Chapter 6

The Effects of Urban Public Transit Investment on Traffic Congestion and Air Quality

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Abstract

Traffic congestion is ubiquitous across urban roadways, and the adverse health effects accompanying deteriorating air quality are an ongoing concern. Beyond these local effects, transportation is also a major contributor of greenhouse gas emissions and is thus a significant element of the climate change debate. A contentious issue currently confronting transportation analysts and policy-makers is what the effects of public transit investment on traffic congestion and on air quality are and therefore what the appropriate level of public transit investment should be. While public transit receives plenty of political support for its "green" reputation and its contribution to sustainability, there have been relatively few studies examining the ex post–effects of public transit investment on traffic congestion or air quality. In this chapter, we review our theoretical and empirical research on the effects of public transit investment on congestion, the demand for automobile travel, and air quality.

Keywords: public transit, congestion, air quality

1. Introduction

Traffic congestion is ubiquitous across urban roadways and the adverse health effects accompanying deteriorating air quality are an ongoing concern. Beyond these local effects, transportation is also a major contributor of greenhouse gas emissions and is thus a significant element of the climate change debate.

The Texas Transportation Institute made headlines with its estimate of the annual costs of traffic congestion in the USA exceeding $120 billion in 2011 [1], owing primarily to the costs imposed by excessive traffic levels on travel times for freight and personal travel. Studies have shown that traffic congestion is the number one concern of individuals in rapidly growing areas in the USA, often ranked higher than crime, school overcrowding, and housing shortages [2].

Urban transportation not only leads to traffic congestion but also to air pollution. In 2010, vehicle emissions in the USA contributed to an estimated 2200 premature deaths and more than $18 billion in public health expenditures [3].

It is clear that the market failures endemic to the urban transportation sector are not being adequately addressed by existing regulatory policies [4]. The market failures in the auto and transit sectors have long been of interest [4].

The government has two potential roles in the surface transportation sector. The first potential role for government is to provide transportation infrastructure in the form of roads and public transit systems and also to operate public transit services. Once the infrastructure is in place, the second potential role for government is to employ policy instruments (such as taxes and other forms of regulation relating to safety, environmental standards, travel demand management policies, and so forth) in order to address the market failures that are inherent to unregulated transportation activity and also to determine the operational aspects of public transit service [4, 5].

A contentious issue currently confronting transportation analysts and policy-makers is what the effects of public transit investment on congestion and on air quality are and therefore what the appropriate level of public transit investment should be [4]. While public transit receives plenty of political support for its "green" reputation and its contribution to sustainability, there have been relatively few studies examining the ex post effects of public transit investment on traffic congestion or air quality [4].

For example, previous empirical studies examining the relationship between transit supply and traffic congestion are limited, and the findings of these studies vary [4]. There is also an ongoing debate in policy circles regarding the efficacy of public transit investment as a means of addressing traffic congestion, for example [6–8], all display skepticism regarding the congestion-reduction possibilities of public transit, while [9] advocates for transit investment [4]. Although investment in public transit may lead to short-term reductions in congestion due to a "substitution effect," in the long run, it may be less effective due to the "induced demand effect" [4, 10, 11].

Similarly, while several studies have considered the relationship between automobile travel and air quality, there have been relatively few empirical studies looking at the effect of public transit on air quality [4]. Although there is generally a consensus that auto travel leads to adverse health outcomes, there is very little empirical evidence on the incremental effect that public transit supply may or may not have on air quality [4].

With $18 billion spent on public transit capital in the USA each year [12], it is imperative to assess the effects of these expenditures on transportation activity and the environment and what path future investment should take [4].

In this chapter, we review our theoretical and empirical research on the effects of public transit investment on congestion, the demand for automobile travel, and air quality. In Ref. [5], we

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develop a theory model to evaluate whether public transit investment has a role in reducing congestion a second-best setting. In Refs. [11, 13], we empirically analyze the effects of public transit investment on the demand for automobile travel and on air pollution, respectively, by applying an instrumental variable approach that accounts for the potential endogeneity of public transit investment to a uniquely created panel dataset of 96 urban areas across the USA over the years 1991–2011.

Our results in Ref. [5] suggest that investments in public transit may have a co-benefit of congestion reduction. Thus, when analyzing potential public transit projects using a cost-benefit analysis framework, interactions between auto and transit users should be taken into account. However, while public transit investment may be able to play a complementary role, efficient pricing of auto travel remains necessary to address traffic congestion in the USA [5].

Our results in Ref. [11] show that, owing to the substitution effect, increases in public transit supply lead to a reduction in the demand for automobile travel, but that this reduction can be offset at least in part by induced demand. Moreover, the magnitude of the effect of public transit on the demand for automobile travel is subject to heterogeneity across urban areas. We also find in Ref. [11] that, for both the substitution effect and the equilibrium effect (which incorporates both the substitution effect and induced demand), public transit supply does not reduce the demand for automobile travel until the demand for automobile travel exceeds a minimum threshold and that beyond this threshold the magnitude of the negative elasticity of the demand for automobile travel with respect to transit capacity increases with the demand for automobile travel [11].

In Ref. [13], we analyze the effects of the level of transit supply on ambient concentrations of carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. We find that—at the margin and given existing urban travel regulations in place—there is no evidence that an increase in transit supply improves air quality [13].

Our research in Refs. [11, 13] improves upon previous empirical studies by using a broader set of urban areas over a longer time period than previous studies and by allowing for heterogeneity in the effects.

Our results have important implications for the design of sustainable transportation policy and for urban transport systems and are of interest to academics and policy-makers alike.

2. Literature review

In this section we review the related literature. We provide a thorough and detailed literature review in Ref. [4].

2.1. Congestion

When externalities arising from auto travel are not internalized, these auto market distortions may have implications for the optimal level of public transit investment. If the speed of auto travel is independent of the volume of transit service, then the second-best transit capacity that accounts for the distortion in the auto market is higher than the first-best transit capacity that would be provided if there were no auto market distortions that needed to be accounted for (e.g., if the auto market distortions were already separately addressed via a Pigouvian tax) [4, 5, 14]. However, if auto and transit modes are interdependent, then the optimal level of transit capacity to provide depends on the extent to which public transit affects the deadweight loss associated with auto travel [4, 5, 15–17].

According to the "fundamental law of traffic congestion," while investment in infrastructure may lead to short-term reductions in congestion, in the long run, it will be ineffective in the absence of efficient pricing due to "induced demand" (often referred to as "latent demand") [4, 5, 11, 18].

The existing empirical evidence on the effect of public transit on traffic congestion is unclear [4]. In their analysis of the effects of rail transit investment on the share of public transit ridership [19], find that, consistent with the "fundamental law of traffic congestion" and the presence of induced demand, rail transit investment does not reduce congestion levels, though it does lead to reduced commuting times for the subset of commuters that switch from bus to rail [4, 19].

In their study of the effects of roadway expenditures on the cost of congestion [10], find that increases in the mileage of rail transit lead to a reduction in congestion costs, but that increases in bus service actually increase congestion costs. Their results are consistent with a congestion externality interdependency between auto and transit travel [4, 10].

In their test of the "fundamental law of traffic congestion" [20], find compelling evidence of induced auto demand, with increases in road capacity being met with commensurate increases in auto travel [4, 20].

In his analysis of travel speeds before and during a transit labor dispute within the Los Angeles transit system in 2003 [21], finds that the average highway delay increased by 47% when transit service ceased operation. The results of Refs. [21–23] provide convincing evidence of the effects of transit at the extensive margin when compared with the counterfactual scenario of no transit service [4].

In their study of the impact of bicycle-sharing infrastructure on urban transportation [24], find that the availability of a bikeshare reduces traffic congestion over 2–3% within a neighborhood. They also find that the congestion-reducing impact of bikeshares is concentrated in highly congested areas [24].

The effects of public transportation and the built environment on the number of civilian vehicles in China are analyzed by Liu and Lin Lawell [25], who apply a two-step Generalized Method of Moments (GMM) instrumental variable model to city-level panel data over the period 2001–2011. The results show that increasing the road area increases the number of civilian vehicles, which provides empirical support for the "fundamental law of traffic congestion" in China. In contrast, increasing the public transit passenger load decreases the number of civilian vehicles, suggesting that public transportation and civilian cars are substitutes. The effects vary by city population, however. For larger cities, increases in the number of public buses increase the number of civilian vehicles, but increases in the number of taxis and in road area decrease the number of civilian vehicles. They also find that land use diversity increases the number of civilian vehicles, especially in the higher-income cities and in the extremely big cities. There is no significant relationship between civilian vehicles and per capita disposable income except in mega cities [25].

Overall, the existing empirical evidence of the effect of transit investment on traffic congestion is mixed [4, 11]. The conflicting conclusions of previous studies may also be due to differences in empirical methodologies employed and the characteristics of the dataset used. Our work in Ref. [11] uses a broader set of urban areas over a longer time period than previous studies, and the regional heterogeneity that our results in Ref. [11] indicate helps to reconcile the seemingly conflicting evidence from the previous literature.

2.2. Air quality

While several studies have considered the relationship between auto travel and air quality [3, 26–28], and the effects of transportation policies such as driving restrictions on air quality [29, 30], there have been relatively few empirical studies looking at the effect of public transit on air quality [4].

In particular, while there is generally a consensus that auto travel leads to adverse health outcomes, there is very little empirical evidence of the incremental effect that transit supply may or may not have on air quality [4]. Two recent studies have provided an initial look at the relationship between transit supply and air quality. Using hourly air quality data from Taipei [31], find that the new rail system's opening reduced carbon monoxide by 5–15% but had little effect on ground level ozone pollution [4, 31]. In their analysis of the environmental effect of expanded rail service in Germany over the period 1994–2004 [32], find that increases in rail service frequency lead to a reduction in some pollutants (NO, NO_2, and CO), though not others (SO_2 and O_3) [4, 32].

The effects of public transit on air quality depend on the relative demand substitutability between auto and transit, and on the extent to which the emission rates vary between auto and transit travel, and are therefore an empirical issue [4]. As the relationship between transit and observed pollution levels is theoretically ambiguous, it is difficult to impute the effect of transit on air quality based on previous studies that focus on the effects of auto travel on air quality [4, 33].

3. Results

In this section we review our theoretical and empirical research on the effects of public transit investment on congestion, the demand for automobile travel, and air quality.

3.1. Theory of public transit investment and traffic congestion policy

In Ref. [5], we develop a theory model to evaluate whether public transit investment has a role in reducing congestion a second-best setting. The model enables us to evaluate the extent to which traffic congestion should be accounted for when evaluating investment in public transit infrastructure when a Pigouvian congestion tax cannot be levied on auto travel. We contribute to the literature by allowing for both demand and cost interdependencies across the auto and transit modes. We find that the level of transit investment should be higher relative to that chosen when the congestion-reduction effects of transit are not accounted for. The importance of accounting for the congestion-reduction effects of transit depends upon the demand and cost interdependencies across the auto and transit modes, which may vary across regions [5].

Our results in Ref. [5] suggest that investments in public transit may have a co-benefit of congestion reduction. Thus, when analyzing potential public transit projects using a cost-benefit analysis framework, interactions between auto and transit users should be taken into account. However, while public transit investment may be able to play a complementary role, efficient pricing of auto travel remains necessary to address traffic congestion in the USA [5].

3.2. The effects of public transit supply on the demand for automobile travel

On average, the total hours of delay attributable to congestion in urban areas in the USA have more than tripled over the past three decades, during which there has been an 83% increase in auto travel, a 16% increase in transit travel, and a 16% increase in travel times [11].

Over the last two decades, the volume of public transit travel in the USA has increased by 43% [11]. During this period, the overall transit network coverage (directional route miles) has increased by approximately 35%, while the capacity provided over the network (vehicle miles per directional route mile) has increased by approximately 11%, yielding an overall increase in total vehicle miles supplied by public transit of 50% [11].

Although investment in public transit may lead to short-term reductions in congestion due to a "substitution effect," in the long run, it may be less effective due to the "induced demand effect" [10, 11]. In Ref. [11] we empirically analyze the effects of public transit investment on the demand for automobile travel by applying an instrumental variable approach that accounts for the potential endogeneity of public transit investment to a uniquely created panel dataset of 96 urban areas across the USA over the years 1991–2011. We estimate both the short-run substitution effect and the longer-run equilibrium effect that account for both the substitution effect and the induced demand effect [11].

To estimate the substitution effect, we run the following regression [11]:

$$autotravel_{rt} = \beta_1 transit_{rt} + x'_{rt}\beta_2 + \alpha_r + \varepsilon_{rt}, \qquad (1)$$

where $autotravel_{rt}$ is the demand for auto travel in region r in year t, as measured by the number of vehicle miles traveled per freeway lane mile; $transit_{rt}$ is the public transit supply in region r in year t, as measured by vehicle revenue miles; x_{rt} is a vector of control variables in region r in year t, including freeway capacity, arterial road capacity, fuel cost, transit fare, employment, income, population, year, and year squared; and α_{rt} is a region fixed effect. We use instruments to address the endogeneity of public transit supply $transit_{rt}$ [11].

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To estimate the equilibrium effect accounting for both the substitution effect and the induced demand effect, we remove the factors associated with the induced demand effect (employment, income, and population) and instead control for their initial levels in the base year of 1991. In particular, we run the following regression [11]:

$$autotravel_{rt} = \beta_1 transit_{rt} + x_{rt}'\beta_2 + \varepsilon_{rt}, \quad (2)$$

where $autotravel_{rt}$ is the demand for auto travel in region r in year t, as measured by the number of vehicle miles traveled per freeway lane mile; $transit_{rt}$ is the public transit supply in region r in year t, as measured by vehicle revenue miles; and x_{rt} is a vector of control variables for in region r in year t, including freeway capacity, arterial road capacity, fuel cost, transit fare, employment in the base year 1991, income in the base year 1991, population in the base year 1991, year, and year squared. We use instruments to address the endogeneity of public transit supply $transit_{rt}$ [11].

To address the potential endogeneity of public transit investment, we use two sources of instrumental variables for public transit investment in our analyses in Ref. [11]. The first instrument we use is lagged political voting records. In particular, we use as instruments the Democratic voting share within the urban area averaged over lagged Presidential, Gubernatorial, or Senate elections [11, 13]. Democratic voters are much more likely than Republican voters to support referenda in relation to public transit investment [34]. Democratic voting shares are expected to be related to public transit investment through two channels: (1) through the effect on the total public funds budget and (2) through relatively stronger preferences for public transit and thus the allocation of total public funds directed to public transit [11].

Conditional on time-invariant region-specific factors that are absorbed by the regional fixed effects, changes in lagged voting records are not related to congestion except through their effect on public transit investment. Similarly, after controlling for employment rate, income, and population, factors causing changes in the lagged Democratic voting share within the urban area in Presidential, Gubernatorial, or Senate elections are unlikely to be related to factors that are causing changes in local congestion, as congestion is not an issue that influences elections above the local level. After conditioning on these variables, voting records can be interpreted as a proxy for underlying transit preferences in the region that is orthogonal to congestion [11].

The second instrument we use for public transit investment in our empirical analyses in Ref. [11] is the lagged level of Federal funds provided for transit in the region. While Local and State funds may be correlated with unobserved factors affecting regional congestion, conditional on time-invariant region-specific unobservables that are absorbed by the regional fixed effects, changes in lagged Federal funds are orthogonal to such potential factors [11].

The data we use in Ref. [11] covers 96 urban areas within 351 counties and 44 states across the USA and spans 21 years from 1991 to 2011. As defined by the Census Bureau, an "urban area" (UZA) refers to a region that is centered around a core metropolitan statistical area (MSA). The data we use in Ref. [11] relating to the auto travel components of each UZA's transportation network are primarily from the Texas Transportation Institute's Urban Mobility Report [1], which are the "best available means of comparing congestion levels in different regions and tracking changes in regional congestion levels over time" ([35], p. 17). The Urban Mobility Report measures traffic delay using data from the US Department of Transportation on traffic volumes and the characteristics of the city (see Ref. [10], p. 467 for discussion). While we measure congestion as the daily vehicle miles traveled per freeway lane mile, our empirical results in Ref. [11] are robust to the particular measure of congestion used.

Our results in Ref. [11] show that, owing to the substitution effect, increases in public transit supply lead to a reduction in the demand for automobile travel, but this reduction can be offset at least in part by induced demand. Moreover, the magnitude of the effect of public transit on the demand for automobile travel is subject to heterogeneity across urban areas. We also find in Ref. [11] that, for both the substitution effect and the equilibrium effect (which incorporates both the substitution effect and induced demand), public transit supply does not reduce the demand for automobile travel until the demand for automobile travel exceeds a minimum threshold and that beyond this threshold the magnitude of the negative elasticity of the demand for automobile travel with respect to transit capacity increases with the demand for automobile travel [11].

Our research in Ref. [11] improves upon previous empirical studies by using a broader set of urban areas over a longer time period than previous studies and by allowing for heterogeneity in the effects.

3.3. Evaluating the effects of transit supply on air quality

In Ref. [13], we analyze the effects of the level of transit supply on ambient concentrations of carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

In particular, we empirically analyze the effects of public transit investment on air pollution by applying an instrumental variable approach that accounts for the potential endogeneity of public transit investment to a uniquely created panel dataset of 96 urban areas across the USA over the years 1991–2011 [13].

We run the following regression for each air pollutant (CO, NO_2, O_3, PM_{10}, $PM_{2.5}$, and SO_2) [13]:

$$pollution_{rt} = \beta_1 transit_{rt} + x'_{rt}\beta_2 + \alpha_r + \varepsilon_{rt}, \tag{3}$$

where $pollution_{rt}$ is the ambient level of that air pollutant in region r in year t; $transit_{rt}$ is the public transit supply in region r in year t, as measured by vehicle revenue miles; x_{rt} is a vector of control variables for in region r in year t, including freeway capacity, arterial road capacity, fuel cost, transit fare, trucking activity, employment, income, population, pollution point sources, weather controls, and dummies for National Ambient Air Quality Standards; and α_{rt} is a region fixed effect. We use instruments to address the endogeneity of public transit supply $transit_{rt}$ [13].

To address the potential endogeneity of public transit investment, we use two sources of instrumental variables for public transit investment in our analyses in Ref. [13]. The first instrument we use is lagged political voting records. In particular, we use as instruments the Democratic voting share within the urban area averaged over lagged Presidential, Gubernatorial, or Senate elections [11, 13]. Democratic voters are much more likely than Republican voters to support referenda in relation to public transit investment [34]. Democratic voting shares are expected to be related to public transit investment through two channels: (1) through the effect on the total public funds budget and (2) through relatively stronger preferences for public transit and thus the allocation of total public funds directed to public transit [11, 13].

Conditional on time-invariant region-specific factors that are absorbed by the regional fixed effects, changes in lagged voting records are not related to air quality except through their effect on public transit investment. Similarly, after controlling for employment rate, income, and population, factors causing changes in the lagged Democratic voting share within the urban area in Presidential, Gubernatorial, or Senate elections are unlikely to be related to factors that are causing changes in local air pollution, as air pollution is not an issue that influences elections above the local level. After conditioning on these variables, voting records can be interpreted as a proxy for underlying transit preferences in the region that is orthogonal to air quality [13].

The second instrument we use for public transit investment in our empirical analyses in Ref. [13] is the lagged level of Federal funds provided for transit in the region. While Local and State funds may be correlated with unobserved factors affecting regional air quality, conditional on time-invariant region-specific unobservables that are absorbed by the regional fixed effects, changes in lagged Federal funds are orthogonal to such potential factors [13].

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For the air quality data in Ref. [13], we use daily air quality data for each Core-Based Statistical Area (CBSA) recorded by the Environmental Protection Agency (EPA) at monitoring stations that measure the ambient level of CO, NO_2, O_3, PM_{10}, $PM_{2.5}$, and SO_2. Each CBSA is then mapped to the UZA of our dataset. On average, 98.6% of the UZA population is contained within the CBSA [13].

According to the results of our empirical analysis of the effects of the level of transit supply on ambient concentrations of carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide in Ref. [13], we find that—at the margin and given existing urban travel regulations in place—there is no evidence that an increase in transit supply improves air quality [13].

Our research in Ref. [13] improves upon previous empirical studies by using a broader set of urban areas over a longer time period than previous studies.

4. Conclusion

It is clear that the market failures endemic to the urban transportation sector are not being adequately addressed by existing regulatory policies [4].

A contentious issue currently confronting transportation analysts and policy-makers is what the effects of public transit investment on traffic congestion and on air quality are and therefore what the appropriate level of public transit investment should be [4]. While public transit receives plenty of political support for its "green" reputation and its contribution to sustainability, there have been relatively few studies examining the ex post effects of public transit investment on traffic congestion or air quality [4].

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