vehicle stock.[47] Second, total revenue losses from the full phase-in of AVs occur because of the structure of taxes related to vehicles, and not because of the phase-in period. The length of the phase-in affects the time over which the revenue losses are felt, but it does not affect the share of revenue that will ultimately be lost. Of course, a long phase-in period means that it will take many years before states feel the entire effects of the changes. Table 6 illustrates the maximum expected effect of full phase-in on tax revenue based on the simulations reported in Tables 7-12. Total revenue losses range from about 2 percent to more than 9 percent of total revenue. [48] More than half of vehicle-related revenue is lost in every state.

[44] California's electric vehicle tax is indexed to inflation beginning in 2021. Inflation is assumed to be 2.0 percent per year.

[45] The current stock of electric cars is ignored in these calculations. California and Tennessee will see less additional electric car tax revenue from AVs than estimated here to the extent that electric vehicles are replaced with AVs. Of course, this simply means that the electric car fee is already being collected and the fuel tax revenue is already lost. Tennessee collected $254,000 in FY 2017-18 from the electric vehicle fee.

[46] https://www.fhwa.dot.gov/policyinformation/statistics/2016/mv1.cfm.

[47] Tennessee is an exception because of fuel tax rate increases that are being phased in between 2017 and 2020.

[48] The percentage loss estimates in Table 6 divide revenue losses in 2040 in Scenario 1 in Tables 7-12 (Panel A) by total revenue and total vehicle revenue raised without AVs in the bottom section (Panel E) of the same tables.

Table 6: Revenue Loss at Full Phase-In With 50% as Many Vehicles				
	Revenue loss (000s)	Revenue loss as a percentage of total revenues	Revenue loss as a percentage of vehicle revenue	Vehicle revenue as a share of total 2016
California	$23,551,017	6.0%	59.2%	14.3%
New Hampshire	$ 245,852	4.8%	67.7%	9.5%
New York	$4,514,179	2.0%	68.3%	6.1%
Ohio	$3,682,116	7.3%	75.4%	12.5%
Tennessee	$2,640,804	8.7%	58.4%	17.3%
Texas	$12,521,450	9.2%	59.5%	19.9%

Third, the size of vehicle-related tax revenue and the specific state tax structures differ dramatically across states, so they are affected very differently. (See Table 6.) New York and New Hampshire, for example, depend much less on vehicle tax revenue than other case study states and, although their relative decline in vehicle-related revenue is large, the aggregate effect on total tax revenue is small. Texas and Tennessee, on the other hand, rely relatively heavily on vehicle taxes and experience larger losses relative to total tax revenue.

Next, very fast adoption of AVs, which reduces fossil fuel usage rapidly, and replacement of a significant share of vehicles dramatically lower revenue sooner and more significantly. Every state generates less nominal revenue from vehicles under Scenario 1 in 2040 than in 2025. The effects diminish as the scenario assumptions become less aggressive, although states always generate less revenue in a scenario with AVs and electric vehicles than a scenario without them. Revenue generated from vehicle-related sources does not fall by more than 3.4 percent of total revenue in any state over the next two decades (by 2040) under scenarios in which adoption is presumed to take place over 30 or more years. Similarly, all states lose less than one-half of fuel tax revenue by 2040 under the less aggressive scenarios. Still, the losses shown in Table 6 may be a good indicator of where state vehicle revenue ultimately is headed, even if it takes more than 15 years for the transition to occur. Revenue losses will be lower as relatively more AVs are needed, but approach the losses in Table 6 as fewer vehicles are needed and adoption is faster.

Fifth, fuel tax revenue is impacted more than vehicle-based revenue under all scenarios. The key reason is that full adoption of electric vehicles eliminates all fuel tax revenue. At least a portion of the revenue remains with taxes on vehicle stocks (such as vehicle registration fees or electric vehicle fees) and sales. Thus, states that rely relatively more on fuel tax revenue are negatively impacted the most. In Ohio, the sales tax on motor vehicle sales will be the only significant source remaining in 2040 under Scenario 1, as all fuel revenue is eliminated. Texas, on the other hand, will still have significant revenue from motor vehicle registrations and motor vehicle title fees in addition to the sales tax revenue.

Finally, an electric vehicle tax moderates the revenue losses. The electric vehicle taxes in California and Tennessee are too small to offset the revenue losses fully, but these states have the smallest loss of vehicle-related revenue. Also, relatively more vehicles per person expand revenue in Tennessee and indexation of the zero emission car fee for inflation in California provides more revenue elasticity as AVs expand.

The following section discusses how tax revenue is affected in each case study state. Each sub-section briefly discusses the level of taxes relative to the economy, the distribution of taxes by source, the contribution of vehicle-related taxes, and the level of tax rates. Then, results of the scenarios are presented.

California[49]

California raises above-average taxes at both the *state*-only and *state and local* government levels. (See Table 2.) The state relies relatively heavily on the personal income tax (52 percent) and relatively lightly on the sales tax (25 percent) versus national norms. (See Table 3.) California generates only 3 percent of revenue from motor fuel excise taxes versus the national average of 5 percent, but California has high excise and other taxes on vehicles. (See Table 4.) Motor vehicle-related taxes in California accounted for 14.3 percent of revenue in 2016 and are forecast to decline to 12.1 percent by 2025.[50] (See Table 7.) California's vehicle share is in the middle of case study states, with New Hampshire, New York and Ohio having lower shares in 2025.

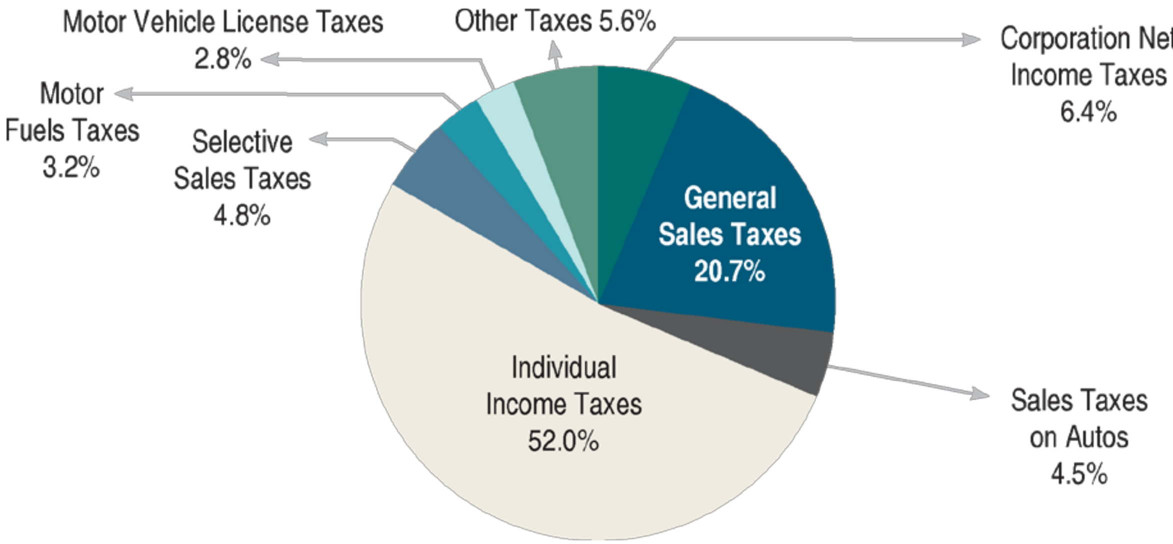
Scenario 1 (Panel A) shows California losing more than three-fifths[51] of vehicle tax revenue contributions as AVs are fully phased in by 2040 and vehicle revenue actually declines over the 15 years.[52] The revenue contribution of vehicles declines by between one-fifth and one-third in the other three simulations, both because AVs are not phased in by 2040 and because more vehicles are expected. In nominal terms, revenue declines only under Scenario 1, and the underlying trend is fast enough that revenue rises under the other three scenarios. The revenue losses in scenarios 2-4 compared with total collections amount to less than 3 percent of total revenue by 2040. Total revenue in Tables 7-12 refers to the aggregate of all state tax revenue, including vehicle- and non-vehicle-related revenue. Lost revenue is the reduction in vehicle-related tax revenue between that raised without AVs (Panel E) and that raised during the same year for each specific scenario. The vehicle share of revenue is vehicle-related revenue divided by total revenue within each scenario.

[49] As of January 2019, the California Department of Finance ebudget website listed this data. These data are no longer publicly available from the California Office of State Publishing.
[50] Motor vehicle-related taxes in California include sales taxes on vehicle sales; motor vehicle registration and fees; motor fuel, motor vehicle license, motor vehicle excise, motor vehicle in lieu, zero emission, and tire replacement taxes; and fines and penalties.
[51] Fines and penalties are assumed to fall proportionately with the rise of AVs and to be zero with the full phase-in of AVs.
[52] Table 6 compares revenue with the status quo of a non-AV, nonelectric vehicle environment. Tables 7-12 and the discussion in the case studies compare the vehicle revenue and total revenue in 2040 within each scenario to the forecasted 2025 revenue, with the exception of the lost revenue calculation.

Table 7: California Revenue Simulations (thousands of dollars)				
Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
	2025	2030	2040	Change, 2025 to 2040
Total vehicle-related	26,048,715	24,761,900	16,242,093	-9,806,622
Total revenue	219,474,524	261,111,730	367,509,012	148,034,487
Lost revenue	0	4,963,157	23,551,016	23,551,017
Vehicle share of revenue	11.9%	9.5%	4.4%	-7.4%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	26,048,715	27,603,082	29,634,125	3,585,410
Total revenue	219,474,524	263,952,911	380,901,044	161,426,519
Lost revenue	0	2,121,976	10,158,985	10,158,985
Vehicle share of revenue	11.9%	10.5%	7.8%	-4.1%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	26,048,715	29,041,492	36,100,219	10,051,504
Total revenue	219,474,524	265,391,321	387,367,138	167,892,613
Lost revenue	0	683,566	3,692,891	3,692,891
Vehicle share of revenue	11.9%	10.9%	9.3%	-2.5%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	26,048,715	28,451,872	33,697,719	7,649,004
Total revenue	219,474,524	264,801,701	384,964,638	165,490,113
Lost revenue	0	1,273,186	6,095,391	6,095,391
Vehicle share of revenue	11.9%	10.7%	8.8%	-3.1%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	22,196,263	26,048,715	29,725,058	39,793,110
Total revenue	155,191,714	219,474,524	266,074,887	391,060,028
Vehicle share of revenue	14.3%	11.9%	11.2%	10.2%

Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

Figure 2: California Distribution of State Taxes

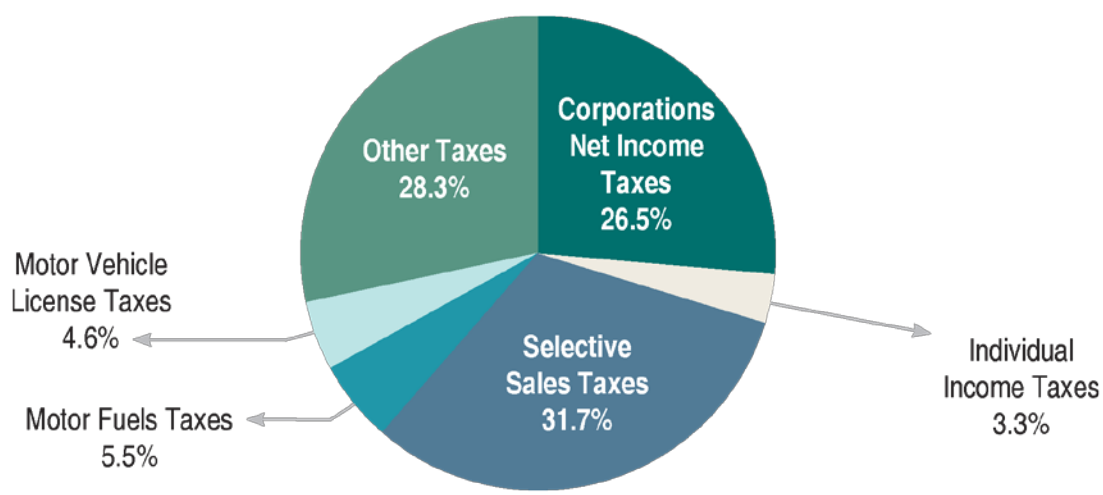


New Hampshire

New Hampshire is a relatively low tax state, generating only 8.9 percent of personal income from taxes at the *state and local* levels, and it has the lowest *state* tax share at 3.3 percent. (See Table 2.) New Hampshire is unique among states, having neither a personal income tax[53] nor a general sales tax. (See Table 3.) The state raises a relatively large portion of taxes from the motor vehicle license and motor fuel excise taxes, with about 5 percent each, but this is in part because these taxes are compared with relatively small state taxes overall. New Hampshire imposes below-average tax rates on gasoline and diesel fuel. (See Table 4.) Motor vehicle-related taxes in New Hampshire will decline from 9.4 percent of total revenue in 2016 to 8.3 percent by 2025.[54] (See Table 8.)

The vehicle share of revenue falls by more than three-fifths under Scenario 1. Less revenue is collected in 2040, although the modest share of taxes collected from vehicles still means that the overall risk to state tax collections is small relative to most other case study states. (See Table 6.) The other New Hampshire scenarios show the vehicle revenue share falling between 20 and 30 percent by 2040, although unlike California, nominal vehicle revenue also declines under Scenario 2.

Figure 3: New Hampshire Distribution of State Taxes



[53] New Hampshire taxes the income from dividends and interest.
[54] Motor vehicle-related taxes in New Hampshire include the gasoline, gasoline road toll, auto rental, and interstate vehicle registration taxes.

Table 8: New Hampshire Revenue Simulations (thousands of dollars)				
Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
	2025	2030	2040	Change, 2025 to 2040
Total vehicle-related	285,891	236,570	117,429	-168,463
Total revenue	3,389,939	3,821,464	4,890,306	1,500,367
Lost revenue	0	72,041	245,852	245,852
Vehicle share of revenue	8.4%	6.2%	2.4%	-6.0%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	285,891	275,212	250,661	-35,230
Total revenue	3,389,939	3,860,106	5,023,539	1,633,600
Lost revenue	0	33,399	112,620	112,620
Vehicle share of revenue	8.4%	7.1%	5.0%	-3.4%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	285,891	285,698	291,887	5,996
Total revenue	3,389,939	3,870,592	5,064,765	1,674,826
Lost revenue	0	22,913	71,393	71,393
Vehicle share of revenue	8.4%	7.4%	5.8%	-2.7%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	285,891	288,571	295,709	9,818
Total revenue	3,389,939	3,873,465	5,068,587	1,678,648
Lost revenue	0	20,039	67,572	67,572
Vehicle share of revenue	8.4%	7.4%	5.8%	-2.6%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	251,261	285,891	308,611	363,281
Total revenue	2,641,946	3,389,939	3,893,505	5,136,159
Vehicle share of revenue	9.5%	8.4%	7.9%	7.1%

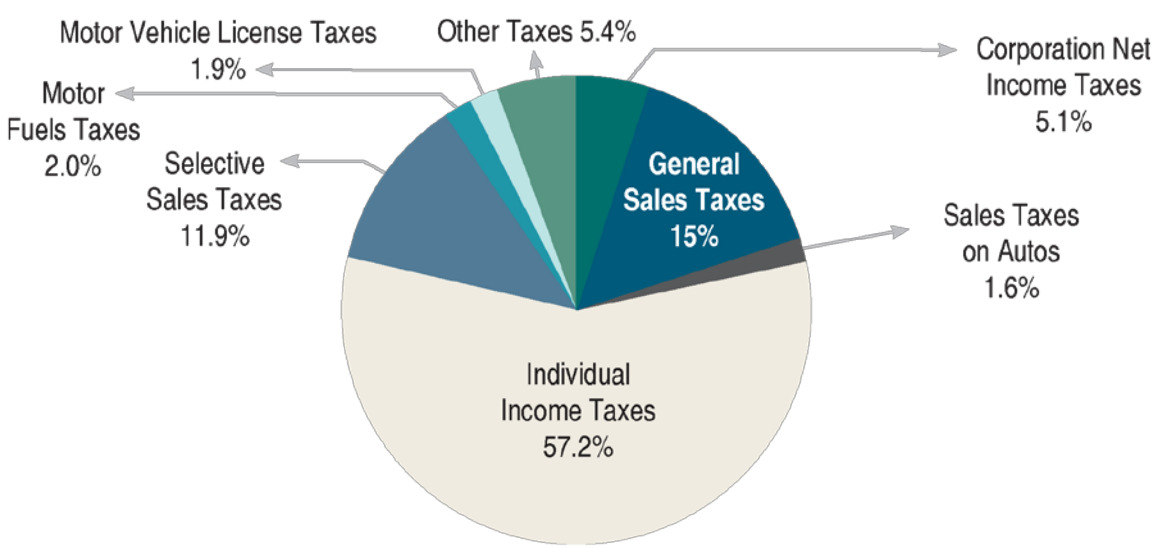
Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

New York

New York has the highest combined *state and local* taxes as a share of the economy among all states, and also has a relatively high *state* share paid in taxes. (See Table 2.) New York generates an even higher share of state tax revenue from the personal income tax and a lower share from the sales tax than California. (See Table 3.) The state raises only 2 percent of tax revenue from each the motor fuel excise tax and the motor vehicle license tax. New York imposes very low fuel excise tax rates, but it collects significant revenue from other vehicle-related taxes. (See Table 4.) New York motor vehicle-related taxes accounted for 6.1 percent of tax revenue in 2016, which is very low relative to other case study states.[55] (See Table 9.) New York's share will fall to 4.6 percent in 2025 without policy changes.

New York experiences the largest loss of the relative vehicle revenue contribution under Scenario 1, by nearly 80 percent, as total vehicle-related revenues fall.[56] Similarly, the revenue losses relative to the baseline are large for New York under the other scenarios, with the state losing about half of the vehicle contribution and experiencing nominal revenue decreases under every scenario. But New York's vehicle revenue losses compared with total revenue are the smallest of any state because the state relies relatively little on vehicle-related taxes. (See Table 6.)

Figure 4: New York Distribution of State Taxes



[55] Motor vehicle-related taxes in New York include certificates of registration and decal fees; motor fuel, truck mileage, fuel use, and auto rental taxes; sales tax on vehicle sales; sales tax on gasoline sales; and motor vehicle registration taxes.
[56] The truck mileage tax is assumed to rise 20 percent at full phase-in as vehicle mileage rises with AVs.

Table 9: New York Revenue Simulations (thousands of dollars)

	2025	2030	2040	Change, 2025 to 2040
Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
Total vehicle-related	5,493,097	4,474,464	2,099,421	-3,393,676
Total revenue	118,412,107	144,525,170	216,860,666	98,448,559
Lost revenue	0	1,347,353	4,514,179	4,514,179
Vehicle share of revenue	4.6%	3.1%	1.0%	-3.7%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	5,493,097	5,193,965	4,557,604	-935,493
Total revenue	118,412,107	145,244,672	219,318,849	100,906,742
Lost revenue	0	627,852	2,055,997	2,055,997
Vehicle share of revenue	4.6%	3.6%	2.1%	-2.6%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	5,493,097	5,425,023	5,349,987	-143,110
Total revenue	118,412,107	145,475,729	220,111,231	101,699,125
Lost revenue	0	396,794	1,263,614	1,263,614
Vehicle share of revenue	4.6%	3.7%	2.4%	-2.2%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	5,493,097	5,437,465	5,382,400	-110,697
Total revenue	118,412,107	145,488,171	220,143,645	101,731,539
Lost revenue	0	384,352	1,231,200	1,231,200
Vehicle share of revenue	4.6%	3.7%	2.4%	-2.2%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	4,990,069,736	5,493,097	5,821,817	6,613,600
Total revenue	81,349,860	118,412,107	145,872,523	221,374,845
Vehicle share of revenue	6.1%	4.6%	4.0%	3.0%

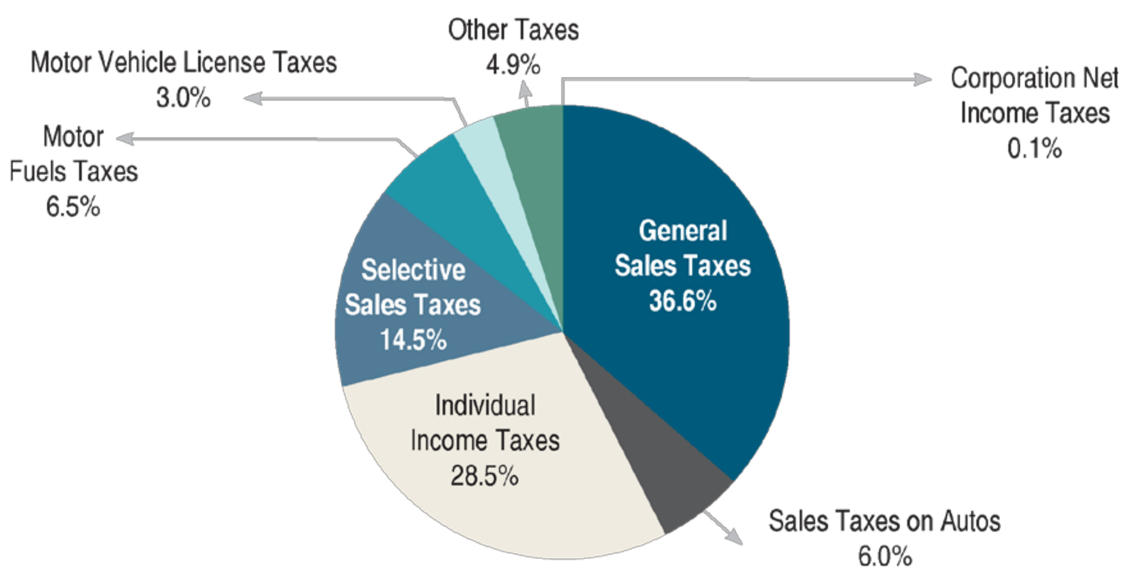
Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

Ohio

Ohio's tax burdens are approximately at the national average for both *state and local* governments and *state* governments alone. (See Table 2.) Ohio relies somewhat more on the general sales tax and somewhat less on the personal income tax than the national average. (See Table 3.) The motor vehicle license tax share of tax revenue is at the national average and the motor fuels excise tax is slightly above average. Ohio's fuel excise tax rates are above average, but its overall burden per gallon of diesel and gasoline taxes is below national norms. (See Table 4.) Motor vehicle-related taxes in Ohio accounted for 12.5 percent of tax revenue in 2016 and will decline to 11.3 percent in 2025.[57] (See Table 10.) Motor vehicle revenue declines in nominal terms under all scenarios.

In Scenario 1, Ohio's loss of vehicle revenue share is the second-largest to New York's, although it is similar to several other states. The other scenarios (2-4 scenarios) suggest a 30 to 45 percent reduction in the vehicle share of revenue, which is approximately in the middle of the states. Ohio loses a relatively large share of revenue at full phase-in of AVs because the state relies very heavily on fuel-based vehicle taxes.[58] (See Table 6.)

Figure 5: Ohio Distribution of State Taxes



[57] Motor vehicle-related taxes in Ohio include motor fuel, petroleum activity, replacement tire, and motor fuel taxes; motor vehicle license fees; and sales taxes on motor vehicles.
[58] The replacement tire fee is assumed to rise 20 percent in addition to the underlying growth rate because of increased mileage with AVs.

Table 10: Ohio Revenue Simulations (thousands of dollars)

Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
	2025	2030	2040	Change, 2025 to 2040
Total vehicle-related	4,021,407	3,208,448	1,201,076	-2,820,332
Total revenue	35,479,335	38,839,278	46,853,067	11,373,732
Lost revenue	0	1,079,901	3,682,116	3,682,116
Vehicle share of revenue	11.3%	8.3%	2.6%	-8.8%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	4,021,407	3,784,296	3,161,714	-859,693
Total revenue	35,479,335	39,415,126	48,813,706	13,334,370
Lost revenue	0	504,053	1,721,477	1,721,477
Vehicle share of revenue	11.3%	9.6%	6.5%	-4.9%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	4,021,407	3,921,601	3,629,507	-391,901
Total revenue	35,479,335	39,552,431	49,281,498	13,802,163
Lost revenue	0	366,747	1,253,685	1,253,685
Vehicle share of revenue	11.3%	9.9%	7.4%	-4.0%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	4,021,407	3,987,174	3,852,412	-168,996
Total revenue	35,479,335	39,618,004	49,504,403	14,025,068
Lost revenue	0	301,175	1,030,780	1,030,780
Vehicle share of revenue	11.3%	10.1%	7.8%	-3.6%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	3,587,852	4,021,407	4,288,349	4,883,191
Total revenue	28,694,883	35,479,335	39,919,179	50,535,183
Vehicle share of revenue	12.5%	11.3%	10.7%	9.7%

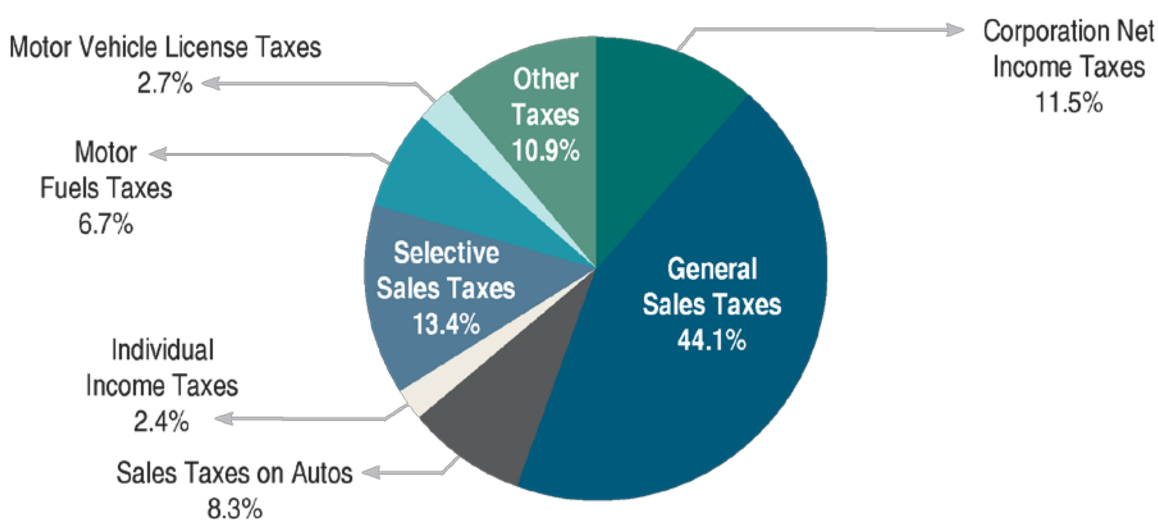
Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

Tennessee

Tennessee has the fourth-lowest share of *state and local* taxes[59] relative to the economy of all states in the U.S. and a comparatively low share paid in *state* taxes. (See Table 2.) The state relies heavily on the sales tax and is phasing out its small income tax. (See Table 3.) Tennessee's motor vehicle license taxes are about at the national norm as a share of revenue, but its motor fuel excise taxes are a large share. Tennessee's excise tax rates are a bit above national averages, but the overall burden per gallon on gasoline and diesel fuels is low. (See Table 4.) Motor vehicle taxes accounted for 17.3 percent of total tax revenue in 2016, and the share will be approximately the same in 2025 because of gasoline and motor fuels tax rate increases that are currently being phased in.

Tennessee's share of vehicle revenue lost under Scenario 1 is approximately the same as California's[60] (see Table 6), even though vehicle-related taxes are relatively important. (See Table 3.) Tennessee has only nominal revenue loss under Scenario 1 because of the electric vehicle tax and slower transitions in the later three scenarios.[61] (See Table 11.) For example, Tennessee would raise $346 million in electric vehicle taxes in 2040 if 0.5 AVs were required to replace each fossil fuel vehicle and AVs were entirely phased in. Tennessee loses between one-fifth and one-third of the vehicle contribution by 2040 under the other scenarios, 2-4.

Figure 6: Tennessee Distribution of State Taxes



[59] See https://www.taxadmin.org/2016-state-and-local-revenue-as-a-percentage-of-personal-income.

[60] The tire tax is assumed to rise 20 percent in addition to the underlying growth rate as the number of miles traveled increases with AVs.

[61] Tennessee motor vehicle-related taxes include motor vehicle registration and motor vehicle title fees; auto rental surcharge, gasoline, motor fuel, special petroleum, tire, and gas and oil severance taxes; sales tax on motor vehicles; and electric vehicle taxes. Auto rental taxes are assumed to fall to zero when AVs are fully phased in.

Table 11: Tennessee Revenue Simulations (thousands of dollars)				
Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
	2025	2030	2040	Change, 2025 to 2040
Total vehicle-related	3,161,135	2,841,012	1,883,998	-1,277,137
Total revenue	18,217,829	20,913,991	27,807,551	9,589,722
Lost revenue	0	705,843	2,640,804	2,640,804
Vehicle share of revenue	17.4%	13.6%	6.8%	-10.6%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	3,161,135	3,241,214	3,382,646	221,511
Total revenue	18217829.15	21,314,193	29,306,199	11,088,370
Lost revenue	0	305,641	1,142,156	1,142,156
Vehicle share of revenue	17.4%	15.2%	11.5%	-5.8%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	3,161,135	3,430,336	4,130,658	969,523
Total revenue	18,217,829	21,503,314	30,054,211	11,836,382
Lost revenue	0	116,520	394,144	394,144
Vehicle share of revenue	17.4%	16.0%	13.7%	-3.6%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	3,161,135	3,363,471	3,832,503	671,368
Total revenue	18,217,829	21,436,449	29,756,056	11,538,226
Lost revenue	0	183,385	692,299	692,299
Vehicle share of revenue	17.4%	15.7%	12.9%	-4.5%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	2,320,287	3,161,135	3,546,855	4,524,802
Total revenue	13,386,169	18,217,829	21,619,834	30,448,354
Vehicle share of revenue	17.3%	17.4%	16.4%	14.9%

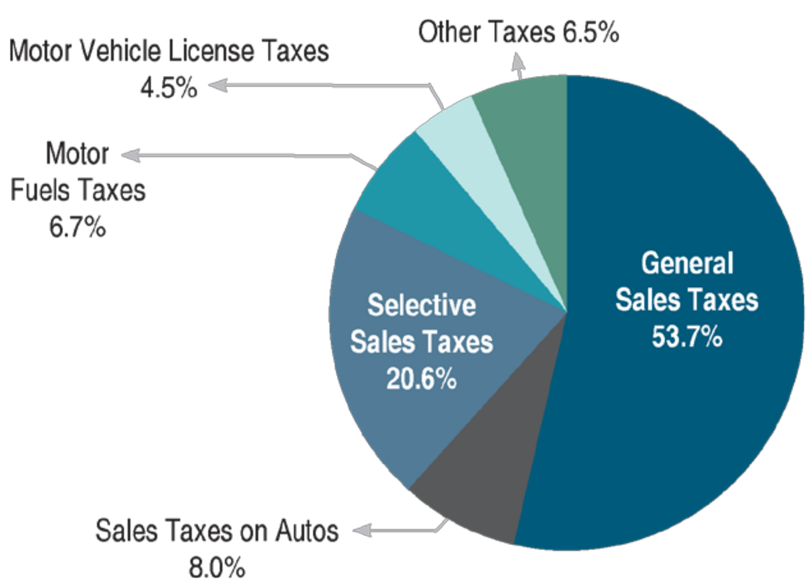
Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

Texas

Texas is a low tax state, both at the *state and local* and the *state*-only levels of government. (See Table 2.) The state relies very heavily on the sales tax and has no income tax. (See Table 3.) Texas' revenue share from both motor vehicle license and motor fuel excise taxes is higher than the average state, but this is because Texas has lower tax burdens overall rather than high license and excise tax rates. The gasoline and diesel tax rates are both lower than the average state. (See Table 4.) Texas' motor vehicle-related taxes accounted for 19.9 percent of revenues in 2016, and the share is estimated to decline to 18.4 percent by 2025. (See Table 12.) Texas has the largest share of revenue arising from vehicles in both years.[62]

Texas' decline in the vehicle share of taxes is similar to California and Tennessee's relatively low percentage loss under Scenario 1.[63] But Texas' loss in overall revenue is the highest of any state given the state's large reliance on vehicle taxes and no electric vehicle tax. Texas loses between one-fifth and one-third of the vehicle contribution under the other scenarios, 2-4.

Figure 7: Texas Distribution of State Taxes



[62] Texas motor vehicle-related taxes include motor vehicle registration, motor vehicle title, and driver's license fees; gasoline, motor vehicle rental, driver's license point surcharges, driver record information, diesel fuel, motor vehicle inspection, and seller-financed sales taxes; and sales tax on motor vehicle sales.

[63] Driver's license point surcharges and driver's licenses are assumed to fall inversely with AV increases and to equal zero at full phase-in.

Table 12: Texas Revenue Simulations (thousands of dollars)				
Panel A				
Scenario 1: Eliminate 50% of vehicles and phase in AVs over 15 years				
	2025	2030	2040	Change, 2025 to 2040
Total vehicle-related	13,774,264	12,686,132	8,506,004	-5,268,260
Total revenue	74,823,221	88,472,181	124,118,724	49,295,503
Lost revenue	0	2,984,844	12,521,450	12,521,450
Vehicle share of revenue	18.4%	14.3%	6.9%	-11.6%
Panel B				
Scenario 2: Eliminate 40% of vehicles and phase in AVs over 30 years				
Total vehicle-related	13,774,264	14,670,358	16,792,695	3,018,432
Total revenue	74, 823,221	90,456,408	132,405,416	57,582,195
Lost revenue	0	1,000,617	4,234,759	4,234,759
Vehicle share of revenue	18.4%	16.2%	12.7%	-5.7%
Panel C				
Scenario 3: Eliminate 0% of vehicles and phase in AVs over 30 years				
Total vehicle-related	13,774,263	15,401,008	20,195,097	6,420,833
Total revenue	74,823,221	91,187,058	135,807,817	60,984,597
Lost revenue	0	269,967	832,357	832,357
Vehicle share of revenue	18.4%	16.9%	14.9%	-3.5%
Panel D				
Scenario 4: Eliminate 40% of vehicles and phase in AVs over 50 years				
Total vehicle-related	13,774,264	15,317,919	19,426,892	5,652,628
Total revenue	74,823,221	91,103,968	135,039,612	60,216,391
Lost revenue	0	353,056	1,600,562	1,600,562
Vehicle share of revenue	18.4%	16.8%	14.4%	-4.0%
Panel E				
Revenue without autonomous vehicles				
	2016	2025	2030	2040
Total vehicle-related	10,383,149	13,774,264	15,670,975	21,027,454
Total revenue	52,132,817	74,823,220	91,457,024	136,640,175
Vehicle share of revenue	19.9%	18.4%	17.1%	15.4%

Source: Author's calculations based on data from state comprehensive annual financial reports (CAFRs), budget summaries, general fund statements, and other sources; see pages 46-47 for the appendix and methodology.

Policy options

States have the opportunity to reform their tax systems in advance of the AV revolution. Early adoption of reforms offers several key advantages. First, the industry could develop more efficiently if businesses and consumers know the tax structure they will face in advance and can plan accordingly. States with the most conducive policies have a better chance of attracting more long-term economic benefits. Second, tax revenue losses will be limited with a smooth transition from a structure based on fossil fuels and vehicle stock to one based on mobility. Third, new laws enacted relatively soon can occur before new industries and practices develop around existing tax structures. Overcoming entrenched interests with the status quo makes reform more difficult, as evidenced by the difficulties enacting reform to taxation of online transactions. Fourth, AVs are likely to be adopted unevenly within and across states and slow adopters could be significantly disadvantaged without reform. For example, rural areas will probably move to AVs more slowly, so without reform rural residents could continue paying taxes based on fossil fuels and numbers of vehicles while urban residents benefit from lesser-taxed shared electric vehicles. The following are three options for states to consider as they reexamine their transportation-based tax structures, although the proposals should not be seen as mutually exclusive.

Tax transportation services

States could tax transportation services rather than the inputs to transportation, such as vehicles and fuel, particularly if most services are delivered via fleet-owned AVs. The sales tax would be levied directly on the value of any purchased transportation services, and fleet companies could be exempt on their purchases of inputs, such as the AVs used to deliver the service.[64] The sales tax would still be levied on individual purchases of AVs. This option is built around the existing sales tax structure, so it does not require a new method of taxation even though it is imposed on a new service. Presumably, the existing fuel and vehicle taxes would remain in place and would be paid by users of the combustion engine vehicle stock and, where applicable, by AVs. Over time, taxes on fossil fuels used on highways would be eliminated as fossil fuel vehicles go away. Vehicle license taxes and other non-fuel-based revenue instruments could be unchanged by this reform.

The net effect on total state tax revenue could increase, decrease or stay the same with a tax on mobility services, depending on the transportation tax rate (the standard sales tax rate or a differential rate for transportation services) and the breadth of the base versus the current taxation of transportation. Defining taxable transportation services very broadly would be the best reform because it would limit planning around the tax system, lead to more stable revenue,

[64] Other taxes on mobility companies could be envisioned, as well. For example, a gross receipts tax could be imposed, rather than a sales tax, by not allowing deductions for intermediate transactions. A tax on profits could also be considered.

and reduce the potential to effectively subsidize (by lesser taxation) certain forms of mobility. A sales tax on transportation would be more revenue elastic than the existing quantity-based excise taxes on fuel. The revenue would also be more stable than the sales tax on vehicle transactions because mobility would be less volatile during recessions than the purchase of vehicles.

Impose VMT taxes

States could impose a tax on all vehicle miles traveled, regardless of whether via AV or traditional transportation modes. A VMT tax represents a more significant transformation in state taxation, and it could be tied to the phasing out or immediate elimination of fuel taxes (and perhaps some other transportation-related taxes, as well). The technology necessary to implement VMT taxes should be easily available in coming years, and much of the revenue would ultimately be collected from fleet companies, although much or all of the tax would likely be forward-shifted to consumers. VMT taxes offer some strong advantages, including the direct link between usage of transportation infrastructure and the tax paid, and the ability to collect the revenue from both AVs and the existing stock. Tax rates could also be adjusted to account for time of day or other congestion factors, which could improve efficiency in the use of transportation infrastructure. Oregon has implemented an optional VMT program, California experimented with road user charges in 2017, and Utah is planning to implement a VMT charge experiment. Motorists who have signed up for the VMT program in Oregon are reported to drive 10 to 14 percent less.

Every measurement technology raises some challenges, with many concerns focused on privacy and government knowledge of individual travel behavior. The decision about which technique to use requires careful tradeoffs of technology and benefits. The use of road sensors to measure VMT has been criticized on the basis of privacy, and measuring mileage with the vehicle odometer is an option raised to lessen the privacy concern. It should be noted that privacy would be much less of a concern if AVs are fleet-owned because the government will not know who was using the vehicle for particular travel. California offers some experience because it tried several technologies, but it generally concluded that the costs of implementation were too high.[65]

Again, the revenue implications depend on the rate that is set; it could be structured to be revenue neutral or increase or decrease relative to existing revenue. Revenue should be relatively stable as VMT would be more consistent across the business cycle than sales of vehicles, and should be nearly as stable as fuel taxes.[66] A mechanism should be in place to adjust rates over time to ensure that revenues have some elasticity or the existing problem of low elasticity of fossil fuel taxes would remain. Without periodic rate adjustments, revenues would rise only with VMT and the ability to keep transportation infrastructure updated would be significantly

[65] See State Tax Notes, January 9, 2019.

[66] As noted above, an initial increase in VMT is expected with AVs, but the increase at the point of transition between driven cars and AVs does not imply that use will continue to grow rapidly over time, except with additional riders. The expected one-time increase in VMT should be considered when the initial VMT rate is set.

inhibited. For example, rates could be indexed to the rate of inflation so that real revenue would rise only with increases in VMT.

Congestion charges

Congestion costs can be internalized by imposing higher prices or tolls during peak times.[67] Fleet companies already have an incentive to internalize congestion costs by charging users higher prices during peak usage times to account for the longer time spent in travel and ration access to services. Alternatively, states have the option of imposing a congestion charge to ration use of the roads in peak times and charge consumers for the externalities imposed on other users. Thus, a key issue is how congestion charge revenue should be distributed between fleet owners and the government. Although private firms should be compensated for any costs arising from longer travel time, the public sector could receive revenue associated with other congestion costs, such as negative externalities.

Conclusion

A new mobility regime of fleet-owned, autonomously operating, electric vehicles is on the horizon beginning in the next decade. The regime will structurally transform how mobility is provided, significantly alter the tasks performed by related employees, and offer important tax revenue implications. States have linked their transportation taxes to fossil fuels, number of vehicles and number of drivers. They are likely to see significant revenue declines in coming years with the movement to electric vehicles, reduction in the number of vehicles and decline in drivers and the associated licenses and penalties. The losses stem from underlying changes in these tax bases, but the timing of the losses depends on the interval during which the new regime develops. Simulations for six states estimate that revenue reductions could range between 2.0 and 9.2 percent of total revenue and 60 percent or more of transportation revenue once AVs are fully adopted. The losses rise with the relative roles that transportation taxes play in total taxes and the relative contribution of taxes on fuel versus on vehicles. Losses are smaller if states impose an electric vehicle tax. Losses occur sooner if AV adoption happens more quickly and are greater if fewer AVs are needed to replace the existing vehicle fleet. Finally, transportation revenue is generally more inelastic than aggregate revenue, so relative declines in transportation tax revenue are occurring even before the population transitions to AVs.

States currently have a window to reform their tax structures prior to the transitions described here. Options, which are not mutually exclusive, include imposing a sales tax (or a gross receipts tax) on mobility, levying a VMT tax, and imposing congestion charges. Adoption of new tax

[67] New York imposes a congestion surcharge on certain vehicles riding in Manhattan. This approach differs dramatically from the proposal here, which would be levied on all vehicles during times when infrastructure capacity is more challenged.

structures will be easier if done before vested interests get established and will allow public- and private-sector decision-makers to best understand the tradeoffs that they will confront.

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Appendix
Data and Methodology

This section describes the approach used in developing the scenarios for the six states. The same approach could be used to create estimates for other states. Four basic steps were followed. First, the taxes and charges directly linked to vehicles were identified. A form of some, such as fuel taxes, can be found in every state. Many other taxes and charges have somewhat different structures across states, or at least have different names. Second, state-level tax revenue data were obtained from the U.S. Census Bureau or from individual states (such as through their websites). In some cases, it was necessary to contact states directly to better understand revenue sources or to obtain the data. It was necessary to estimate the data in several cases. The baseline was adopted as 2016. Analysts in each state should be much better able to identify the vehicle-related taxes and the appropriate data sources.

Third, the effects of AVs on tax revenue were normally estimated by manipulating revenue and not tax bases because the former are generally more available than the latter. Tax revenue is projected to rise from 2016 until AVs begin coming to market (assumed to be 2025) at the compound annual rate that revenue rose from 2000 to 2016.[68] The calculations were made separately for each specific revenue source and for each state. Simulated 2025 tax revenue then serves as the baseline for the analyses. Revenue was assumed to continue rising from 2025 until 2040 at the same rates in the no AV/no electric vehicle scenario (Panel E). Revenue was reduced in the other scenarios according to the assumptions about adoption rates for AV/electric vehicles and the number of AVs needed to replace the existing vehicle stock. Current tax policy is adopted, including any rate increases that have already been enacted. AVs are assumed to increase VMT by 20 percent as they are adopted, which increases taxes on tires, for example. Thus, the underlying tax bases are assumed to continue growing or declining as they have historically, except for the effects of AVs.

Tax revenue generally depends on the sale of fuel (such as gasoline or diesel fuel taxes), the sale or size of the vehicle stock, penalties and fines, and the number of tires or drivers. Also, two states have taxes on electric vehicles. Each tax source was treated separately to determine how revenue is affected by adoption of AVs. Fuel-based taxes were assumed to decline in proportion to the increase in AVs and to fall to zero when AVs are fully phased in as electric vehicles. Vehicle-based taxes are presumed to fall proportionally from the baseline number of vehicles (which is measured by revenue) to the expected number of vehicles, although state-specific growth rates based on the 2000-16 period are still occurring during the simulation period. Registration revenue is estimated to fall proportionately to the required number of AVs over the phase-in period, depending on the number of AVs needed to replace internal combustion engine

[68] A shortened time period was used when data were not available for the entire 16-year window.

vehicles. The number of drivers and the amount of penalties and fines are assumed to fall proportionately with growth in AVs so that both become zero when AVs are fully phased in.

Two taxes were presumed to experience revenue growth. Tire-related revenues were assumed to grow at their underlying rate plus a 20 percent increase because of growing VMT per person as AVs are adopted. All AVs are presumed to be electric, so electric vehicle tax revenue grows with the number of AVs. This estimate was based on the current number of vehicles per person (which falls if the number of AVs is smaller than the number of internal combustion engine vehicles) and an estimate of the population, assuming that state population continues to rise at the same rate as between 2010 and 2018.

Fourth, assumptions were made on when AVs will begin coming to market, the length of the phase-in period until AVs fully replace internal combustion engine vehicles, the relative number of AVs to replace internal combustion engine vehicles, and so forth. These assumptions are varied to create the range of estimated state revenue losses presented in the scenarios above. Other scenarios could be developed as well. Straight-line adoption of AVs is assumed across the phase-in periods, but this could be adjusted, such as assuming an initial slow AV adoption rate followed by acceleration as the vehicles become better accepted.