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## Comment Stephen J. Redding

One of the pieces of conventional wisdom about the US economy is its decaying infrastructure. On a recent report card, the American Society of Civil Engineers (ASCE) awarded US infrastructure a grade of D+. According to an article in the *New York Times* (John Holusha and Kenneth Chang,

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“Engineers See Dangers in Aging Infrastructure,” August 2, 2007), “many of the nation’s 600,000 bridges are in need of repair or replacement. About one in eight has been deemed ‘structurally deficient,’ a term that typically means a component of the bridge’s structure has been rated poor or worse, but does not necessarily warn of imminent collapse.” While these views are widely accepted in the public policy debate, they sit somewhat awkwardly with the empirical evidence presented in chapter 3, which suggests that if anything the condition of the US Interstate Highway System has improved over the past 20–30 years. These findings raise the important question of what explains this disconnect between the conventional wisdom and the empirical evidence in chapter 3. Is the conventional wisdom simply factually incorrect, in which case the evidence presented in this chapter will permit a better-informed public policy debate? Alternatively, is there a political economy explanation for the widely held perception of the poor state of US transport infrastructure? Or do the official metrics on the conditions of highways and bridges reported in chapter 3 provide an incomplete picture of its state of health? Can past values of these official measures, for example, predict known cases of bridge collapse or other failures of transport infrastructure?

More broadly, this chapter makes three main contributions to our understanding of US infrastructure. First, the chapter documents the quantity and quality of US roads, bridges, buses, and subways in each year in recent decades. Second, the chapter investigates total expenditure and unit cost for each type of infrastructure over this period. Third, it proposes a simple theoretical framework that can be used to compare actual infrastructure investments to alternative possible investments. In my view, all three of these contributions are hugely valuable. The authors are undertaking a tremendous public service in collecting together in one place comprehensive data on the performance of the US transportation network and providing a tractable framework for evaluating the provision of different types of transport infrastructure. As a result, I think that the chapter will be highly influential and widely cited. In the remainder of my comments, I focus on three main points. First, I review some of the evidence on infrastructure costs. Second, I consider the issue of market failures and the potential divergence between private and social marginal returns to alternative forms of transport infrastructure. Third, I examine the benefits of infrastructure investments.

Beginning with infrastructure costs, this chapter and Mehrotra, Uribe, and Turner (2019) replicate an earlier finding by Brooks and Liscow (2019) of a substantial rise in total expenditure and construction cost per lane mile of Interstate Highway since the early 1970s. When I first encountered this finding, I thought that it had a natural explanation in terms of the Balassa-Samuelson effect from macroeconomics. According to this explanation, productivity growth in the manufacturing sector raises worker wages, which bids up costs for nontraded sectors such as construction that use

labor. However, this explanation is straightforward to rule out, because the rise in Interstate construction costs is not driven by a rise in labor costs. Another potential explanation could be that Interstate Highways today are more likely than in the past to be built in urban locations with a higher cost of land than rural locations. But the rise in Interstate construction costs is also not explained by higher costs of land or by a range of other controls for observable location characteristics relevant for construction costs, such as terrain and topography.

Resolving this puzzle ought to be a major objective for the research literature and the public policy debate going forward. There remain several plausible potential explanations on which further evidence is needed. For example, the timing of the construction of different segments of the Interstate is likely to be nonrandom, giving rise to a selection problem. The first segments of the Interstate to be constructed are likely to have been those with highest benefits relative to costs. If later segments have lower benefits relative to costs, and some of this decline in net benefits is explained by higher costs, this could explain a rise in construction costs per lane mile of Interstate Highways over time. Another potential explanation could be that a lane mile of Interstate today is not the same as a lane mile of Interstate in the past, so that we are not comparing like with like. For example, if there is greater provision of sound walls or other features today than in the past, and these features provide benefits such as lower noise or air pollution, these benefits should be taken into account and weighed against the higher construction costs.

A further possibility involves political economy considerations, such as greater representation of the concerns of local residents over time. While construction costs for some early segments of the Interstate were relatively low, this could have come at the cost of adverse consequences for the neighborhoods that they bisected. A famous example is the Cross-Bronx Expressway in New York, which was driven through the heart of the Bronx, with potential negative consequences for social and economic interactions within this neighborhood. As argued in Brinkman and Lin (2019), resistance to initial routes for Interstate Highways increased over time, and costly rerouting of highways to reduce the negative disamenities to local residents could in part explain rising construction costs over time. Again economic benefits to local residents in terms of neighborhood preservation should be offset against higher construction costs as part of a wider cost-benefit analysis of the impact of Interstate Highway construction.

Turning now to the issue of market failure, the authors compare relative expenditure and relative usage for different forms of transport infrastructure. They argue that the fact that we spend about the same amount on public transit buses, which provide about two billion rides per year, as on the Interstate System, which provides nearly a trillion miles of vehicle travel per

year, should be central to the policy debate. I agree, and in drawing attention to relative levels of usage and government expenditure on different forms of transport infrastructure, the authors perform a valuable service. However, it would be useful to have more discussion earlier in the chapter about market failures and their relevance for government expenditure on alternative transport modes. This is a point of which the authors are well aware. Indeed, the divergence between private and social marginal returns to transport infrastructure features prominently in the theoretical model developed toward the end of the chapter. Nevertheless, it would be useful to emphasize up-front that the rationale for government intervention rests on market failures and externalities. For example, if congestion pricing is either technologically or politically infeasible, one could argue that the congestion externalities from private car use contribute in part toward the case for supporting public transit. Additionally, since public transit is disproportionately used by individuals with lower income, one could argue that income distributional considerations should also be taken into account in evaluating the implications of government expenditure on alternative forms of transport infrastructure.

In this context, although the authors have already undertaken an impressive amount of work in assembling such comprehensive data on US infrastructure, cross-country comparisons could be informative. For example, given the extensive provision of public transit in many European countries, one would conjecture that they devote relatively more government expenditure to public transit than the United States does. Does this imply that relative expenditure is even more out of line with relative usage in these countries than in the United States? Can the United States learn anything from the European experience? Or do these differences in levels of public and private transport provision between Europe and the United States reflect two alternative equilibria? What is the role of local economic conditions, such as population density, in influencing the case for government expenditure on alternative forms of transport infrastructure? More broadly, what are the implications of new technologies such as ride hailing (for example, Uber and Lyft) and autonomous vehicles for government support for these alternative transport modes?

Turning finally to the benefits of transport infrastructure, a growing empirical and theoretical literature concerned with evaluating these benefits has emerged in recent years. One of the key challenges in evaluating the causal effects of transport infrastructure is that its placement is likely to be nonrandom, such that locations that receive more transport infrastructure could have developed more rapidly than other locations, even in the absence of the transport infrastructure. To overcome this challenge, an important strand of recent research to which the authors have been influential contributors has exploited quasi-experimental variation in transport networks

from, for example, strategic plans and historical exploration routes, including Baum-Snow (2007), Baum-Snow et al. (2017), Duranton, Morrow, and Turner (2014), and Duranton and Turner (2012).

Another key challenge is that transport infrastructure not only has direct economic effects on the locations through which it is constructed but also indirect effects on other locations, because of the reallocation of economic activity or general equilibrium interactions in goods and factor markets. To take account of these interactions and evaluate the real income effects of transport infrastructure investments, another strand of recent research has developed quantitative models of the spatial distribution of economic activity, including Ahlfeldt et al. (2015); Allen and Arkolakis (2014, 2017); Desmet, Nagy, and Rossi-Hansberg (2018); Donaldson (2018); Donaldson and Hornbeck (2016); Fajgelbaum and Schaal (2017); Redding (2016); Redding and Sturm (2008); and Tsivanidis (2018), as reviewed in Redding and Rossi-Hansberg (2017). These quantitative spatial models are rich enough to connect directly with central features of the observed data, such as gravity equations for goods trade and commuting flows, and yet remain sufficiently tractable as to permit transparent counterfactuals to evaluate the impact of alternative possible transport infrastructure investments on the spatial distribution of economic activity.

In the light of this recent research, it would be interesting to embed the demand for transport in the theoretical model developed by the authors in a richer quantitative structure that connects directly with the observed data. For example, one simple approach could be to view transportation as simply another economic activity that can be analyzed as a special case of Hulten's (1978) theorem. In particular, under the (strong) assumptions of a representative agent, no distortions and a closed economy, the change in aggregate real income ( $d \ln W$ ) from a small shock to productivity ( $d \ln A_i$ ) for an economy activity  $i$  can be evaluated as

$$(1) \quad d \ln W = \sum_i \lambda_i d \ln A_i,$$

where  $\lambda_i$  is the Domar weight (sales share) of economic activity  $i$ .

An advantage of this approach is that it can be used for either *ex ante* evaluation before transport infrastructure investments are made or *ex post* evaluation after these investments have been completed. A disadvantage is that for large changes in transport infrastructure, equation (1) holds only as a first-order approximation. More broadly, quantitative spatial models provide a framework for evaluating the impact of transport infrastructure investments on the spatial distribution of economic activity for both small and large changes. An example is provided by Redding (2016), which considers a model of trade in goods between locations connected by labor mobility. In this setting, the general equilibrium of the model can be summarized by two key equilibrium conditions: (1) goods market clearing such that income

in each location equals expenditure on goods produced in that location; (2) population mobility such that workers receive the same real income across all populated locations.

An important property of these quantitative spatial models is that the equilibrium conditions for a counterfactual transport infrastructure improvement can be written solely in terms of variables that are observed in an initial equilibrium (such as income and trade shares) and the assumed impact of the change in transport infrastructure on goods trade costs (or in other contexts on commuting costs or migration frictions). For example, in Redding (2016), the counterfactual goods market clearing condition (from the first equilibrium condition above) can be written as follows:

$$(2) \quad \hat{w}_i \hat{\lambda}_i Y_i = \sum_{n \in N} \hat{\pi}_{ni} \pi_{ni} \hat{w}_n \hat{\lambda}_n Y_n,$$

where locations are indexed by  $i$ ,  $n \in N$ ;  $w_i$  denotes the wage;  $Y_i = w_i L_i$  is income;  $L_i$  is population;  $\lambda_i$  indicates the population share ( $\lambda_i = L_i / \sum_{n \in N} L_n$ );  $\pi_{ni}$  is location  $n$ 's share of expenditure on goods produced by location  $i$ ; and a hat above a variable denotes its relative change between the counterfactual equilibrium (denoted by a prime) and the actual equilibrium (no prime), such that  $\hat{w}_i = w'_i / w_i$ . The relative change in trade shares ( $\hat{\pi}_{ni}$ ) satisfies

$$(3) \quad \hat{\pi}_{ni} \pi_{ni} = \frac{\pi_{ni} (\hat{d}_{ni} \hat{w}_i)^{-\theta}}{\sum_{k \in N} \pi_{nk} (\hat{d}_{nk} \hat{w}_k)^{-\theta}},$$

where  $\hat{d}_{ni} = d'_{ni} / d_{ni}$  is the relative change in the costs of trading goods between locations  $i$  and  $n$  as a result of the counterfactual changes in transport infrastructure.

Similarly, the counterfactual population mobility condition that equates real income across all populated locations (from the second equilibrium condition above) can be expressed as follows:

$$(4) \quad \hat{\lambda}_n \lambda_n = \frac{\hat{\pi}_{nn}^{-(\alpha\epsilon/\theta)} \hat{\lambda}_n^{-\epsilon(1-\alpha)} \lambda_n}{\sum_{k \in N} \hat{\pi}_{kk}^{-(\alpha\epsilon/\theta)} \hat{\lambda}_k^{-\epsilon(1-\alpha)} \lambda_k}.$$

Given observed data on income ( $Y_i$ ), trade shares ( $\pi_{ni}$ ) and population shares ( $\lambda_i$ ) in an initial equilibrium and assumed changes in goods trade costs from a counterfactual transport infrastructure improvement ( $\hat{d}_{ni}$ ), this system of equations (2), (3), and (4) can be used to solve for unique counterfactual changes in wages ( $\hat{w}_i$ ), trade shares ( $\hat{\pi}_{ni}$ ), and population shares ( $\hat{\lambda}_i$ ) in response to the transport infrastructure improvement. Using these solutions for changes in wages, trade shares, and population shares, one can in turn recover the change in real income across all locations. Therefore, through embedding the demand for transport in the theoretical model developed by the authors in a richer quantitative structure, the authors would be able to connect more closely with the data used in the first part of the chapter and

make richer quantitative statements about the impact of alternative forms of transport infrastructure on the spatial distribution of economic activity and real income.

Notwithstanding these comments and suggestions for future research, the authors already have written a great chapter. They have performed a hugely valuable public service in collecting together in one place comprehensive data on the performance of the US transportation network and providing a tractable framework for evaluating the provision of different types of transport infrastructure. The chapter should greatly enlighten the public debate about the current state of US infrastructure and the case for alternative forms of transport infrastructure investment.

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