Excess Capacity and the Economics of Public Transit Investment:

A Study of a Growing American City

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Abstract

Declining ridership in public transport weakens the case for investments in expanded service or large investments in public transit infrastructures. Our study documents the decline in public transit ridership in Nashville, Tennessee, USA. Using data from Federal sources for 2002-2018 we document the influence of higher numbers of hours of bus service, employment, and, gasoline prices on public transit ridership. We find a surprising negative relationship between ridership and miles of bus service provided. Given the several control variables in the model, quadratic trend estimates inform us that peak ridership occurred in 2007 and the seasonally adjusted ridership might be falling since then. A second regression for the period after the great recession of 2008-09 gives a similar result regarding the declining ridership. Falling ridership in Nashville matches downward trends in other cities around the country. A major contribution of our study lies in the identification of separate roles for hours and miles of bus service. Using that insight, we decompose the time series while incorporating a quadratic trend to account for relative changes in the slope over time. Evidence of an underlying downward trend in ridership challenges the value of making large scale investments in transit capacity especially in the presence of increasing excess capacity.

Keywords: public transit ridership, hours of bus service, miles of bus service, employment, gasoline prices, Nashville

JEL Codes: R41, L92, H72

1. Introduction

Should US cities continue to expand capacity for public transit service? Answer to this simple question critically rests on the changes in excess demand/supply in public transit ridership over time. A rising excess demand may support additional investments in augmenting public transport infrastructure while a growth in excess capacity may not support an expansion in the public transit infrastructure.

Public transit ridership in the USA began to decline in the last decade. Formal in-depth study of the downward trend in US cities is limited. This study estimates the peak transit ridership and subsequent decline in Nashville, the capital of the State of Tennessee in the USA. We decompose the time series and estimate regression models with a quadratic trend to discover the downward trend in the public transit ridership in Nashville. We also perform an extensive regression analyses to identify the drivers behind the decline.

Public transit operators in the US spent $19.4 billion in capital expenses to expand capacity in 2016. (Note 1) They spent $46.4 billion in operating their services. Cities like Los Angeles, Orlando, Minneapolis, and Seattle continue to expand their public transit facilities. (Note 2)

At the same time, a growing body of evidence suggests that riders are making fewer trips by scheduled transit service. (Note 3) The goal of this study is to estimate the association of total trips by transit with potential influences on ridership and trends not associated with observable causes. Understanding the drivers behind the decline in transit ridership is important because a sustained, underlying decline in ridership challenges the economic argument for expansion of capacity in the transit industry.

We use the monthly data from the National Transit Database for the scheduled intra-urban bus service in Nashville. (Note 4) The commuter railroad and commuter buses serve longer distances and are not ready substitutes for the intra-urban bus routes. Nashville's Metropolitan Transit Authority (MTA) also operates on-demand services—aimed

primarily for people with limited mobility when requests made the day before—but these show little association with scheduled bus service.

Disregarding the declining ridership and to combat the growing congestion, the city of Nashville proposed a referendum to significantly augment the public transit system operated by the MTA. Voters in Nashville overwhelmingly defeated that referendum asking for a one-cent sale tax to pay for $5.4 billion in capital expenditures. Some estimates pegged the price tag at well over $9 billion accounting for debt service and operational costs. (Note 5) Declining ridership as documented in our study might help explain the some of the concerns about the existing excess capacity and the electorate's strong willingness to cast negative votes.

Here is a preview of our conclusions.

Nashville has expanded intra-urban bus service faster than the rise in ridership leading to significant excess capacity. This excess capacity in the current transit infrastructure in Nashville is increasing because the ridership in Nashville's public transit system has been declining in the raw data for many years. The decline in Nashville's ridership is statistically significant and a long-term phenomenon.

Nashville's current public transit infrastructure can accommodate a sizeable increase in demand if riders show a willingness to use the service and the providers employ technology needed to make the service more efficient. Capacity does not seem to be a constraint in Nashville. Given the existing excess capacity, the plan of the city to make significant investments in the expansion of the public transit system seemed to be a weak and unnecessarily costly proposition whose economic value is questionable.

Our results are firmly in line with national trends. For example, a report from the Congressional Research Service summarizes extensive evidence on the national decline in transit ridership. (Note 6) Therefore, a decline in public transit ridership in Nashville is not outside the national trend.

Our study begins by introducing the data with scatterplots and stating the main hypotheses explored in the paper. Next, we decompose the structure of the time-series data on ridership. Third, we introduce the regression models and consider their limitations. Fourth, our study interprets results followed by a discussion of the import of the findings.

2. Trends in the Raw Data

We start by noting the long-term changes in the public transit ridership in Nashville. Our monthly data cover the period between 2002 and 2018 with an average of 689,326 trips. Ridership did not behave in a linear fashion during this time. Ridership rose and fell over the last 16 years as illustrated in Figure 1. The number of rides increased in the years 2002 to 2008. Ridership dropped from 2008 to 2010 during the great recession. Ridership recovered for a short duration around 2011 only to slowly and steadily decline in recent years. (Note 7)
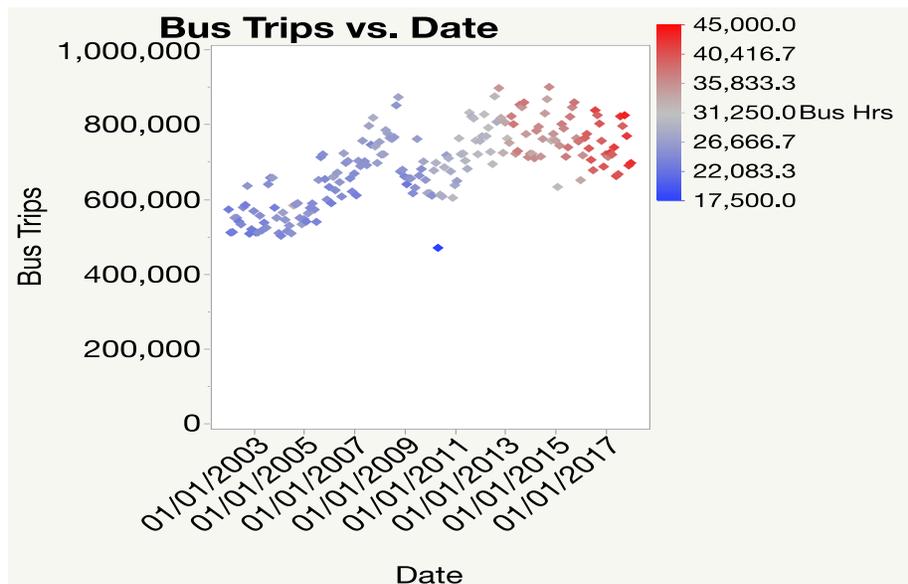

Figure 1. Trend in Unlinked Passenger Trips, 2002-2018

Source: *Data from the Federal Transit Administration, "Monthly Module Adjusted Data Release," https://www.transit.dot.gov/ntd/data-product/monthly-module-adjusted-data-release Bus Trips=UPT: Unlinked*

Passenger Trips, Bus Hours = VRH: Vehicle Revenue Hours. Data are from January 2002 to January 2018.

During the same period, while the ridership trend was distinctly non-linear, the city kept on expanding the transit service partly in response to the emerging congestion problem presumably emanating from a strong population growth and economic growth that the city has been experiencing in recent years.

Noting the changes in the ridership over time and the efforts undertaken by the city to add more services, we form several hypotheses and test them.

Hypothesis 1: Hours of Bus Service Increase Rides

Our study asks if an expansion in the public transport system will be able to attract additional ridership. The growth in ridership is necessary to cover some of the expenses of running the transport system from operational revenues and to assure that the benefits of augmented public transit services exceed the added costs.

To examine the relationship between additional bus hours and rising ridership, we hypothesize that when buses are in service for more hours, more people will take bus trips. At least visually, there is no clear proof to suggest that this hypothesis is true.

Figure 1 shows the effect of the significant increases in the number of hours buses operated in service in each month with blue points at the lowest level, generally in the earlier years, shading to light gray points in the middle level of hours, and red points at the highest level of hours of bus service in recent years.

In the early years, increasing ridership is associated with more hours of bus service. In recent years, the scatterplot does not give any clear evidence that more bus hours contribute in any meaningful way to increasing ridership.

Hypothesis 2:   Miles of Bus Service Affect Rides

Although an increase in the time that buses run relate to increased frequency and longer hours of bus service, it does not necessarily mean an expansion in geographic and temporal coverage. The number of miles traveled by the buses is a second dimension of service, albeit one closely related to bus hours. Buses running for longer hours, even on the same route will accumulate more mileage. Because buses may run at different speeds depending on time-of-day and location, mileage may have a different effect than hours. For example, during peak hours, slower buses running for longer hours might accumulate less mileage.

Recognizing that the two measures are related, we state a second hypothesis that the number of miles buses travelled in service each month may affect ridership. The affect could be positive or negative, given bus hours.

Figure 2 shows a strong positive relationship between miles and hours of buses in service. Blue dots to the lower left occurred in the early years, red dots to the right are recent years. The period from August 2012 to June 2014 shows a steeper line, with more miles generated for given hours than in the subsequent era.

Nashville launched limited-stop rapid bus service on some routes during this period. The outlier at the bottom left of the scatter is the May 2010 flood.
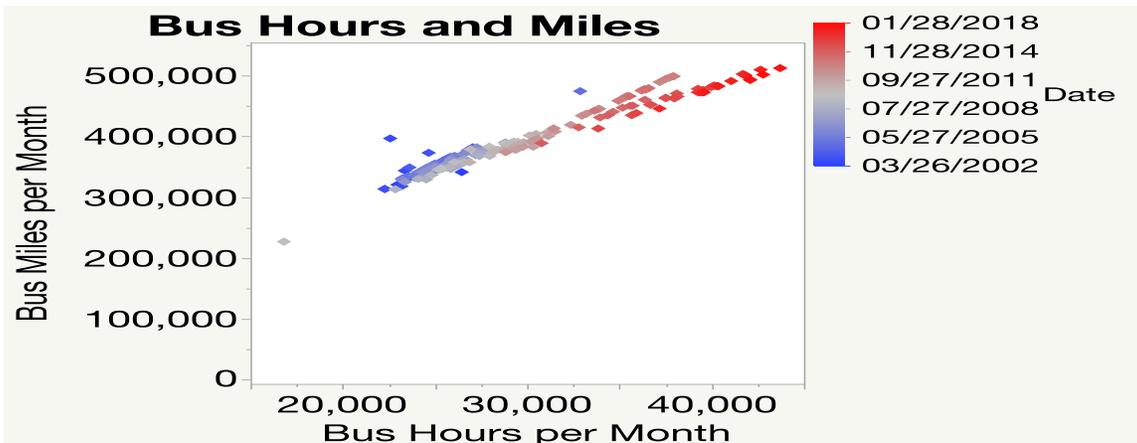
Figure 2. Vehicle Revenue Mile and Vehicle Revenue Hours

Source: Data from the Federal Transit Administration, "Monthly Module Adjusted Data Release," https://www.transit.dot.gov/ntd/data-product/monthly-module-adjusted-data-release   VRM: Vehicle Revenue Miles, VRH: Vehicle Revenue Hours. VRM = 112517 + 9.458 VRH,   r-square= 0.9519. Mean of VRM = 395531.

This observation is not surprising. Buses in service for longer hours would accumulate more miles. However, the relationship depends on traffic and stops. Buses share the same roads as cars and other vehicles. Nashville has no dedicated bus lanes. Limited-stop buses do move faster than buses that make more stops because stops take time. Limited stop buses also make use of the interstate highways connecting central city transit hubs to relatively far flung corners of the city.

Hypothesis 3:   Higher Gasoline Prices Increase Bus Rides

Because our study covers a long period (January 2002 to January 2018), we account for changes in the cost of private transportation and its impact on the demand for public transit.

During these sixteen years, gasoline prices have increased significantly while vehicle efficiencies have registered an improvement as well. An average gallon of gasoline was $1.325 in July 2002. (Note 8) The price of gasoline price rose to over $2.50 a gallon, the highest in last four years. (Note 9) This represents a nearly 100% increase in nominal gasoline prices in our sample period.

Our third hypothesis posits that the retail price of gasoline influences bus ridership positively. The logic goes like this. As gasoline prices rise, the cost of operating a private car increases. That increase in the cost of vehicle operation encourages commuters to move from private vehicles to public transit. This is a classic substitution hypothesis where we can treat the public transport as a substitute for the private transport.
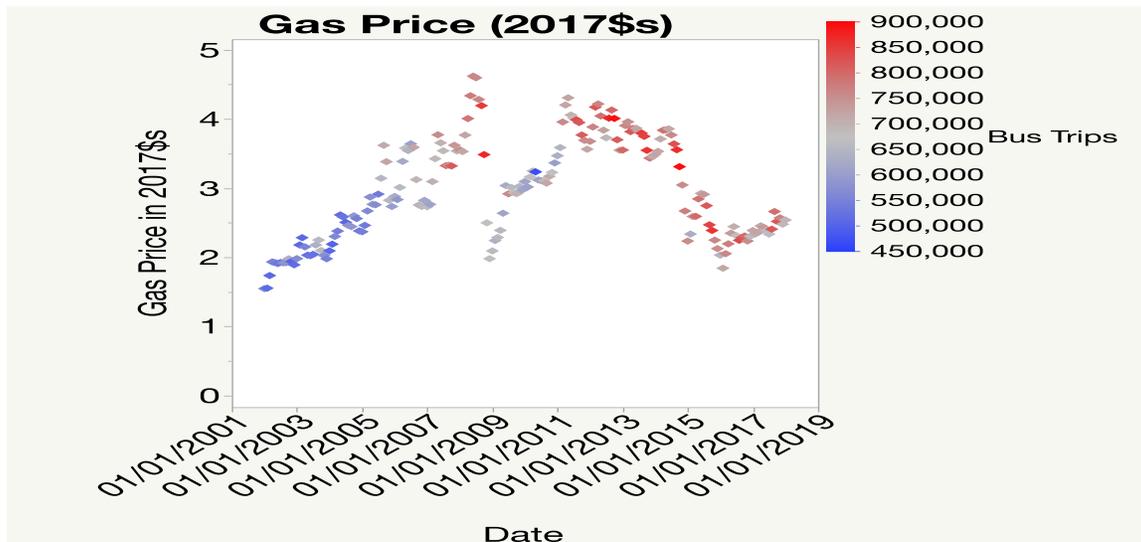

Figure 3. Average National Price of Gasoline per gallon in 2017$s

Source: U.S. Energy Information Administration, "U.S. Regular All Formulations Retail Gasoline Prices (Dollars per   Gallon)," https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMM_EPMR_PTE_NUS_DPG&f=M   Deflated to December 2017 values of the Consumer Price Index, U.S. Bureau of Labor Statistics, (from FRED).

Figure 3 shows monthly national trends in the retail price of gasoline, deflated by the Consumer Price Index. This adjustment focuses the analysis on the real increase in gasoline prices instead of inflated values.

Blue dots to the lower left show lower levels of ridership. Red dots show high levels of trips. Gasoline prices peaked before the great recession and again after the recovery. Red dots continue from 2011 to 2017, even as the real price of gasoline fell.

Hypothesis 4: Higher Employment Increases Bus Rides

During the period of our study, the population of Nashville grew considerably. For example, between the 2000 Census and 2017 The American Community Survey shows that population of Nashville grew from about 545,000 to about 644,000. (Note 10) At the same time, the Middle Tennessee Region in general, and Nashville in particular, experienced considerable growth in economic activity. Nashville's job market has become tight, and employers often reported difficulties in finding suitable employees. (Note 11)

To explore the relationship between underlying economic conditions and demand for public transport, we posit a

fourth hypothesis: Ridership will increase with regional employment, reflecting increased demand for trips to work.

To test our hypothesis, we use the employment data for total non-farm employment in the Nashville—Murfreesboro—Franklin Metropolitan Statistical Area. (Note 12) Figure 4 shows the growth in employment with the break during the great recession and faster growth since then.
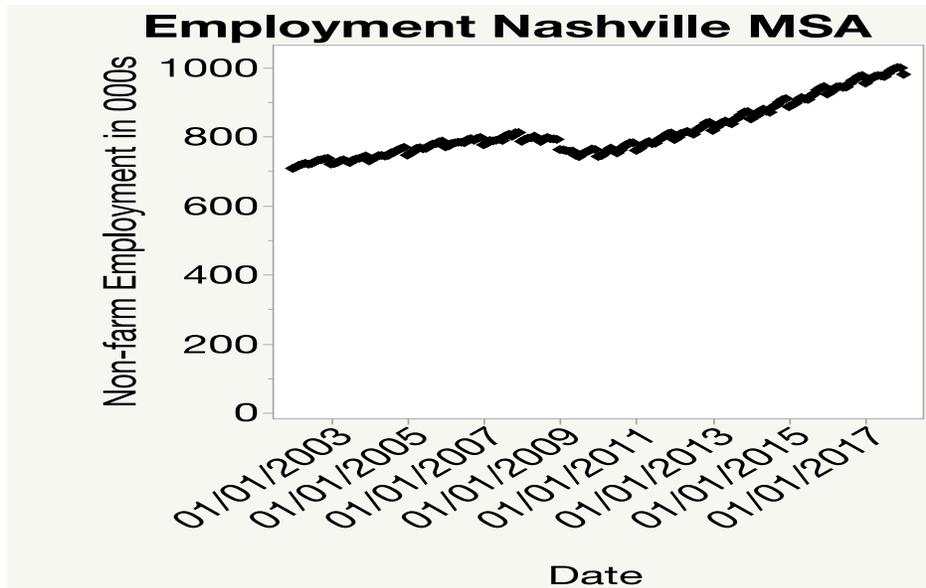

Figure 4. Trend in Non-farm in Employment in the Nashville MSA

The growth in metropolitan area employment coupled with the decline in ridership paints a cautionary picture as depicted in Figure 5.

First, during the 2002-2018 period, employment grew steadily making Nashville one of the most thriving economic centers in the USA. Second, during the same period, there has not been a matching sustained growth in the public transit ridership pointing to the possibility that capacity constraints in public transport did not limit economic growth. Third, the growth in employment and decline in public transit ridership happened despite costly expansion (more bus times and miles) in the public transportation system.
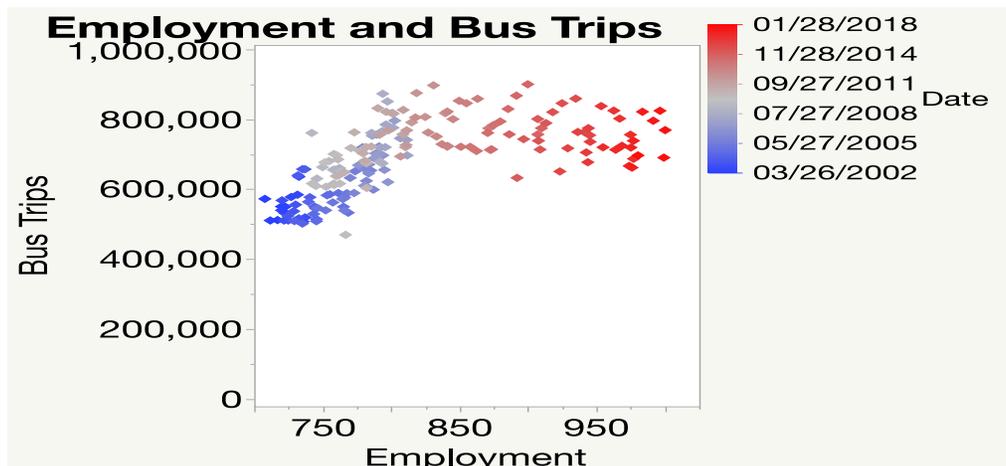

Figure 5. Employment and Bus Trips

Source: All Employees: Total Nonfarm in Nashville-Davidson--Murfreesboro--Franklin, TN (MSA), Thousands of Persons, Monthly, Not Seasonally Adjusted,

We can tentatively draw a few inferences from these observations.

First, there seems to be no significant evidence that lack of public investment in transit has damped Nashville's

growth. Nashville experienced a growth in employment and population with an all-bus intra-urban transit service.

Second, the simultaneous decline in ridership and a rise in employment suggest a limited role for public transportation in Nashville's growth. The rise in working from home and flexible work schedules may explain such a phenomenon.

Third, during our sample period, alternative, privately provided transportation services like Uber and Lyft have made major inroads into Nashville's transportation mix. These services are coming to play significant roles in revitalizing Nashville's urban core. (Note 13) Part of the growth in rideshares like Uber and Lyft and the decline in public transit ridership may be driven by the changing preferences of the commuters towards more convenient, private, just-in-time transportation (like Uber and Lyft) compared to the fixed schedules and routes of conventional buses.

In this study, we estimate a regression model to explain the decline in ridership in public transportation. We will present estimates of the joint effects of the four explanatory variables, hours, miles, the price of gasoline, and employment in explaining monthly ridership.

3. Decomposition of the Time Series

To understand the time series nature of the ridership data, we decompose the raw time series into several constituents: trend, seasonality, and randomness. We carry out this decomposition of the raw data, for the 3-month moving average data, and for seasonally adjusted data. In each of those cases, we overlay the trend with the original (or, adjusted) time series and its trend. These results appear in Figures 6 though 11.
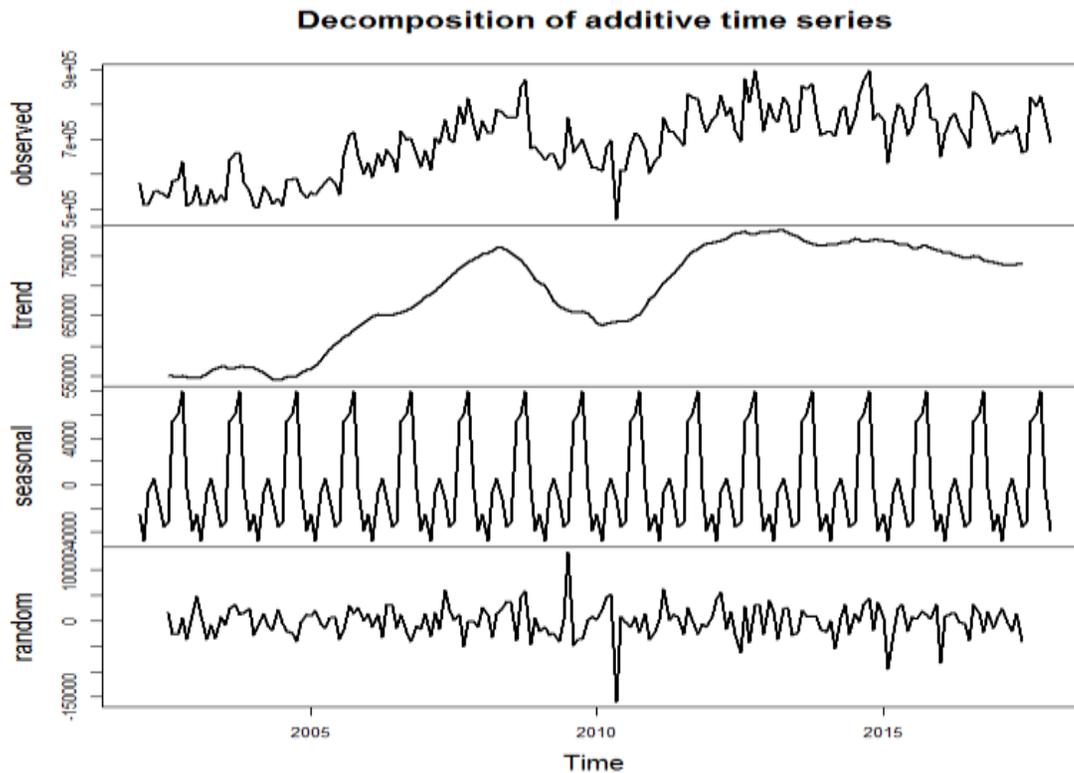
Figure 6. Decomposition of the Monthly Ridership (raw) Data

Source: *Data from the Federal Transit Administration, "Monthly Module Adjusted Data Release," https://www.transit.dot.gov/ntd/data-product/monthly-module-adjusted-data-release*

Monthly Ridership with Trend (in Red)
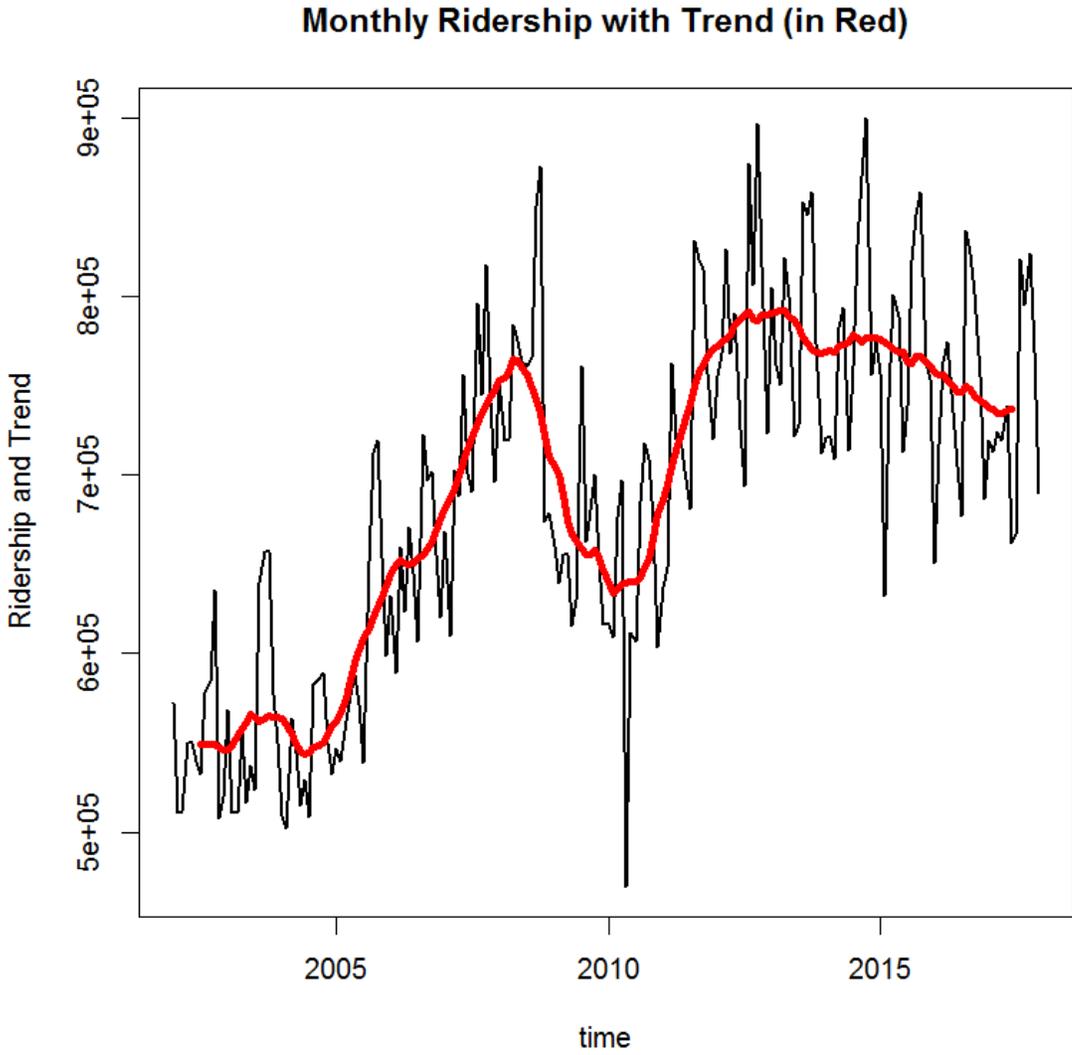
Figure 7. Overlay of the Raw Ridership Data Along with the Decomposed Trend
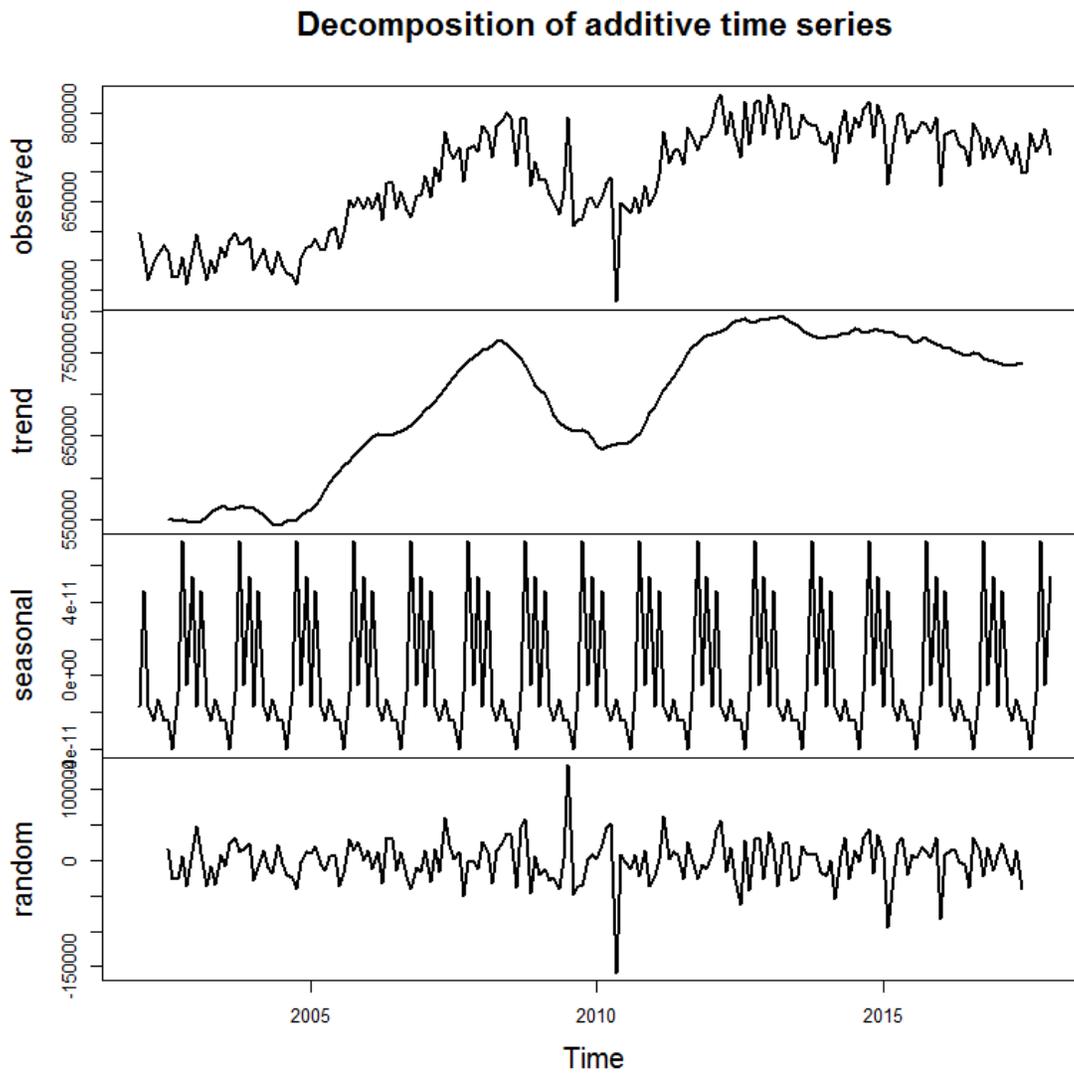
Figure 8. Decomposition of the Seasonally Adjusted Time Series Ridership Data
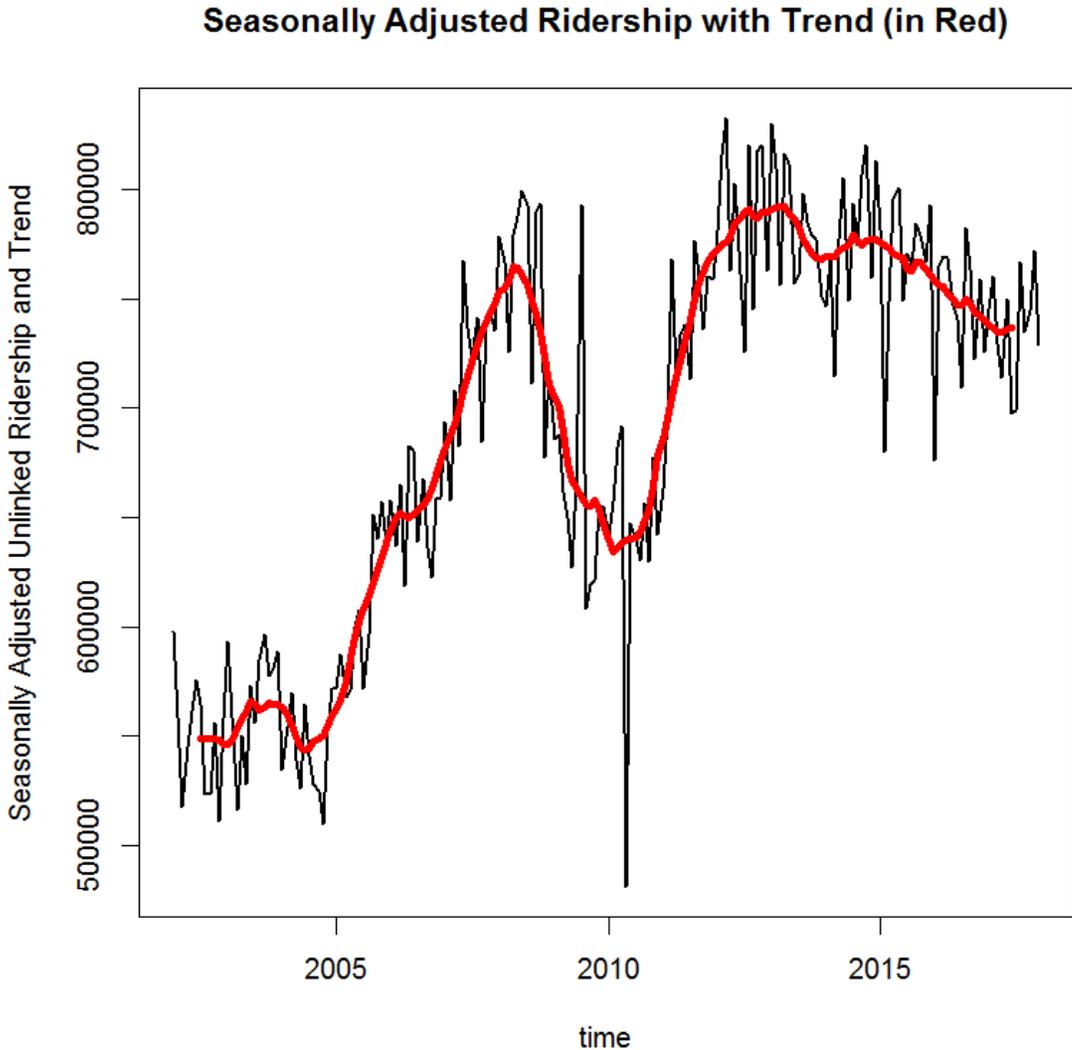
Figure 9. Overlay of the Raw Ridership Data Along with the Decomposed Trend
for the Seasonally Adjusted Time Series Ridership Data
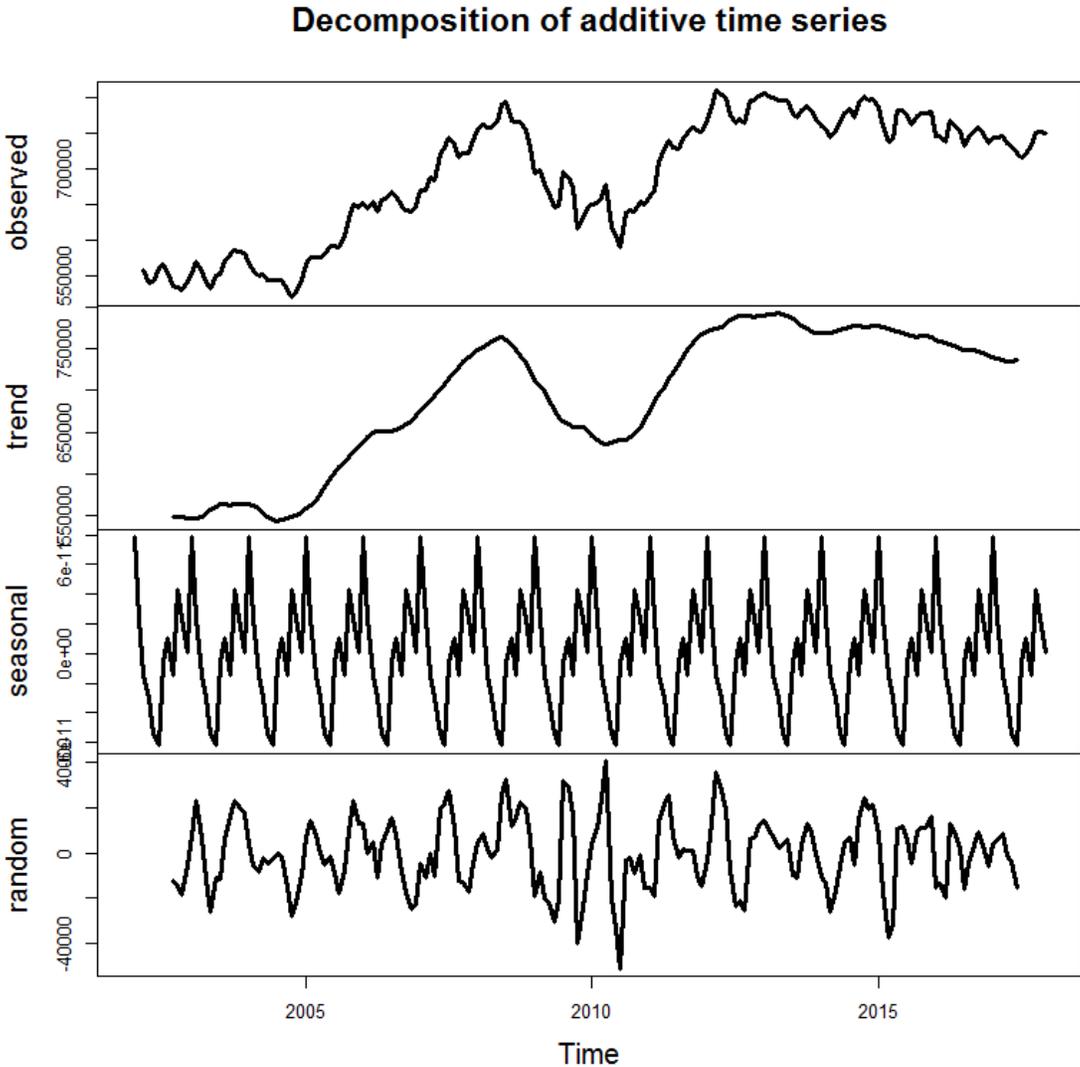
Figure 10. Decomposition of the Seasonally Adjusted
3-Month Moving Average Time Series of the Ridership Data

Smoothed (3-Month Average) Ridership with Trend (in Red)
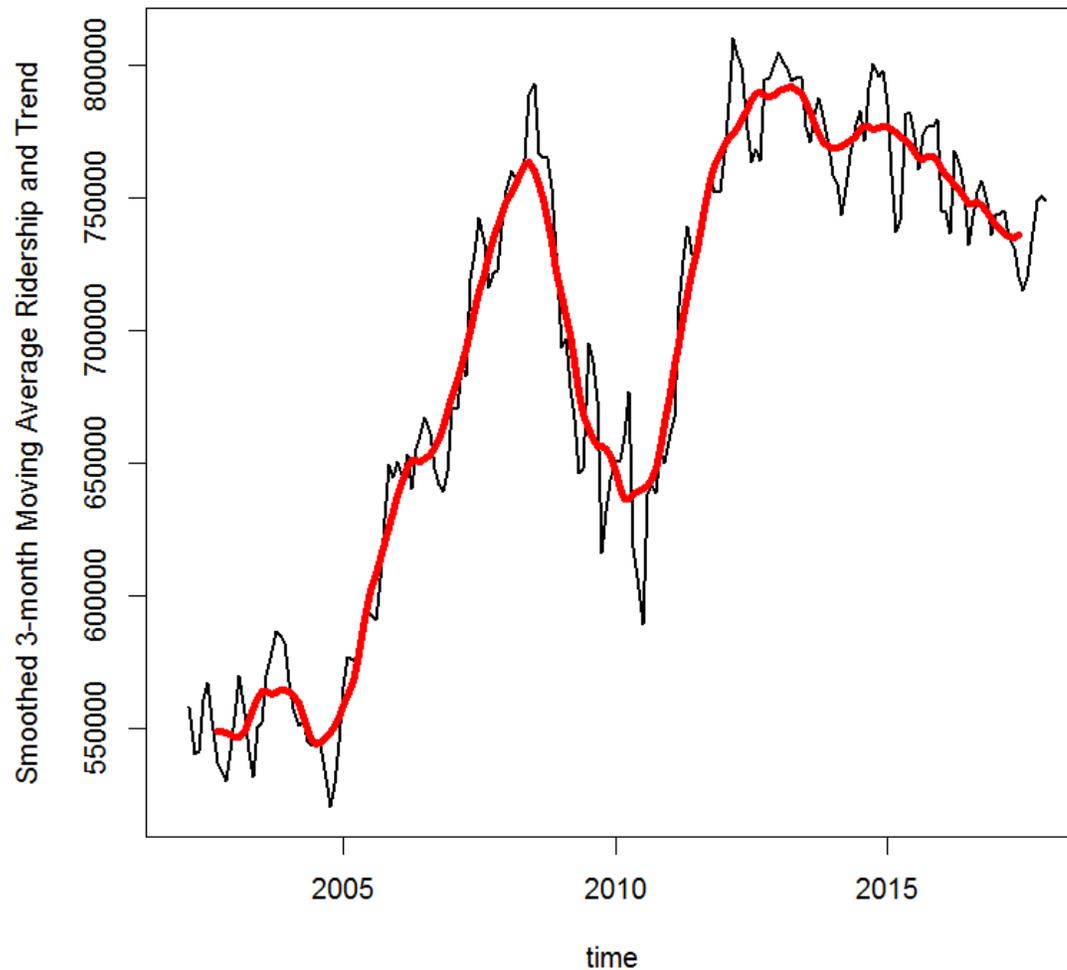
Figure 11. Overlay of the Seasonally Adjusted 3-Month Moving

Average Time Series of the Ridership Data Along With the Decomposed Trend

We notice a downward trend in the ridership numbers since 2012. This downward trend appears in the raw, seasonally adjusted, and seasonally adjusted 3-month moving average data. We also tried the same analysis with a 6-month moving averages and 12-month moving average data. We omit those analyses from this report because they qualitatively paint the same picture. The downward trend in ridership since 2012 is apparent in all cases. This finding is strong and robust over multiple specifications and smoothing techniques.

Nashville has experienced a pronounced decline in public transit ridership for many years. The ridership increased initially in our sample period only to drop significantly during the recession years. Ridership increased in the post great-recession recovery period that also coincided with one of the most remarkable growth eras in Nashville's history. However, that trend reversed even while the growth in economic activity remained unabated.

4. Regression

A multiple regression investigates the relationships introduced above in a single model. We estimate the time-series regression model shown below. The model is similar to Kyte et al. (1988). (Note 14) However, we measure bus service with both hours and miles. We include gasoline prices and employment, as does Kyte, but do not have monthly data on fares. We include a lagged value of bus rides, applying the same geometric distributed adjustment to all independent variables. (Note 15) Kyte uses a more complex lag structure.

$Rides_t = f(Bus\ Hours_t,\ Bus\ Miles_t,\ Gas\ Price_t,\ Employment_t,\ Trend_t,\ TrendSQ_t,$

$Lagged\ Bus\ Trips_{t-1},\ monthly\ binaries_{t,m},\ Flood\ binary) + error_t$

We include monthly binaries, omitting December, and include a binary for the flood in May 2010. We include a quadratic trend to allow for the possibility of a change in the direction of the trend. Lane (2012) estimates a similar model using monthly data from the National Transit Database. (Note 16) Lane (2012) estimates models for each of 33 metro areas. Lane uses only Bus Miles, not Bus Hours as in our model. He includes binaries for sharp changes in service that are not relevant in Nashville with the exception of the flood of May 2010. (Note 17)   A binary variable isolates the flood of May 2010. Lane (2012) includes only a linear trend in contrast to the quadratic trend in our model. Lane (2012) uses nominal local gasoline price but suggests that nominal and real gasoline prices have similar effects. Our study adjusts for the real changes in the gas prices. Lane (2012) estimates models with ridership separately for bus and rail, a split not relevant in Nashville.

5. Limitations

Our regression model is not complete. Given the incompleteness of our regression models, interpretation should be cautiously undertaken. We do not have monthly data on fares and we do not include transit fares in the estimation. These are very important omissions that is basically driven by lack of easily available public data. Omission of an important explanatory variable could bias the estimates of the coefficients.

In addition, ridership may influence the level of fares. The MTA sets fares administratively with political influence where the fare structures are often calculated on the basis of stakeholder interest as opposed to economic rationale that would lead to minimum financial burden on the transit system and hence, the city budget. In 2017, the nominal fare was $1.70 per trip including transfers. In fiscal 2016, the MTA reported an average fare per unlinked trip as $0.98. (Note 18) An unlinked trip counts each time a rider boards a transit vehicle as a trip. A trip with one transfer will count as two unlinked trips.

If each linked trip involved one transfer, the average fare per unlinked trip would be $0.85. The MTA offers rides on central circulator routes with zero fares. It offers discounts to seniors, students, and passes for the day, week, or other packages. It sells rides to major employers, including the State of Tennessee and Vanderbilt University. Individual employees and students, then, have zero out-of-pocket expense per ride. The MTA's operating cost per unlinked rider was $5.20 in 2016. (Note 19) This figure does not include about $2 of overhead plus about $1.25 per unlinked trip for the capital cost of the bus.

Fare revenue, then recoups about twelve percent of total costs. Political leaders might support higher subsidies and lower fares to promote tourism or other goals. In other settings, they might support higher fares to increase the level of transit services. Estimates of the price elasticity of demand for bus trips are generally well below one. Therefore, raising fares increases revenue and supports expansion of service. (Note 20) Modeling the fare setting behavior of the MTA is beyond the scope of this essay and introduces an important limitation for our results. Fares could be an endogenous variable if included in the model.

Nashville's MTA lowered fare revenue per ride in the recent era. Fare revenue per trip averages $1.10 in 2013 and $0.98 in 2016 as mentioned above. (Note 21)

Rising household income is also likely to influence transit ridership. We do not have a monthly data series on income. For some lower income households, transit use is routine and used for many purposes. For some higher income households, transit use is one of several available modes of travel. Higher income households are more sensitive to the price and quality of service of alternatives. Omission of household income is a potential source of omitted variable bias and a limitation of our study.

As noted above, higher employment would generate more work trips, a larger population, and potentially more use of transit. At the same time, higher transit ridership might attract more employment. When causality flows both ways, the interpretation of the coefficient is ambiguous.

We have not adapted the model to identify the coefficient as representing a specific direction of causality. Measuring employment at the MSA level rather than the county level may bias the coefficient on employment downward and reduce the precision of the estimate.

Although people may travel by transit or private conveyance, transit has little discernible effect on traffic congestion. Careful study of the relationship between the level of transit services—bus and rail—and traffic shows that higher level of transit service has no demonstrable effect on traffic. (Note 22) The logic is that the number of trips expands to fill the roads, regardless of the level of transit service available. That transit trips increase when gasoline prices

increase is not sufficient to show that congestion falls consequently.

6. Results

The estimated regression, reported in Table 1, shows important seasonal effects. February, June, July, and November have ridership like December. The other months have higher ridership, other things equal. The other estimated coefficients are statistically significantly different than zero. Bus miles have a surprising negative sign, discussed below. The coefficient on the flood-month binary shows 146,759 fewer bus trips in that month, an amount 21 percent below average.

Table 1. Regression Estimates: Bus Trips per Month

Variable	Estimated Coefficient	Standard Error	t-Statistics	Prob >|t|
Intercept	-101,544.60	95,137.56	-1.07	0.2870
Bus Hours	18.50	4.69	3.95	**0.0001***
Bus Miles	-0.89	0.29	-3.01	**0.0030***
Gas Price in 2017$s	23,944.47	6,950.63	3.44	**0.0007***
Employment (000s)	207.94	122.46	1.70	**0.0910***
Trend	1,457.82	340.91	4.28	**<.0001***
Trend Squared	-10.64	2.50	-4.25	**<.0001***
Lag Bus Trips	0.44	0.06	7.37	**<.0001***
Jan dummy	38,786.52	12,490.88	3.11	**0.0022***
Feb dummy	23,442.49	13,120.12	1.79	0.0760
Mar dummy	50,716.46	12,559.96	4.04	**<.0001***
Apr dummy	37,808.15	12,421.35	3.04	**0.0027***
May dummy	29,130.29	12,640.80	2.30	**0.0224***
Jun dummy	4,713.75	12,601.52	0.37	0.7090
Jul dummy	14,365.42	12,800.43	1.12	0.2630
Aug dummy	97,619.49	12,626.84	7.73	**<.0001***
Sept dummy	79,171.84	12,824.05	6.17	**<.0001***
Oct dummy	78,790.27	12,790.95	6.16	**<.0001***
Nov dummy	10,301.77	12,957.29	0.80	0.4280
May '10 flood dummy	-146,758.70	41,964.53	-3.50	**0.0006***

* Statistically significant at the 0.05 level with two-tailed test except as noted in the text. Adjusted r-square = 0.883, Mean Bus Trips = 689,940, ANOVA F(19,172) = 80.51, n=191.

Monthly data are for Bus Trips (Unlinked Passenger Trips) from January 2002 to January 2018. Root Mean Squared Error = 34,048. Mean of Bus Hours = 29,990. Mean of Bus Miles = 396,083. Mean of real gas price = $2.97. Mean of Employment in 000s =815.715.

Lagged Bus Rides The estimated coefficient on the lagged value of ridership is 0.44. This value shows that riders adjust to changes slowly. The slow change may signal that riders develop habits and that adjustment in transit trips is costly, as in finding alternate modes of travel and changing locations of residences, employment, and other destinations. The near total adjustment occurs within six months. The longer-term effect of each explanatory variable is its coefficient divided by one minus the value of the coefficient on the lagged bus trips.

Bus Hours An added hour of a bus-in-service is associated with 19 more riders immediately. With the near full

adjustment in six months, the added hour of bus service per month is associated with 33 added riders, other things equal. As figure 1 hinted, the hours of bus service are important in understanding ridership.

Bus Miles An added mile of bus service, given the other variables in the estimated model, has a significant negative association with ridership. Each added mile—given hours—is associated with one less rider immediately, and 1.60 fewer riders after six months. The estimated linear relationship between miles and hours shown in Figure 2 suggests that each added hour associates with 9.5 more miles of bus service. An added bus hour yields 33 more riders, but a decrease of 15 (= 9.5 * 1.60) with more miles of service after six months of adjustment. The net gain from an added hour of service with the average associated miles is 18 trips after six months.

A plausible interpretation of the negative coefficient on miles of service—given hours—is that transit attracts more riders when buses move at slower speeds in densely developed areas of the city and during rush hours when more people want to travel. Call this a go-with-the-people strategy. In contrast, a cover-the-county strategy offers access to dispersed locations with extended hours of service and faster moving buses that attract fewer riders per mile.

Price of Gasoline The real price of gasoline has a substantial positive association with transit ridership. A dollar increase in the real price of gasoline is associated with an immediate increase of 23,944 of monthly riders. The long-term effect reached after six months is 42,757. This is a 6.2 percent movement in ridership at the average ridership in the observed period. This shift in bus ridership with a $1 change in the real price of gasoline implies a cross price elasticity of demand of 0.15. (Note 23)

This estimate is similar to the value of 0.17 reported in a recent study using microdata by Jung, Yu, and Kwon (2016). (Note 24) Kremers et al. (2001) use a meta-analysis to argue that elasticities estimated within a city—like our estimates—are generally smaller than those estimates with national data. (Note 25)   Taylor et al., (2003), however, use a national cross-section analysis to estimate the cross price elasticity of demand of gasoline prices at 0.178, a value similar to our estimate. (Note 26) That our estimate is similar to that found in other studies helps validates our approach.

Employment Total non-farm employment has a small but statistically significant association with bus trips at the five percent level with a one-tailed test, given the other variables in the regression model. The immediate effect of 1,000 more employees is 208 more bus trips per month. The long-term effect is 308 bus trips per month. This is less than one percent of the likely 40,000 one-way trips 1,000 employees would make in a month with 20 workdays. Employment grew before the great recession, dropped in the recession, and grew steadily after the bottom of the recession as shown in Figure 4.

A scatterplot of ridership against employment in Figure 5 shows that bus trips grew with employment before the great recession. Since the great recession, however, bus trips have an unclear association with employment in the scatter. The regression shows a relationship.

7. Trend

The coefficients of both the linear (=b) and quadratic (=c) trend variables are statistically significant. The estimated parabolic trend line reaches a peak at (–b/2c=) 68.5. This peak is in August 2007.

The trend accounts for some influences on ridership not reflected in the variables included in the estimated regression. Changing land-use patterns are one possible explanation.

New, dense, expensive housing has become dominant in central Nashville. Higher income people who dwell in these units may be less likely to use transit because they place a high value on time and avoid the waiting and transfers often required in using transit. At the same time, middle- and low-income households have moved away from the center of the city for lower cost housing and often for suburban employment.

Traditional transit riders find transit less useful in making the crisscross trips in lower density areas that are common in the suburbs. The year 2007 may mark a point when new roles in the center of the city surpassed the older roles. A consequence may be a trend decline in transit ridership, other things equal.

Another possible cause is the growth of the ride-hailing services, Uber and Lyft. These services came to Nashville in 2013 and have grown significantly. (Note 27) Uber and Lyft may complement traditional transit service by making easy connection to the high capacity service. They may, however, also substitute for traditional transit. Pickup is often faster and closer to a trip's origin. The route is direct to a destination, often in less than half the time and mileage required by transit. Car services, particularly with discounts for shared rides, may be a significant substitute for some transit trips.

8. Regression of Ridership Model Since the Great Recession

The period from July 2011 to January 2018 shows a stable pattern that gives a clearer trend. Table 2 reports a regression estimate of the determinants of bus trips in this recent period. The lagged bus trips variable shows no effect. The response of bus trips to changes in the explanatory variables is instantaneous. The lagged adjustment estimated over the full series is important in understanding the turbulence in the recession, but not important in the more stable, recent period. The seasonal effects in the recent period differ somewhat from the estimates for the full period.

Table 2. Regression Estimates: Bus Trips per Month, Post Recession

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1,859,007.00	756,804.40	-2.46	**0.0169***
Bus Hours	40.95	9.69	4.23	**<.0001***
Bus Miles	-2.39	0.69	-3.49	**0.0009***
Gas Price in 2017$s	41,603.50	13,138.19	3.17	**0.0024***
Employment (000s)	2,563.93	1,375.55	1.86	**0.0672***
Trend	7,652.82	4,829.36	1.58	0.1183
Trend Squared	-56.98	11.79	-4.83	**<.0001***
Lag Bus Trips	-0.06	0.11	-0.51	0.6150
Jan dummy	78,852.25	35,904.83	2.2	**0.0320***
Feb dummy	68,087.57	30,665.02	2.22	**0.0302***
Mar dummy	50,771.49	24,492.10	2.07	**0.0425***
Apr dummy	55,925.58	19,132.53	2.92	**0.0049***
May dummy	46,014.58	18,092.35	2.54	**0.0136***
Jun dummy	6,527.67	24,390.06	0.27	0.7899
Jul dummy	17,263.31	29,793.03	0.58	0.5645
Aug dummy	116,342.08	20,634.35	5.64	**<.0001***
Sept dummy	129,483.30	18,109.65	7.15	**<.0001***
Oct dummy	114050.9	15838.14	7.2	**<.0001***
Nov dummy	50086.736	15685.12	3.19	**0.0022***

* Statistically significant at the 0.05 level with two-tailed test except as noted in the text. Adjusted r-square = 0.867, Mean Bus Trips = 766,107, ANOVA F (18, 60) = 21.7346, n=79. Monthly data are for Bus Trips (Unlinked Passenger Trips) from July 2011 to January 2018. Root Mean Squared Error = 24,842. Mean of Bus Hours = 43,714. Mean of Bus Miles = 452,453. Mean of real gas price = $3.11. Mean of Employment in 000s =798,459.

Bus hours show a coefficient of 41 compared to the long-term effect (33 trips) computed from the first regression. Added bus miles show a loss of 2.4 trips per added mile. This is larger than the long-term value of 1.6 computed from the first regression. With a decrease of 2.4 trips with each added mile, the 9.5-mile average with each added hour of bus service, trips would decline by 23 through the mileage affect, leaving a net gain of 18 trips with an added hour of bus service. This is the same net long-term gain estimated in the first regression for the combined effects of bus hours and miles.

The real price of gasoline shows an increase of 41,604 for a one-dollar real increase. This is close to the long-term effect (42,757) estimated in the first regression.

Employment shows a modest association with growth in bus trips with a one-tailed test at the 5 percent level of statistical significance, given the other variables in the model. The 2,564 monthly one-way trips are associated with an increase in employment of 1,000. With 20 workdays per month and a round trip each day, the coefficient implies a six percent increase in monthly one-way work trips per month. According to the Census, 2.1 percent of people who work in Davidson County travelled to work by public transportation in 2016. (Note 28) The estimated coefficient is not statistically significantly different than the rate observed by the Bureau of the Census.

There is, however, a modest downward trend in bus trips, despite the growing employment. The peak of the estimated quadratic trend is in July 2007 and close to the peak of August 2007 estimated in the regression of the full series. Although the linear coefficient is not statistically significant, the coefficient of the square term is significant and negative. This coefficient indicates a modest downward trend in bus ridership, given the other explanatory variables in the regression.

9. Discussion

In this paper, we perform extensive analyses of the effect of Nashville's employment and public transport service on public transit ridership. We find no statistically significant evidence of an upward trend in public transit ridership at least since 2012 as show in the decomposition of the time series. This finding is despite rising hours of bus service, declining fares, and growing employment. In fact, our study points to a downward trend in Nashville's public transit ridership since 2012. The estimated coefficients on the quadratic trend in the regression show a peak in Nashville's public transit ridership occurred more than a decade back.

Our findings elaborate observations in the Congressional Research Service (CRS) report. (Note 29) The CRS report does not address the contrasting roles of bus hours and bus miles included in our research. Nashville's record of varying hours and miles somewhat independently allows us to estimate their separate effects. The evidence on gas prices here is consistent with the CRS summary and of other published studies as noted above.

The lagged effect is apparent over the long term as the pattern of bus use changes significantly. In the more recent period, the full response to a change in an explanatory variable appears immediately pointing to a quick change in the behavioral responses of the commuters.

10. Conclusion

The estimates presented in this paper are consistent with the recent downward trend in ridership after the great recession that is the main theme in the CRS report. Our research is richer than the CRS study in several ways. This study controls for the role of several other factors and checks for the robustness of the time series results through different methods.

Expansion of transit service in Nashville and other cities faces a headwind. The pronounced decline in transit usage estimated here reduces likely net future benefits. (Note 30)

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