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Comment Clifford Winston

Introduction

For several decades, a familiar refrain to motivate policy discussions about how to improve the performance of the nation's largest civilian public investment has been "America's road system is deteriorating, and urban traffic congestion is worsening." As early as Pigou (1920), economists have argued that efficient transportation infrastructure policy maximizes the difference between the social benefits and cost of its provision and use, including the

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costs that users impose on one another, by specifying pricing guidelines to regulate demand and investment guidelines to specify design.

In a 1991 *Journal of Economic Perspectives* paper, I summarized the basic theory of optimal pricing and investment and the empirical evidence on the economic effects of the policy, which showed the potential for large annual welfare gains from more durable roads and reduced maintenance costs, less congestion and savings in travel time, and a significantly improved national highway budget balance.[1] Thirty years later, America's road system is still not being efficiently maintained, traffic congestion continues to worsen in more urban areas, and the federal Highway Trust Fund routinely runs deficits, while economists have provided more evidence that strengthens the case for using efficient transportation infrastructure policy to improve the system's performance.[2]

Despite the accumulating evidence, policy makers continue to eschew efficient pricing and investment. Instead, they have repeatedly claimed that the United States has been experiencing an infrastructure crisis that can be solved only by raising large amounts of revenue to fund repaving and expanding the road system. Large-scale infrastructure spending gained traction as a response to the impact of the coronavirus on the US economy, with President Trump calling for a $2 trillion package that would be used to restore the nation's roads, bridges, tunnels, and ports. Newly elected President Biden is proposing a $1.9 trillion infrastructure policy.

Beginning with Aschauer (1989) and Munnell (1990), the macroeconomics literature has supported policy makers' approach by producing evidence that increasing investment in the highway capital stock spurs productivity growth. Melo, Graham, and Brage-Ardao (2013) survey more recent literature.

Given that many microeconomists have remained dubious about repeated claims of large potential returns to increased spending on highway infrastructure because the glaring inefficiencies in current investment policy would reduce those potential returns, one would think that micro- and macroeconomists would have engaged in a debate on this issue.[3] However, direct engagement has not occurred, which has been a source of frustration for transportation economists like me, because we stress that efficient pricing is

1. The theory is applicable to all transportation infrastructure in addition to highways and has been applied to airports, air traffic control, and ports. I discuss only highways here.

2. Chapter 3 in this volume, by Giles Duranton, Geetika Nagpal, and Matthew Turner, concludes that the condition of the US road system is generally not deteriorating. However, roads may still not be in good condition in certain metropolitan areas with a large amount of traffic. In addition, as I discuss later, pricing and investment policies to keep roads in good repair have been inefficient for decades. Thus, to the extent that the condition of the US road system has been maintained or even improved, the increasing public expenditures to achieve this outcome have been excessive.

3. Chapter 4 in this volume, by Valerie Ramey, is a rare macroeconomic analysis that shows how inefficiencies can compromise infrastructure investment returns.

a vital prerequisite for making efficient infrastructure investments and we argue that analyses that neglect efficient pricing do not yield useful policy recommendations.

I mention this tension to disclose that I am not an impartial commenter on the chapter by Leah Brooks and Zachary Liscow, which focuses on explaining the variation across states in the cost per mile of new Interstate highway construction from 1956 to 1993 and concludes that while a large variation exists, it cannot be explained by any single influence among the subset that they consider. My perspective leads me to take immediate issue with the authors' chapter because it is not directed at making more efficient use of the current highway capital stock, valued at more than $3 trillion (Winston 2013), and it does not develop an efficiency benchmark from a transportation economics perspective to assess the historical construction of the highway capital stock.[4]

In what follows, I provide perspective on the challenges to improving the current road system by updating and expanding the components of an efficient transportation infrastructure policy that I discussed 30 years ago and by summarizing the critical inefficiencies in current transportation policy that reduce returns from highway spending. Against this background, I offer some comments on the Brooks and Zachary chapter that stress the importance of developing an efficiency benchmark to guide an assessment of the relative efficiency of states' construction spending. I then argue that the politics of highway infrastructure policy, which has generally prevented constructive policy reforms, may change in the future as autonomous vehicles gain widespread adoption and use by travelers and trucking companies. This watershed moment in the development of transportation is likely to create potentially large political costs for policy makers by making the costs of inefficient highway policies that have compromised nonautonomous road travel for decades much clearer to the public. Finally, I stress the importance of transportation economics as a fundamental approach for identifying ways to improve highway infrastructure.

An Update of Efficient Transportation Infrastructure Policy

Small and Verhoef (2007) provide a rigorous theoretical overview of efficient pricing and investment policy for automobiles and trucks. Recent

4. According to the Federal Highway Administration, roughly 92 percent of current public road mileage and 90 percent of current Interstate Highway mileage had been completed by 1980. Weighted to account for road use, as measured say by vehicle miles traveled, those fractions of completed mileage would probably be even greater because roads for more heavily traveled routes were generally constructed earlier. I am grateful to Don Pickrell for providing the data that underlie the figures, which are contained in Federal Highway Administration, *Highway Statistics 2018*, table HM-220 (https://www.fhwa.dot.gov/policyinformation/statistics/2018/pdf/hm220.pdf), and "The Dwight D. Eisenhower System of Interstate and Defense Highways, Part VI— Interstate Status and Progress," final table (unnumbered) (https://www.fhwa.dot.gov/highwayhistory/data/page06.cfm#b).

empirical research has broadened our perspective on the policy's potential benefits and on the growing costs of its absence. Recent research has also quantified other critical inefficiencies in highway policy, including inflated input and project costs, misallocation of highway revenues, the protracted time to complete projects, and the slow adoption of technological innovations that could improve operations and safety.

Efficient Highway Pricing and Investment

Highways provide the capacity to accommodate travel by cars and trucks, in the form of traffic lanes, as well as durability, in the form of pavement strength, to facilitate use by heavy trucks. Highway users impose costs on one another by contributing to congestion, which increases all users' travel time and reduces the reliability of trip times, as well as by wearing out the infrastructure, which necessitates maintenance expenditures to repair damaged pavement and vehicles.

Highway pricing and investment rules jointly constitute an efficient long-run policy, in which a user's full marginal cost is determined at the optimal levels of capacity and durability. The efficient pricing rule establishes congestion tolls and pavement wear charges so that users are charged for the social marginal costs of their trip. The technology available to set those prices more accurately and to charge highway users without disrupting their journey has greatly improved during the past 30 years.[5]

Today, a highway authority can set real-time congestion tolls by using data generated by travelers' use of GPS navigation services to determine traffic volume on a stretch of road during a given time interval and by drawing on plausible congestion-cost estimates available in the empirical literature and even available by experimentation. Singapore, for example, is well known for its sophisticated congestion-pricing scheme, which varies sharply by location, the extent of congestion, and time of day. Singapore's introduction of a global navigation satellite system will further improve the accuracy of road pricing.[6] Stockholm uses video analytics to identify the license plates of cars without transponders that facilitate automated congestion payments.

The extent of pavement damage depends on a truck's weight per axle, where the damage caused by an axle is defined in terms of the number of equivalent standard-axle loads (ESALs) that would cause the same damage; the standard is a single axle bearing an 18,000-pound load. Efficient road pricing encourages truckers to reduce their ESALs or weight per axle whenever possible by shifting to trucks with more axles (or by adding an axle to their truck), thus extending pavement life and reducing highway-maintenance expenditures and vehicle-repair costs (Small, Winston, and Evans 1989).

5. Vickrey (1963) outlined how congestion pricing could be implemented in practice using cameras at toll booths and sending motorists a bill by mail.

6. Lehe (2019) provides a recent review of urban congestion pricing schemes.

A highway authority can implement an axle-weight tax by estimating a truck's ESAL miles using high-speed weigh-in-motion technologies, which use sensors that are installed in one or more traffic lanes to identify a vehicle and record its number of axles, vehicle load, and location while the vehicle continues to travel in the traffic stream. The total charge would then be calculated as the product of the truck's ESAL miles and a plausible estimate of the resurfacing costs per ESAL mile, which would vary by road type indicated by location, and would be sent to the truck's owner.

The efficient investment rule calls for capacity and durability to be provided to the point where the marginal benefit from increasing investment in each dimension equals its marginal cost. Expanding highway capacity may be difficult in certain urban areas where land is not available to widen a road. And in cases where a congested area has expanded road capacity by adding a lane or even a new road, the new capacity is likely to be filled to a large extent in the long run by travelers who formerly avoided the congested thoroughfare, a phenomenon known originally as Downs's law (1962) and now widely referred to as "induced traffic."[7] Expanding road capacity will provide temporary benefits in travel time savings to current road users as well as benefits to new travelers drawn to the improved road, but the only way to reduce congestion permanently is to set an explicit price for capacity.

Optimal highway durability is achieved by minimizing the sum of up-front capital costs when the road is being built and the recurring maintenance costs that are necessary to keep it in good repair. Small and Winston's (1988) critique of the pavement thickness guidelines from the American Association of State Highway and Transportation Officials concluded that optimal thicknesses were significantly higher than those that the guidelines dictated for current and actual thicknesses, especially on heavily traveled Interstates. For example, Small and Winston estimated that the optimal thickness for heavily traveled rigid concrete pavements is 13.8 inches, compared with AASHO's estimate of 11.2 inches. Increasing thickness by 2.6 inches would more than double the life of the pavement. Greater road thicknesses would substantially reduce periodic maintenance expenditures and, because they would lower the marginal cost of an ESAL mile, would also soften the impact of efficient pavement wear charges on truckers.[8]

Finally, the different capacity and durability requirements of cars and trucks suggest that highway engineers unnecessarily inflated construction costs by designing freeways to accommodate both cars and trucks in the same lanes. Because cars account for the vast majority of traffic, they require several lanes but their weight does not require thick pavement, while heavy trucks require fewer lanes with thicker pavement. If policy makers designed

7. Duranton and Turner (2011) report evidence supporting Downs's law in their analysis of a cross section of US cities.

8. I am not aware of more recent evidence comparing optimal and current highway durability.

freeways that separated cars and trucks, they could have built fewer expensive lanes with thick pavement.

Recent empirical evidence identifies additional potential benefits that strengthen the case for efficient highway pricing and investment policies, including lower vehicle repair costs, greater reliability of travel, improved land use, and better public health. Smoother pavements would reduce the wear and tear on motorists' and truckers' vehicles. Driving on damaged roads is estimated to cost US motorists $130 billion in additional annual operating costs and repairs (The Road Information Program 2019), and to impose significant costs on truckers. Smoother traffic flows would result in more reliable travel that motorists would value approximately as much as they value reduced travel times (Small, Winston, and Yan 2005). By substantially reducing residential sprawl because the out-of-pocket cost of commuting would no longer be underpriced, taxpayers would benefit from improved land use patterns that increase residential density and lower the cost of public services (Langer and Winston 2008). And less congested travel would improve adults' and infants' emotional and physical health by reducing stress, whose costs include domestic violence, and pollution (see Winston and Karpilow 2020 for a survey of the evidence).

A less studied potential benefit from efficient pricing and investment, which I discuss below in the context of autonomous vehicles, is that reducing the cost and improving the speed and reliability of highway travel would also improve the efficiency of other major sectors of the US economy, including trade, labor, urban, and industry.

Reducing Project Costs and Choosing Socially Beneficial Projects

Efficient highway policy calls for roads to be built and maintained at minimum cost and for policy makers to allocate highway funds to projects that yield the greatest social benefits. However, various regulations have increased the cost of the inputs used to build highways and the time required to do so. In addition, policy makers have not allocated highway funds to projects that produce the largest social benefits because projects are often selected for political or geographic "equity" reasons.

State and federal (Davis-Bacon) regulations have increased wages and expanded the labor force that is hired to manage and complete highway projects. Together, federal and state transportation departments currently employ roughly 200,000 workers in part just to ensure that projects meet all regulations. Winston (2013) surveys the evidence on those inflated labor costs. Buy America requirements for construction materials used in Federal-Aid Highway projects, such as bridge repairs, raise costs when less expensive foreign materials could have been used without sacrificing quality (Platzer and Mallett 2019).

The complexity of the planning process, regulations on highway design, and other factors may also increase the time costs to complete highway projects. Before highway authorities can begin actual roadwork, they must perform engineering analyses and obtain permits indicating that they have satisfied National Environment and Policy Act (NEPA) and, if applicable, state environmental quality reviews to ensure that projects are built in a safe and responsible manner and that they will not adversely affect the environment and communities. Gallen and Winston (forthcoming) summarize evidence that the average time to complete such a NEPA review has grown sharply over time and that the permitting process for major projects may take as long as 10 years.

Once roadwork begins, project managers may have to form work zones, which reduce capacity, slow travel speeds, and delay vehicles. A work zone is an area of a road where construction, maintenance, or utility-work activities occur, and it is typically marked by signs (especially ones that indicate reduced speed limits), traffic-channeling devices, barriers, and work vehicles. The Federal Highway Administration estimates that work zones accounted for nearly 900 million person-hours of traveler delay in 2014 (Work Zone Management Program 2016). Valued at even half the (private) average hourly wage (the US Department of Transportation's guideline for valuing most local travel) in 2014 of $24.50, work zone delays create an annual welfare loss of nearly $11 billion, and the losses persist even if a project is not delayed.[9]

There are many ways to spend highway funds to reduce the social costs of road travel, including congestion and traffic accidents. However, earmarked or demonstration projects, which have become a growing political cost of ensuring that multiyear federal transportation bills are passed, as well as highway funds that are allocated throughout the country generally do not satisfy those objectives. Money from the federal Highway Trust Fund for highway projects is distributed among states based on formulas that produce inefficient allocations because they include factors, such as a state's size, that are not accurate indicators of road congestion. Winston and Langer (2006) found that holding the level of spending constant, highway officials could reduce highway costs $13.8 billion per year, accounting for users' congestion costs and states' highway expenditures, if expenditures were explicitly targeted to those areas of the country with the greatest congestion. In addition, Metropolitan Planning Organizations often misallocate highway funds within urban areas because they target them to meet many objectives other than reducing social costs.

Adopting the Latest Technologies

As noted, technological advance is an important part of an efficient infrastructure policy because it can enable policy makers to implement real-time

9. US Department of Transportation, "Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis," December 2016 (https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic).

efficient prices for cars and trucks. Policy makers can also adopt the latest technologies to enable investments to improve highways' design characteristics and maintenance at modest cost and to enhance traffic safety.

To take some examples, Ng and Small (2012) pointed out that most highways in major metropolitan areas operate in congested conditions during much of the day, yet highway design standards are based on free-flow travel speeds. Highway authorities could effectively expand capacity during peak travel periods to reduce delays by adjusting the number and width of lanes on a freeway in response to real-time traffic volumes that are measured by GPS navigation services. To enable vehicles to move faster, heavy traffic volumes would call for more but narrower lanes, while lighter traffic volumes would call for fewer but wider lanes.

Technology exists to install lane dividers that can be illuminated so that they are visible to motorists, and so that they can also be adjusted in response to traffic volumes to increase or decrease the number of lanes that are available. As I pointed out previously, adding road capacity in dense urban areas where land is scarce is a very expensive proposition; however, installing variable lane widths could overcome prohibitive construction costs and benefit motorists.

The rapid evolution of material science (including nanotechnologies) has produced advances in construction materials, construction processes, and quality control that have significantly improved pavement design, resulting in greater durability, longer lifetimes, lower maintenance costs, and less vehicle damage caused by potholes. For example, Little et al. (1997) estimated that the SUPERPAVE effort in the late 1980s and 1990s (Transportation Research Board 2005), which developed new asphaltic binder specifications for repaving, produced roughly \$0.7 billion (in 2020 dollars) in such benefits.

Other investments that apply recent advances in material science technologies are also possible, but they are often delayed because state departments of transportation try to minimize their expenditures—rather than the sum of their own and highway users' costs—and because departments of transportation award contracts on the basis of the minimum bid, not on the technological sophistication of the contractor (Winston 2010). Finally, state departments of transportation have been slow to implement advances in roadway structural monitoring technologies that would allow them to monitor the health of both pavements and bridges on a continuous basis, thus providing valuable information for optimal repair and rehabilitation strategies that could reduce the cost of highway services (Lajnef et al. 2011).

The large benefits of highway travel have been tempered by the recurring social costs of vehicle accidents, which, accounting for vehicle damage, injuries, and fatalities, run in the hundreds of billions of dollars (Winston and Karpilow 2020). Winston and Mannering (2014) summarized ways that technological advances could help improve road safety, including modernizing traffic signal control and basing it on real-time traffic flows; using

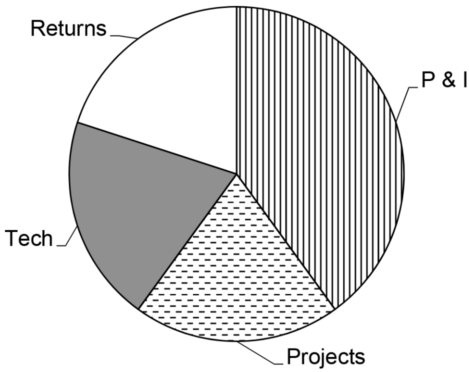

Fig. 2C.1 Highway returns and policy inefficiencies

photo-enforcement technology (roadside cameras) to enforce speed limits and other traffic laws, and to reduce dangerous high-speed police chases; and making much greater use of information technology to reduce the time to dispatch incident response teams to help accident victims and to advise motorists to avoid areas where incidents have recently occurred.

Summary

During the past 30 years, research in transportation economics has indicated that the cost of highway policy inefficiencies is substantially greater than was previously estimated from simple deadweight loss diagrams of the failure to impose congestion pricing and cost minimization calculations that found excessive maintenance costs. Inefficient pricing and investment, excessive production costs, misallocated funds, and slow technological advance have wasted hundreds of billions of dollars of the nation's expenditures on its highway capital stock, contributed to the decline in the road system's efficiency, missed opportunities to increase the pace of highway safety, and by doing so have reduced the efficiencies of other important sectors in the US economy.

Figure 2C.1 presents a pie chart to illustrate how the extensive waste generated by highway policy inefficiencies eats away at the potential returns from investments in the road system and leave at best a modest share in actual improvements for operators and users.[10] Shirley and Winston (2004) developed a theoretical argument that highway infrastructure investments generated benefits by lowering firms' inventories and estimated returns from those investments based on that mechanism. The authors found that annual

10. The divisions in the pie chart are hypothetical based on plausible assumptions that the largest source of inefficiency is attributable to suboptimal pricing and investment and that the inefficiencies related to technology adoption and project costs and selection are also significant.

returns have fallen over time to less than 5 percent by the 1990s, and they suggested that their finding could be partly explained by the cumulative impact of policy inefficiencies. Winston and Langer (2006) estimated that in a given year, one dollar of highway spending reduced users' congestion cost only 11 cents in that same year, and that those cost savings quickly dissipated in subsequent years because of road depreciation.

Implications of the Discussion for Brooks and Liscow

The main implication from my extended discussion of efficient transportation infrastructure policies for Brooks and Liscow is that all highway policies, including but not limited to spending, should be evaluated against an economic efficiency benchmark. When assessing the construction of the Interstate Highway System, the optimal level of construction costs per mile should be determined as part of a dynamic welfare maximization investment problem where capacity and durability design solutions account for the expectations of demand (road use by cars and heavy trucks) and capital and maintenance costs, subject to regulatory, technological, and geographical constraints. States' actual construction costs should then be compared with their optimal construction costs—instead of compared with the median construction cost, as Brooks and Liscow do, or even with a minimum cost achieved by a particular state—to assess individual states' and the nation's construction cost efficiency.[11]

My discussion identified factors that are likely to exacerbate dynamic inefficiencies. For example, suboptimal prices lead to excessive road use and wear and tear, which may distort expectations of demand and costs, while regulations of labor and capital inputs, misallocated funds, protracted times to build road projects, and continued reliance on obsolete technology are likely to raise highway spending significantly. Brooks and Liscow report that the cross-state variation in labor costs explains none of the temporal increase in highway construction spending per mile. However, as I pointed out, labor expenditures have been inflated by state and federal (Davis-Bacon) regulations; reforming those regulations could produce at least a one-time permanent reduction in construction costs.

The authors' omission of an efficiency benchmark raises questions about comparing construction costs across states. Why is the median cost of construction a desirable benchmark for assessment? Perhaps higher construction costs reflect greater concerns with long-run efficiency and require better—but more costly—materials and design. States with lower construction costs may be sacrificing long-run efficiency, as has proven to be the case

11. Estimated construction costs for roads built to optimal capacity and durability can be determined from analyses by Keeler and Small (1977) and Small and Winston (1988), respectively, for completed US highways.

for states that underbuilt heavily used pavements and bridges. States with higher construction costs may be more efficient than other states because they are better prepared to provide highway services for large flows of traffic that include significant heavy truck operations, or they may have designed their roads to better withstand ice and snow, which can cause pavements to crack and become more susceptible to damage caused by heavy trucks. The authors' conclusion that the Interstate Highway System could have cost billions of dollars less to build if all states' construction costs were at the median value begs the question of whether such a state's road system would be more efficient in the long run than are other states' road systems. I am not aware of any evidence that states whose construction costs approach the median are known for their relatively efficient highway investment programs.

In sum, while the authors document cost disparities, they do not identify states that could possibly serve as a model for others in optimizing highway construction costs and they do not explain why those states, if any exist, were successful. It is quite possible that inefficiencies that have contributed to cost disparities were present at the start of the federal Interstate Highway System and have persisted for decades, and there is little reason to expect that policy makers are planning to pursue efficient reforms in the near future.

Political Economy and the Potential for Future Improvements in the System

The issue of why policy inefficiencies exist for so long is a challenging political economy puzzle for scholars and practitioners. Becker (1983) long ago asked rhetorically, Why can we not allocate resources so that an inefficiency is eliminated and that everyone shares in the efficiency improvement, with the gainers compensating the losers if necessary?

Inefficient highway policies have their roots in the 1950s, and policy makers have shown little interest in reforming them. In the absence of strong causal evidence, Winston (2021) concluded that status quo bias appears to be more consistent with the evidence on the persistence of policy inefficiencies than are other explanations. For example, New York City politicians have long expressed their opposition to congestion pricing on the grounds that it would place an undue burden on a large share of their constituents, who commute by car and do not have the option to use other modes to avoid a high peak-hour toll. Yet, Assemblyman David Weprin, the most vocal and a successful opponent of the 2018 New York City tolling plan, and the plan's sponsor, Robert Rodriguez of East Harlem, had the same share of constituents who would have to pay the new toll—a mere 4.2 percent.

One year later, a negative shock appears to have overcome the status quo bias that impeded congestion pricing in New York City—namely, the increasingly desperate financial situation of the city's transit system. Some form of congestion pricing is now likely to be implemented in Manhattan, with much of the toll revenue used to finance transit operations and improvements. However, the US Department of Transportation has not yet approved the city's congestion pricing project, and its implementation is expected to be delayed for a few years.

Highway budget deficits, attributable to a federal gasoline tax that has not been raised since 1993 while motor vehicle fuel economy has increased significantly, have caused some policy makers to consider a tax on vehicle miles traveled (VMT) as an alternative to a higher federal gasoline tax to raise highway revenues.[12] A VMT tax could be designed to vary by time of day and location and to charge vehicles for their contribution to congestion, pavement wear, emissions, and safety costs. Langer, Maheshri, and Winston (2017) present evidence that a hypothetical urban-rural differentiated VMT tax would be more efficient than raising the federal gasoline tax. Oregon and Utah are testing a VMT tax, and other states have indicated an interest in doing so, but such a tax has yet to be implemented anywhere in the country.

A different negative shock during the 1970s, high rates of inflation, arguably played a role in influencing policy makers to deregulate large parts of the intercity transportation system, which greatly improved its performance and benefited rail and truck shippers and airline travelers (Winston 2021). However, there has been very limited interest among policy makers in privatizing and deregulating US transportation infrastructure, and scholarly assessments have not suggested that widespread adoption of such a policy would produce significant social benefits.[13]

Looking further into the future, it is entirely possible that a positive shock—namely, the introduction and widespread use of autonomous vehicles—could spur policy makers to adopt more efficient highway infrastructure policies. Winston and Karpilow (2020) argue that autonomous vehicles represent a watershed moment in the development of transportation, which promises not only to vastly improve road travel and generate huge benefits to travelers, shippers, and delivery companies, but also to benefit major sectors of the US economy by reducing congestion and virtually eliminating vehicle accidents. The authors estimate that their overall impact on annual GDP growth is likely to exceed one percentage point.

To be sure, autonomous vehicles are still undergoing development and testing. However, Winston and Karpilow (2020) argue that policy makers

12. Some states have raised their gasoline taxes to help fund highway projects.

13. Public-private partnerships have a limited history in the United States. In recent years, investments have amounted to $20 billion to $40 billion, and the gains have been small; see Engel, Fischer, and Galetovic (2014) and their chapter in this volume. Winston and Yan (2011) simulated the effects on travelers of privatizing highways in Southern California and found that travelers could benefit from faster and more reliable travel in certain circumstances. However, in practice, the United States has no experience with highway privatization where the goal of the policy was to generate competition between highway providers that would improve the efficiency of road travel. It is uncertain whether policy makers could design a competitive private highway system effectively and that sufficient managerial talent exists to operate competing highway companies in the United States that would remain profitable and that would provide highway services that would raise motorists' welfare.

pose a greater risk than do industry participants to how soon US society realizes the huge potential benefits of autonomous vehicles, because policy makers could fail to remedy the inefficiencies in highway pricing, investment, and production policies that have compromised travel by nonautonomous vehicle for decades and that must be reformed to enable autonomous vehicles to operate efficiently and safely.

The global pandemic caused by the coronavirus has given new meaning to the familiar phrase "the whole world is watching." Taking a more positive perspective, the whole world will be watching in the future as countries, and cities and states within those countries, compete intensely to successfully develop and adopt autonomous vehicles. Given the enormous benefits at stake and the visibility and importance of global, interstate, and intercity competition, policy makers who weaken their jurisdiction's autonomous vehicle operations by failing to reform their highway policies may incur large political costs.

Transportation Economics and Transportation-Related Issues

Scholars should be attentive to research in their field that is conducted by scholars in other fields, especially because such research may provide new insights and reveal shortcomings in a scholar's own field. However, in my less than objective view, research on transportation infrastructure by scholars in fields other than transportation economics has shown that transportation economics has a serious marketing problem within the economics profession.

I indicated in the introduction a major difference in the approaches of macroeconomists and transportation economists to improving transportation infrastructure and the absence of a debate to resolve that difference. More recently, I have become concerned that literature in other fields that addresses a transportation-related issue has neglected research in transportation economics on pervasive policy inefficiencies and its importance for drawing useful policy recommendations.

Perhaps transportation economics research is perceived as directed toward a small share of the economy. That is a misapprehension: Winston (2013) points out that pecuniary spending on transportation accounts for 17 percent of GDP, that time expenditures by travelers and shippers are comparable to pecuniary spending, and that both public and private investments in transportation capital are enormous. Given that transportation is an input into virtually all activities in an economy, using the insights of microeconomic transportation analysis as a foundation for understanding how to improve the productivity of the broader economy should be a key research priority.

My discussion of autonomous vehicles illustrated how transportation can have significant implications for major economic sectors and the US and global economy. Future research in transportation economics is likely to draw on big data and artificial intelligence to analyze autonomous vehicle operations in detail and to quantify with increasingly greater accuracy how that innovation affects many activities and sectors throughout an economy. The evolution of future research on autonomous transportation systems and their effects on the broader economy may help to overcome the perception of the field's narrowness. At the same time, I hope that the distinct features of transportation economics—specifically, its sound microeconomic foundations, disaggregated empirical work, and close attention to the efficacy of government policy—will gain greater appreciation by other economists and that the economics profession will give greater recognition to the field's contributions and importance.

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