Is Public Bus Transit a Competitor or a Subordinate to Public Rail Transit?

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Several US metropolitan areas are served by both bus and rail transit, setting up a possible competitive interface between the two modes. We study the effect of rail competition on the costs of bus operations by analyzing a sample of bus systems that serve 94 US metropolitan areas and a sample of light and heavy rail systems that serve 28 of those metropolitan areas. We find that the presence of a rail system significantly increases bus costs, with newer rail systems exacerbating this effect relative to older systems, and that this effect accounts for a notable share of transit's overall deficits. We discuss the possible mechanisms at work and suggest that they strengthen the case for the private sector to play a greater role in urban transportation to improve its efficiency.

Keywords: transit, bus, rail, cost, competition

JEL Codes: H42, L20, R48

I. INTRODUCTION

Public ownership and operation of urban transit has been a long-running experiment that followed in the wake of the financial contraction of private transit companies. The growth of household income and automobile ownership in the 1950s caused losses in ridership that in turn led private transit systems to incur large financial losses and confronted city governments with three choices: provide financial assistance and regulatory relief to the private systems and give them a chance to make adjustments that might enable them to once again become financially viable competitors; allow private transit companies to fail if they could not compete against the automobile without assistance; or convert transit companies to subsidized public enterprises, as a few cities had already done.

By 1964, city governments had overwhelmingly chosen the last option, in no small part because the Urban Mass Transportation Act of 1964 promised them federal grants to do so. But subsidizing public transit service did not improve its competitive position, and its market share of travelers in most urban areas has continued to decline to the point where it was below the share of telecommuters even before the COVID-19 pandemic. Currently, fewer than 5 percent of commuters use public transit, while at the same time transit's subsidies have continued to grow and now exceed $20 billion annually.

Because of its declining ridership and growing subsidies, transit's social desirability was in serious question before the COVID-19 pandemic (Winston, 2013).[1] The adverse trends in ridership and subsidies have only accelerated since the pandemic, making transit's social desirability even more doubtful. Since the pandemic began in 2020, farebox revenue has dropped to 19 percent of operating expenses, compared with 49 percent of operating expenses in 2019. At the same time, transit ridership remains down more than 25 percent nationwide—and more than 50 percent in some large cities—and is not expected to return to pre-pandemic levels for at least a decade, as some people who used to commute on public transit will instead work from home (Quiroz-Gutierrez, 2021). Transit has also continued to lose passengers because, as its ridership has declined, it has reduced service frequency and experienced higher crime rates (Bosman et al., 2022), causing some passengers to shift to alternative modes, such as automobile, and possibly not returning to transit even when the COVID-19 pandemic is over or transit's service and safety improve.

In response to the sharp drop in ridership and revenues, public transit has received additional taxpayer-funded subsidies in the form of nearly $70 billion of supplemental funding provided during the pandemic. Few limits have been set on the amount of time transit agencies have to spend the supplemental funding or on when they must return any of it.

Public transit's poor performance can largely be explained by demographic changes and operating disadvantages that have resulted in average load factors of less than 30 percent for most systems, which is far below break-even. Transit cannot keep pace as households' high levels of automobile ownership enable them to move to new suburban communities and exurbs (Baum-Snow and Kahn, 2005).[2] Transit's operations are characterized by the "streetcar problem," when during morning peak periods it commits seat capacity provided by large buses or trains composed of several passenger cars that are filled with passengers who access transit from their residences

[1] Anderson (2014) studies the Los Angeles metropolitan area and argues that the net benefits of public transit systems may be much larger than believed because they reduce congestion. However, it is important to assess whether safety is compromised when congestion is reduced (Maheshri and Winston, forthcoming). In addition, transit's benefits from reducing congestion could be achieved at a lower cost by implementing congestion pricing.

[2] Expansion of bus and rail are primarily limited by the cost, political difficulties, and the time needed to add new routes to increase service frequency (in the case of bus) or to construct new track to expand coverage (in the case of rail).

and board en route to a central destination. Almost the same capacity is offered throughout the day, but it is not filled again until evening peak periods when passengers return from the central business district to outlying residential areas.

Transit's load factors have fallen further when bus systems have expanded their networks and new rail systems have been built where there is low potential demand for public transit. Buses in cities such as Los Angeles were once able to fill nearly 50 percent of their seats over the course of a day; but today, bus transit's average load factor throughout the day in Los Angeles is less than 15 percent and rail transit's load factor is less than 30 percent. While we are not aware of a precise estimate of the break-even load factor for public transit, break-even load factors for airlines are roughly 70 percent.[3]

A notable feature of urban transportation is that many metropolitan areas are served by both bus and rail transit systems. When cities took over bus and rail operations, they could have benefited urban travelers by developing those operations such that multimodal transit service generated competition that would improve transit efficiency and increase its overall market share. Instead, cities have primarily developed their operations in ways that exacerbate transit inefficiencies by raising costs and increasing deficits that must be funded by taxpayers.

We are not aware of any evidence that suggests policymakers have sought to increase urban transit competition. We hypothesize that policymakers in cities with rail systems, which tend to be more heavily subsidized than bus systems, prefer that their rail system does not compete with their bus system. That is, they have designed bus system operations to play a subordinate and occasionally complementary role to the rail system. Such a system would increase the costs of the bus system by reducing its network efficiency and average load factors, without necessarily improving the financial condition of the rail system.

In this paper, we document the effect of rail competition on bus costs by analyzing a sample of bus systems that serve 94 US metropolitan areas and a sample of light and heavy rail systems that serve 28 of those metropolitan areas. We find that the presence of a rail system significantly increases bus costs, with newer rail systems exacerbating this effect relative to older systems, and that this effect accounts for a notable share of transit's overall deficits. We discuss the possible

[3] It could be argued that transit's financial problems, especially rail transit's, are attributable to inefficient road prices that do not account for automobile externalities and reduce their costs to travelers. However, Winston and Shirley (1998) find that transit's share would still decline if the urban transportation modes charged efficient marginal-cost prices and if transit provided optimal service frequency.

mechanisms at work and suggest that they strengthen the case for the private sector to play a greater role in urban transportation to improve its efficiency.

II. CONCEPTUAL APPROACH

Multimodal transit systems in US metropolitan areas appear to have a competitive interface because they serve many of the same origins and destinations. For example, when bus and rail provide downtown trips, bus routes often run directly above subway tunnels. Generally, rail fares are higher than bus fares, while rail offers faster trip times, especially as the trip distance increases. In theory, transit competition could lead to efficiency and reduce fares, but this does not occur in practice because transit fares are usually established through elaborate political negotiations, including contributions by local jurisdictions based on property or other taxes, and are insensitive to competitive forces that reduce costs.

Costs are therefore the relevant performance measure of bus transit that could be affected by the presence of rail service in a metropolitan area, and vice versa. In addition, the same agency typically operates both the bus and rail transit service in most cities that are served by both modes, so their cost structures are related and they suffer from the same inflated management overhead.

We hypothesize that transit agencies do not want to attract any unnecessary attention by running excessive deficits, so they avoid having bus and rail compete by giving rail competitive advantages to increase its revenues and decrease its (larger) budget deficits and drain on the public purse. Operationally, transit agencies might reconfigure their bus systems suboptimally to "force feed" their rail systems, inflating bus operating costs by exacerbating peaking, empty backhauls, deadheading, and the like. We test our hypothesis by estimating how the presence of rail operations affects the cost of bus operations.

We are not aware of previous work that has analyzed the interdependence of bus and rail transit costs; thus, we begin with a model that takes the following generic form:[4]

$$\text{bus cost} = f(\text{rail}, \text{output}, \text{capacity}, \text{input prices}, \text{service quality}, \text{other influences}) \quad (1)$$

The presence of rail is captured by a dummy variable, which we assume is exogenous because civic boosters and city officials play a vital role in bringing a rail system to a city through their

[4] Viton (1981) and Winston and Shirley (1998) developed equilibrium models of bus and rail transit competing against each other and the automobile.

considerable efforts to generate political support and obtain outside (usually federal) funding. Such efforts are made because rail systems are thought to enhance a city's reputation and prestige (Winston and Maheshri, 2007).

Even with the support of civic boosters and city officials, it can take decades for a city to have a rail transit system; for example, it took some thirty years for Baltimore's Light RailLink system to evolve from a proposal to serving passengers. The gestation period for the Los Angeles Metro Rail system took a similar length of time. A rail system's financial performance does not appear to be a factor because rail's profit motives evaporated when local governments took ownership of those systems and tightly regulated fares, which included subsidies, and did not adjust their service offerings in response to changing demographics. Even the private rail systems that existed previously had been subject to pricing regulations that compromised their profitability (Gómez-Ibáñez and Meyer, 1984).

The standard measure of a bus system's output is passenger-miles traveled, defined as the cumulative sum of the distances ridden by each passenger. Capacity is measured by a system's route-miles; input prices include fuel, wages, and capital costs for vehicles; and service quality is typically measured by travel speed and reliability.[5] Regarding other cost influences, bus transit companies are under less pressure to reduce costs if they receive additional revenues from dedicated taxes and they may incur additional costs by operating in difficult weather conditions or on unfavorable terrain.

Although equation 1 is a plausible specification of transportation costs, the primary goal of our analysis is to estimate the effect that the presence of a rail system has on bus operating costs, so it is important for us to exclude variables that could capture the effect of the rail system on those costs. For example, it is inappropriate to include passenger-miles in the specification because the presence of an alternative mode of travel, namely, rail, will decrease bus ridership. We therefore cannot hope to identify the true effect of rail presence on bus costs if we include bus passenger-miles as an explanatory variable. In place of passenger-miles, an important omitted variable, we include *current* population, which is highly correlated with passenger-miles but is arguably uncorrelated with the presence of rail, which appears to be explained by political factors and long-standing boosterism. Note that cities with large populations (e.g., Los Angeles) did not have a rail transit system until recently and older cities with smaller populations (e.g., Boston) have had a rail

[5] Buses use petroleum and diesel fuel, but their prices are highly correlated.

system for more than a century. We explore how our findings are affected by the choice of including current population or passenger-miles in the specification.

We should also not include region fixed effects because those would be perfectly correlated with the rail dummy, which does not vary for individual transit systems over our period of study.[6] Route-miles and average trip distance are also potentially problematic as explanatory variables because rail could serve destinations that bus might otherwise serve and because systems with rail tend to have shorter average trip distances for bus, especially where buses provide more feeder service and fewer long-distance trips.

Given the preceding considerations, we specify our base-case model of bus costs for transit system i at time t in a log-linear form as a function of the rail dummy and purely exogenous influences as:

$$\ln(\text{cost}_{it}) = \beta\ \text{rail}_i + \alpha_1 \ln(\text{population}_{it}) + \alpha_2 \ln(\text{fuel price}_{it}) + \alpha_3 \ln(\text{dedicated taxes}_{it}) + \alpha_4\ \text{days freezing}_{it} + \gamma_t + \varepsilon_{it} \tag{2}$$

We measure bus costs as operating expenses because it is not clear why the presence of rail also would affect bus capital costs.[7] The explanatory variable of interest is a time-invariant rail dummy indicating the presence of a rail system at location i. We classify a rail system to be either heavy rail (e.g., Washington's Metrorail system) or light rail (e.g., Dallas's DART Light Rail). As noted, population is used as an explanatory variable in place of passenger-miles.

Fuel price, specifically, the average price per gallon of gasoline, is assumed to be an exogenous influence on bus operating costs. Dedicated taxes levied by state or local governments generate revenues that can be used to offset excessive operating costs, which we contend are largely governed by exogenous political forces. Such revenues reduce the incentive for transit systems to operate efficiently, so we expect dedicated taxes to have a positive effect on operating costs, holding population constant. Days freezing refers to the number of days in the calendar year for which temperatures are below 32°F, an influence that increases bus maintenance costs and is

[6] There are two exceptions: Phoenix's Valley Metro Rail, which began operations in December 2008; and Virginia Beach's Tide light rail, which began operations in August 2011.

[7] We found through sensitivity tests that the results are not changed when we specify total costs, which include operating and capital costs, such as the annualized value of the bus fleet and structures.

clearly exogenous. Finally, include year fixed effects, γ_t, to control for macroeconomic factors that affect all transit systems in a year, and ε_{it} is the error term.[8]

III. SAMPLE AND DATA SOURCES

To construct our estimation sample, we considered the 100 largest metropolitan areas by population. After making some appropriate adjustments and accounting for limitations of some of the areas because of missing data, we assembled a balanced panel of 94 transit systems with annual data from 2002–18 that are included in the US Department of Transportation's (DOT's) National Transit Database.[9]

Table 1 summarizes the transit systems in our sample, which include 28 bus-and-rail systems and 66 bus-only systems. This sample enables us to identify the effect of a rail system on bus costs in both a geographic and temporal dimension.[10] We classify the systems as old if the system was operating during or before 1960 and new if the system began operating after 1960.[11]

We distinguish between old and new systems because we hypothesize that metropolitan areas attempt to increase ridership of their new, expensive rail systems by giving them priority over bus in terms of favorable routes and type of service. Metropolitan areas may be less likely to prioritize old rail systems, so the effect of those systems on bus costs may be less than the effect of new rail systems on bus costs. Rail was introduced to US urban transit beginning with the Boston subway in 1897; thus, it is not surprising that a narrow majority of bus-and-rail systems are old, but a clear majority of bus-only systems are relatively new.[12]

[8] Wages and capital costs do not vary sufficiently to permit their inclusion in the specification and their exclusion did not affect our main findings. We were unable to obtain data on exogenous measures of service quality.
[9] We dropped Hartford CT, New Haven CT, McAllen TX, and Poughkeepsie NY due to missing data, and we dropped Ogden UT and Provo UT because they belong to the same transit system as Salt Lake City UT.
[10] That is, some systems do and some do not have rail service at the same point in time, and systems that added rail service did so at different points in time
[11] We conducted sensitivity tests and found that our conclusions do not change much if we used 1965 or 1970 as a cutoff year to distinguish between new and old systems.
[12] As a point of qualification, some cities that only have buses today once had electric streetcars, which were replaced by buses once buses became less costly to operate. The earliest electric streetcar systems predate subways by a few decades.

Table 1. List of Transit Systems Considered

Bus-and-Rail Systems		Bus-Only Systems			
City	Age	City	Age	City	Age
New York	Old	Riverside	New	Albany	Old
Los Angeles	New	Detroit	Old	Knoxville	Old
Chicago	Old	Tampa	New	Baton Rouge	New
Dallas	New	Orlando	New	Oxnard	New
Houston	New	San Antonio	New	El Paso	New
Washington	New	Las Vegas	New	Allentown	New
Miami	New	Austin	New	Columbia	New
Philadelphia	Old	Cincinnati	Old	Sarasota	New
Atlanta	New	Kansas City	New	Dayton	New
Phoenix	New*	Columbus	Old	Charleston	New
Boston	Old	Indianapolis	Old	Greensboro	New
San Francisco	New	Nashville	Old	Fort Myers	New
Seattle	New	Providence	New	Stockton	New
Minneapolis	New	Milwaukee	Old	Boise	New
San Diego	New	Jacksonville	New	Colorado Springs	New
Denver	New	Oklahoma City	New	Little Rock	New
St. Louis	New	Raleigh	Old	Lakeland	New
Baltimore	New	Memphis	New	Akron	New
Charlotte	New	Richmond	Old	Des Moines	New
Portland	New	Louisville	Old	Springfield, MA	New
Sacramento	New	Birmingham	New	Winston-Salem	New
Pittsburgh	New	Grand Rapids	New	Deltona	New
Cleveland	Old	Rochester	Old	Madison	New
San Jose	New	Tucson	Old	Syracuse	New
Virginia Beach	New*	Fresno	Old	Durham / Chapel Hill**	New
New Orleans	Old	Tulsa	New	Toledo	New
Salt Lake City	New	Honolulu	Old	Wichita	Old
Buffalo	New	Omaha	New	Augusta, GA	New
		Worcester	New	Palm Bay	New
		Bridgeport	New	Jackson, MS	New
		Greenville	New	Harrisburg	New
		Albuquerque	Old	Spokane	New
		Bakersfield	Old	Chattanooga	Old

Notes: Old systems are bus-only systems that were in operation before 1960 or bus-and-rail systems where rail was in operation before 1960. Rail refers to light rail or heavy rail. The New Orleans streetcar system is classified as light rail. * Indicates that operations began mid-sample. ** Indicates that the transit systems were combined to coincide with the Metropolitan Statistical Area definition.

Table 2 presents summary statistics for the variables used in our estimations. Most of the data we use come from the DOT's National Transit Database. Population is at the level of the metropolitan statistical area and is from the US Census Bureau.[13] Weather data are from the National Oceanic and Atmospheric Administration and data on fuel prices are from the Energy Information Administration. All dollar values are deflated using the consumer price index and are expressed in real 2019 dollars.

Table 2. Summary Statistics

	Overall		Old Systems		New Systems	
	Mean	SD	Mean	SD	Mean	SD
Operating Cost	146,339,535	310,880,544	243,229,816	536,493,923	113,173,560	164,546,022
Passenger-Miles	130,261,960	246,240,983	190,040,717	363,314,781	109,799,425	186,155,769
Population	2,113,140	2,676,142	2,637,806	3,960,055	1,933,254	2,030,857
Income	41,623	10,399	41,739	8,731	41,583	10,916
Dedicated Taxes	44,889,469	200,676,480	84,490,654	360,536,636	31,333,807	94,463,620
Route Miles	533	425	500	315	544	456
Route Density	186	243	281	406	153	136
Fuel Price	3.551	0.789	3.581	0.800	3.540	0.785
Days Freezing	65	49	74	41	62	52

Notes: Old systems are bus-only systems that were in operation before 1960 or bus-and-rail systems where rail was in operation before 1960. All dollar values are expressed as 2019 dollars. Route density is thousands of people per route per year. Fuel price is dollars per gallon.

The old transit systems carry more passengers over a larger network, operate in larger cities, and, as expected, have higher total operating costs than the new systems. However, the systems have comparable operating costs per passenger-mile, suggesting that the old systems are unable to exploit possible economies of size and route density to significantly reduce operating costs.

IV. ESTIMATION RESULTS

We present ordinary least squares estimates of our base specification in equation 2 in column 1 of table 3. The central finding is that the presence of rail *increases* bus costs, and the effect is large and statistically significant: rail's presence increases bus costs by roughly 71 percent.[14] We

[13] We collapse the transit systems of Chapel Hill NC and Durham NC into one system because they belong to the same metropolitan statistical area.

[14] Recall that the percentage impact of a dummy variable on the dependent variable in a log-linear regression is equal to $100 \times (\exp(b - \mathrm{SE}(b)^2/2) - 1)$, where b is the estimated coefficient on the dummy variable and $SE(b)$ is the estimated standard error of b.

discuss below the specific mechanism by which the presence of rail increases bus costs after we finalize our discussion of the estimates. The remaining variables in the model have their expected signs, as population (a proxy for demand), gasoline prices, dedicated taxes, and days below freezing also bear a positive relationship to bus costs. Overall, the model fits the data well, with an R^2 of .83, even though we have not included passenger-miles.

Table 3. Estimation Results

Log Operating Expenses	(1)	(2)	(3)
Rail	0.555***	0.399***	0.204***
	(0.194)	(0.075)	(0.072)
Log Population	1.199***		
	(0.105)		
Log Passenger-Miles		0.835***	0.936***
		(0.032)	(0.031)
Log Gasoline Price	3.378***	0.223	–0.146
	(1.246)	(0.289)	(0.400)
Log Dedicated Taxes for Operations	0.014**	0.002	–0.002
	(0.007)	(0.002)	(0.003)
Days below Freezing	0.004***	0.001***	0.001***
	(0.001)	(0.0001)	(0.0001)
Estimator	OLS	OLS	IV
R^2	0.833	0.958	0.952
No. of Observations	1,596	1,596	1,596

Notes: All specifications include year fixed effects. The specification in column 3 uses log population as an instrument for log passenger-miles. Robust standard errors clustered at the transit-system level are shown in parentheses. Statistical significance is indicated at the ***1%, **5%, and *10% levels.

The second column of the table begins our exploration into how the presence of rail affects bus costs; in other words, what variables might the rail dummy be capturing? Column 2 of table 3 shows that when we replace population with passenger-miles, it has a statistically significant effect on costs and noticeably reduces the effect of the rail dummy, which suggests that rail affects bus costs by causing changes in bus operations in ways that reduce its patronage.

Passenger-miles may be endogenous because it is correlated with unobserved influences on bus costs. Thus, we instrument passenger-miles with population, which is correlated with passenger-miles but is not causally related to costs once we control for passenger-miles in the specification.[15] As we show in column 3 of table 3, the coefficient on the rail dummy variable falls even further when we estimate the model in this way. In sum, it appears that the presence of rail increases bus costs primarily by affecting its operations in ways that decrease its traffic.

We checked whether the findings were sensitive to the size of the transit systems by re-estimating equation 2 for the top 60 metropolitan statistical areas based on population, composed of 28 bus-and-rail systems and 32 bus-only systems, and the coefficient estimates for the effect of rail on bus operating costs with and without passenger-miles were very similar to the estimates obtained from the full sample of 94 transit systems. We also estimated equation 2 using a sample of transit systems with systemwide passenger-miles above the median, which resulted in 27 bus-and-rail systems and 20 bus-only systems, but the results did not change in any meaningful way. Finally, we excluded New York's transit system from the sample, which accounts for about 40 percent of transit passengers nationwide, and the results also did not change much.

We have assumed that the presence of rail has a homogeneous effect on all bus systems' operating costs, regardless of any important differences between the systems. A key distinguishing feature between transit systems that may influence the effect of rail's presence on bus operating costs is the age of the system. For example, it might be expected that older systems, where rail and bus "grew up together," would be designed in a harmonious way such that rail has a smaller effect on bus costs compared with newer systems, where rail service was added to an existing system and bus operations had to be adjusted to accommodate rail.

In table 4, we present estimation results for the base specification without passenger-miles for old and new systems, and for the specifications with passenger-miles with and without passenger-miles instrumented by population. We set a cutoff year of 1960 to distinguish old from new systems and we performed some sensitivity tests around this cutoff point. Comparing columns 1 and 4, we find, as hypothesized, that the coefficient for the rail dummy is larger for the new systems than for the old systems when we do not control for passenger-miles. This finding is consistent with the hypothesis that city officials and planners wanted to encourage rail ridership in the new systems even to the detriment of bus, because it was much more expensive to construct those systems in the more recent period than in the past.[16]

[15] The first-stage regression using population as an instrument for passenger-miles had an *F* statistic of 33.73.
[16] Rosenthal (2017) notes that the construction costs of New York's Second Avenue Subway amount to a record $2.6 billion per mile. The cost of Honolulu's light rail system is likely to significantly exceed $0.5 billion per mile by the time it is completed.

Table 4. Estimation Results for Old Systems versus New Systems

	Old Systems			New Systems		
Log Operating Expenses	(1)	(2)	(3)	(4)	(5)	(6)
Rail	0.585***	0.482***	0.295**	0.651***	0.388***	0.191**
	(0.183)	(0.115)	(0.134)	(0.239)	(0.092)	(0.082)
Log Population	1.179***			1.185***		
	(0.104)			(0.133)		
Log Passenger-Miles		0.852***	0.943***		0.818***	0.916***
		(0.058)	(0.060)		(0.038)	(0.035)
Log Gasoline Price	5.719***	–0.352	–1.228	2.026*	0.521	0.350
	(1.640)	(0.624)	(0.815)	(1.180)	(0.331)	(0.362)
Log Dedicated Taxes for Operations	–0.001	0.003	0.001	0.025***	0.001	–0.004
	(0.009)	(0.004)	(0.004)	(0.008)	(0.003)	(0.004)
Days below Freezing	0.003	0.002**	0.001	0.004***	0.001*	0.001**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.0001)	(0.0001)
Estimator	OLS	OLS	IV	OLS	OLS	IV
R^2	0.902	0.973	0.970	0.825	0.955	0.949
No. of Observations	407	407	407	1,189	1,189	1,189

Notes: Old systems are bus-only systems that were in operation before 1960 or bus-and-rail systems where rail was in operation before 1960. All specifications include year fixed effects. The specification in columns 3 and 6 use log population as an instrument for log passenger-miles. Robust standard errors clustered at the transit-system level are shown in parentheses. Statistical significance is indicated at the ***1%, **5%, and *10% levels.

When we control for passenger-miles in columns 2 and 5, the rail coefficient for the old systems becomes larger than the rail coefficient for the new systems, suggesting much of the effect of rail on new systems' bus operating costs is captured by passenger-miles. Because new rail systems are those where bus routes were reconfigured to curtail their line-haul service to downtown destinations and feed the rail system by providing more suburban service, higher passenger-miles on rail are partly achieved by using feeder bus service to carry more passengers, which is likely to be more costly than using bus to carry passengers for line-haul service. It is conceivable that the agencies' reduction in bus line-haul service and increase in feeder service could reduce total bus operating costs. But we did not find that to be the case, perhaps, as we discuss below, because of the relatively higher cost of operating buses to provide feeder service.

Note the small effect of rail in column 6 of table 4. In contrast, rail's effect on bus operating costs in old systems, as shown in column 3, is larger and apparently includes additional influences that collectively increase bus operating costs by roughly 33 percent. We conducted sensitivity tests using alternative cutoffs for new systems as operating during or after 1965 and 1970 and found no substantive change in the results; namely, the presence of rail has a greater effect on bus operating costs for new systems than for old systems, but controlling for passenger-miles explains most of the effect for new systems, although additional influences still affect operating costs for old systems. We discuss those possible influences below.

Based on the parameter estimates in table 4, we estimate that the presence of rail in old transit systems raises annual bus operating costs by about $2.1 billion due to both demand and pure cost effects, and that the presence of rail in new transit systems raises annual bus operating costs by about $2.7 billion, due primarily to demand effects. The combined $4.8 billion increase in operating costs for new and old systems accounts for a notable share of public transit's total operating and capital subsidies, which exceed $25 billion (Winston and Karpilow, 2020).

V. DISCUSSION

What explains the different effects that new and old rail systems have on bus costs? We hypothesize that cities that have built expensive, relatively new rail systems, especially ones that serve suburbs, do not want to be criticized for running excessive rail transit deficits, which might jeopardize additional rail subsidies for system expansion or modernization. Thus, the newer systems attract some riders who may have used bus by removing buses from line-haul service and relegating them to feeding the rail system.

We have been unable to find data that systematically indicate the share of buses that were previously used for line-haul service and then relegated to feeder service after a rail system was built. However, considerable anecdotal evidence supports the hypothesis that certain bus routes have been converted to feeder service when a new rail system was built.[17]

This change in operations increases bus costs because feeder service is more costly to operate than line-haul service. Feeder buses are less intensively utilized because they spend dwell time

[17] For example, private communications with DOT personnel indicated that bus routes were realigned in the late 1970s and early 1980s to "force feed" Washington's newly constructed Metrorail system, which required riders who previously enjoyed continuous bus service to their destinations to make inconvenient and time-consuming transfers, sometimes at both ends of the rail trip. As another example, the DOT's (1995) report on bus–rail integration in St. Louis in the early 1990s notes that "extensive advertising and promotions" were used to inform bus ridership that "some bus routes would be slightly modified to become a feeder network for the light rail system." Finally, the completion of the extension of the Silver Line on Washington's Metrorail system was accompanied by an announcement that Northern Virginia bus systems would modify their routes to connect to the new stations (George, 2022a). Notably, the Silver Line extension was four years behind schedule, and it is not clear that the new bus routings will attract many riders if the region's travelers are satisfied with the transportation- and non-transportation-related choices that they made during the intervening years.

waiting at rail stations and operate less efficiently by stopping more often, traveling at slower speeds, and so on. Bus system costs may also be higher because fewer resources are allocated to keep buses in good condition. Finally, the change in operations converts for many passengers what was once a direct bus trip into a more time-consuming bus trip plus a rail trip, which reduces bus demand and load factors.

Bus ridership, as measured by passenger-miles, aggravates these cost-increasing effects because much of it is concentrated during peak hours, increasing dwell times at bus stops and rail stations. Thus, when we controlled for passenger-miles in the specification, we found that it captured much of the original effect of the rail dummy variable. That is, the rail dummy was capturing demand-related effects that increase costs.[18]

We also found in old systems that the rail dummy is capturing some additional effects on bus costs even when we controlled for passenger-miles. One explanation is that there may be omitted variables that raise operating costs but do not affect demand, which the rail dummy was capturing. For example, suppose the presence of a rail system forces a bus system to hire additional workers who are used to help coordinate buses with rail operations. This would increase bus operating costs but would not affect demand, so the rail dummy would be capturing pure cost-related influences on bus costs. The effect might also arise from higher wages for rail operators and mechanics—and perhaps managerial overhead as well—that spills over to bus operations, such that bus drivers and mechanics have higher wages in cities that also have rail systems, especially older ones, than in cities with only bus service.

An alternative explanation is that the inclusion of passenger-miles may introduce endogeneity that biases the estimated coefficient of the rail dummy variable, so it only appears to capture pure cost-related effects. For example, although fares are regulated, costs may affect passenger-miles by reducing service quality. Thus, there may be reverse causality between those variables. Bus passenger-miles are negatively correlated with the rail dummy, so the bias to bus passenger-miles could bias the estimate of the rail dummy. However, when we tested for this possibility by

[18] It could be argued that passenger-miles reflects the equilibrium of demand and supply. Transportation supply is typically measured by seat-miles, and seat-miles multiplied by the average load factor yields passenger-miles. As previously discussed, transit's low load factors exist because its operations do not enable it to keep pace with the nation's demographic and socioeconomic changes. Because rail's operations are even less flexible than bus's operations, a system that favors rail will be more disadvantaged by demographic and socioeconomic changes that affect demand.

instrumenting passenger-miles with exogenous population to reduce the endogeneity bias, we found that the pure cost-related effect captured by the rail dummy still existed for old systems.

VI. POTENTIAL IMPROVEMENTS TO URBAN TRANSPORTATION

Public urban bus and rail transit have accumulated vast inefficiencies and have developed a symbiotic relationship that has increased bus costs and is likely to ensure that transit's financial problems and declining market share persist. In addition, bus service is often relegated to feeding rail service when it could benefit the public in certain situations by substituting for it. For example, both bus and rail transit significantly curtailed service during the COVID-19 pandemic and greatly inconvenienced some essential and other workers who normally relied on transit to travel to their workplaces (Verma, 2020). Those workers would have been less inconvenienced if new bus service had been initiated on line-haul routes served by rail transit. By completely substituting for rail line-haul service and offering greater frequency than rail was offering during the pandemic, the new bus service would have reduced travelers' waiting times (at a possible cost of increasing their overall travel times) and would have reduced taxpayers' overall transit subsidies because rail is more costly than bus transit to operate.

In any case, public transit has continued to decline during and is expected to continue to decline after the pandemic. We therefore consider potential public and private sector sources of improvement for urban transportation.

VI.A. Public Transit's Continuing Decline

The failure to use bus more effectively in metropolitan areas offering both bus and rail transit service harms lower-income travelers because bus riders are generally poorer than rail riders (Winston and Shirley, 1998), are less able to afford an alternative mode, and have fewer opportunities to work at home. Bus has recovered much of the ridership that it lost with the onset of COVID-19 in such cities as Washington and Boston, while rail is struggling to recover even half of the ridership that it lost in those cities (Gelinas, 2022). At the same time, rail has cut its service in those cities, while bus routes and frequencies have not been adjusted in response to demographic changes and dislocated rail travelers' dependence on bus service, which particularly harms essential workers.

In theory, bus systems are more flexible than rail systems and their routes could be more easily reconfigured to adapt to modern traffic patterns, improve the speed and reliability of service, and attract more passengers. However, proposals to redesign bus networks are often shelved because they are met with strong opposition from riders who claim they will be inconvenienced because stops will be eliminated. Thus, current average bus speeds in the densest metropolitan areas in the country are less than 10 miles per hour, while average bus speeds in the New York metropolitan area are about 8 miles per hour (Ley, 2022).

In addition to being hamstrung to improve service quality, bus and rail transit systems seem incapable of taking the most basic actions to reduce their deficits and taxpayer-funded subsidies. For example, the Washington Metropolitan Area Transit Authority has lost millions of dollars in revenue because roughly 1 in 3 Metrobus rides goes unpaid as drivers do not attempt to prevent fare evasions (George, 2022b). According to the Metrobus operating training manual, drivers are discouraged from bringing attention to someone who skips a fare and should not stop a fare evader or delay a trip if a passenger avoids paying. In New York City, nearly 30 percent of bus riders and 8 percent of subway users do not pay their fare, costing the city more than $300 million a year, according to data released by the state-operated Metropolitan Transportation Authority (Rosenberg, 2022). Fare evasion has contributed to putting the Seattle and Tacoma Sound transit system on a financially unsustainable trajectory and facing insolvency. According to Schulz (2022), the lack of enforcement is to blame for widespread fare evasion, and New York, Seattle, and several other cities with transit systems have reduced or completely withdrawn enforcement efforts.

In response to nearly $25 million in annual losses from fare evasion before the pandemic, the Bay Area Rapid Transit system decided to install a new generation of fare gates to deter fare evasion and has begun to eventually replace 715 fare gates across the system and to raise the height of barriers separating free and paid areas (George, 2022c).

The Kansas City Area Transportation Authority decided to avoid the issue of having its users help to finance operations by eliminating fares systemwide in 2020. The program is set to sunset at the end of 2023, but local officials are preparing to make it permanent. The system serves only a small portion of Kansas City's residents and did not cover much of its costs with fares. Policymakers could consider a lower-cost alternative to a multimillion-dollar, fully taxpayer-supported streetcar and bus transit network to serve the system's most dependent transit users.[19]

VI.B. Can Reforming Automobile Policies and Transit Operations Improve Transit?

The existence of inefficient parking and roadway prices for automobiles is often cited as a justification for subsidizing transit on second-best grounds. But policymakers could consider creating an environment where greater competition between the modes and new innovations improve the US transportation system. In the long run, the adoption of autonomous vehicles could facilitate the adoption of efficient prices for automobile travel and eliminate its subsidies. In addition, autonomous vehicles might pose a substantial threat to public transit as a viable mode and could eventually eliminate the need for taxpayer-funded subsidies that have maintained transit operations.

In the short run, subsidies for both automobiles and public transit will continue to exist. Winston and Shirley (1998) found that if policymakers eliminated those subsidies by setting efficient prices and service levels for both modes, then public transit's market share would decline further, and its social desirability would be even more questionable. The authors also found that transit's share would not increase much if automobiles were charged congestion prices; instead, highway travel would be spread more evenly throughout the day.

Efforts to improve bus service times by instituting exclusive bus lanes have also raised concerns about inefficient policies for both transit and automobiles. For its part, automobiles have slowed bus travel times by violating exclusive bus lanes, but the police have generally not issued traffic citations to discourage such violations.[20] At the same time, exclusive bus lanes reduce welfare by reducing capacity for automobile travel and increasing highway users' congestion costs (Winston and Langer, 2006). Again, in the long run, the adoption of autonomous vehicles could

[19] The Washington Metropolitan Area Transit Authority announced that it would be the first large metropolitan area to offer free public bus transit starting on July 1, 2023. Policymakers might consider whether they could improve the mobility of the most dependent bus transit users at a lower cost than offering free transit on a costly inefficient public bus transit system.
[20] Camera technology could be used for exclusive bus lane enforcement (Descant, 2022).

resolve the issue because they would not violate exclusive bus lanes if any existed; more likely, those lanes would not exist because public buses would no longer operate.

VI.C. Bike and Electric Scooter Sharing

Bike and electric scooter sharing could complement transit and increase its ridership by solving the "last mile" problem by enabling people who do not live within walking distance of an urban rail station or a bus transit stop to have access to those services (Zhou, Li, and Zhang, forthcoming; Chu et al., 2021). However, it is questionable whether those modes should be subsidized and provided by the public sector, and it is not clear whether they could operate profitably in the private sector. For example, although China has some 300 million bikeshare users, its two largest companies discontinued service. In the United States, bikes and scooters are unlikely to attract sufficient use to help improve transit's financial picture or to reduce automobile externalities. Furthermore, widespread adoption may not be a panacea because it is likely to introduce new safety issues.

VI.D. Private Urban Transit

An alternative approach to improving the efficiency of public transit is to privatize it, which would not force bus to be subordinate to rail. Empirical evidence indicates that privatization of all US bus systems could produce large cost savings and eliminate bus subsidies (Jerch, Kahn, and Li, 2017; Winston and Shirley, 1998).

Private van and minibus services, which have achieved success throughout the world because of their low costs and responsive service, could improve urban transportation if they were allowed to serve more US urban areas. Currently, such services exist in a handful of major US cities, but the operators tend to keep a low profile because, although some companies are legal, others have not obtained a license to operate. Nonetheless, they exist because they provide a highly valued, low-cost service, with fares that are usually only a few dollars and with a route network made by and for working-class people.

Correal (2018) provides examples of private vans' service areas and fares in the New York metropolitan area, while Reiss (2014) provides a graphic overview of the service provided by "dollar vans" in New York City, whose routes are generally not served by subways or buses. Said (2019) reports that Via, a private transit operator, will run on-demand vans in Cupertino, which are eagerly awaited because the public bus option run by the Santa Clara Valley Transportation

Authority is too slow. Indeed, some companies in the San Francisco Bay Area, such as Google, are so dissatisfied with the public transportation system that they provide private transit service to their employees.

The developers of the app Dollaride are hoping to generate more business for private vans in New York City (and possibly elsewhere) and to challenge public bus transit in the same way that Uber has taken on the taxi industry (de Freytas-Tamura, 2019). The app allows users to see where licensed vans are operating within a one-mile radius, as well as where they are headed, helping commuters decide whether taking a van might be faster than waiting for a bus. The app also allows van drivers to spot passengers more easily and to plan for growing demand and possibly future routes. It is also possible that Dollaride or similar apps could encourage unlicensed vans to register with the city.

Private urban rail systems exist in Hong Kong and Japan, where they take advantage of high traffic density and multiproduct operations that include non-transportation services. It is an open question whether any US urban rail system could be as financially successful as those Asian systems. It is more doubtful that urban transit public–private partnerships would significantly improve US public transit systems.[21]

Greater competition *and* innovation is critical for improving urban transportation. The private sector's role in improving urban transportation will surely increase when autonomous vehicles are widely adopted, as households will effectively have their own low-cost transit system that provides reliable service to any destination in a metropolitan area, which will make it difficult for public bus and rail transit to survive financially, even if they are automated (Winston and Karpilow, 2020).

Public bus and rail transit systems might consider how, if at all, they could complement autonomous vehicles to justify their continued operations. The Washington Metropolitan Area Transit Authority experienced a false start when it attempted to provide automated urban rail transit service, only to suspend it after a deadly train crash in 2009. The system is now hoping to restore automated train service on all lines by 2024. On-demand, autonomous transit experiments are being explored in some metropolitan areas; for example, the Rideshare, Automation, and

[21] Austen (2022) reports that Canada has had mixed experiences with public–private urban transit partnerships. Rail transit projects in Ottawa, Toronto, and Montreal have been marred by cost overruns and delays, while projects in Vancouver and Kitchener/Waterloo are regarded as successful.

Payment Integration Demonstration in Arlington, Texas, hopes to show how autonomous transit could be a viable part of future urban transportation systems.

Privatized bus and rail systems are likely to have greater flexibility and financial incentives than public transit systems to adapt to a world of autonomous urban transportation. Importantly, their financial survival would be subject to the market test of providing services that respond effectively to changes in households' socioeconomic and demographic characteristics and that increase social welfare. If private autonomous transit companies cannot compete effectively with autonomous cars, governments run the risk of repeating the mistakes they made with public transit by taking ownership of those companies.

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