Bus Rapid Transit and Economic Development:
A Quasi-Experimental Treatment and Control Analysis

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Abstract

In this article, we evaluate the relationship between bus rapid transit (BRT) systems and economic development from the Great Recession which began in 2008, its first full calendar year, through 2011, the first full calendar year of recovery. Unlike other studies of transit system development outcomes, we use a quasi-experimental design that assesses the difference BRT station areas make with respect to changes in jobs compared to the counter-factual argument that the changes would have occurred anyway. This entailed developing a technique to create pseudo BRT station areas as controls. We apply our analysis to all 11 BRT lines in the United States operating in 2008 and before. Using descriptive and shift-share analysis, we find that BRT station areas perform moderately better than the pseudo BRT station area controls. We also find that BRT station areas perform moderately to substantially better at shifting the share of jobs in manufacturing, industrial, office, health care and arts-entertainment-recreation economic groups than pseudo BRT station areas. That these outcomes are detected over such a short period of time but on the heels of a major economic calamity may help advance ongoing BRT planning and investments.

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Introduction

As of this writing, nearly 100 bus rapid transit (BRT) lines exist, are being built, or are being planned for installation across the United States, from small metropolitan areas of just a few hundred thousand people to metro areas of tens of millions of people. BRT's popularity is driven by its low capital cost relative to rail transit systems, its flexibility in design and installation, and increasingly by anecdotes of its success in attracting development and jobs (Institute for Transportation and Development Policy 2013a). This may be attributable in part to unique aspects of BRT systems that combine the certainty of fixed-rail systems with the cost-savings of rubber-tired buses (Weinstock et al. 2011; Institute for Transportation and Development Policy 2013b; Nikitas and Karlsson 2015).

That public transit generally (Nelson et al. 2009) and BRT specifically should advance economic development is a reasonable assumption (Thole and Samus 2009; GAO 2001, 2012). Unfortunately, there is only one study that comprehensively addresses this assumption. Since Belzer, Srivastava and Austin (2011) evaluated the change in jobs with respect to transit station proximity across several transit modes from 2002 to 2008 before the Great Recession, there have been no widely published studies about the relationship between BRT systems and jobs. There is only one case study on economic development outcomes associated with BRT–Eugene-Springfield's Emerald Express (EmX), but it is an isolated study that has not been replicated (Nelson et al. 2013). Therefore, measuring system type-specific return-on-investment – especially BRT systems that has not been explored so far – is critical to support and strengthen justifications of BRT system investment for economic growth at various spatial level (Cervero and Dai 2014).

This study helps close the gap in BRT economic development research by addressing the following question:

> *Is there an association between BRT and economic development generally since the Great Recession and into recovery?*

We apply this question to each of the BRT systems initiated in the United States since 2008. Our article starts with profiles of the 11 BRT lines operating in nine metropolitan areas since 2008; reviews the research design, data and methods; presents results for descriptive and shift-share analysis; and offers a summary with implications.

This study helps close the gap in BRT economic development research by addressing the following question: is there an association between BRT and economic development generally since the Great Recession and into recovery? To answer this question, this study focuses on analyzing economic impacts of each of the BRT systems initiated in the United States since 2008. Particularly, this study will identify economic impacts of each BRT systems after the Great Recession by comparing census block groups within a 0.5-mile buffer around their nearest BRT station with block groups that have similar economic and demographic characteristics but do not fall within a 0.5-mile buffer around a BRT station.

BRT Lines Profiled

What follows is a profile of each of the BRT systems that are used for analysis. We review them chronologically based on the metropolitan areas with the oldest system. We also note how each line was rated by the Institute for Transportation and Development Policy (2013b). Using objective criteria, it rates all the world's BRT systems as Basic, Bronze, Silver and Gold. BRT systems that do not receive a rating are technically not considered such by that organization (see Nelson 2015 for details). However, we include all U.S. BRT lines that are declared as such by their agencies.

Pittsburgh, Pennsylvania. Pittsburgh launched the South Line (rated Basic) in 1977, just three years after the world's first system in Curitiba, Brazil, and it became the U.S.'s first BRT system. The South Line's 4.3 miles of exclusive bus lanes encompass previously underserved areas, from the suburbs to downtown. Funding for the system came from U.S. DOT, the State of Pennsylvania, and Allegheny County. The Port Authority of Allegheny County operates the system. By 1983, Pittsburgh launched the East Line (rated Bronze) with 6.8 miles that connect the eastern suburbs to downtown. In 2000, the West Line (rated Basic) was initiated.

Las Vegas, Nevada. In 2004, the BRT system, called MAX (rated Bronze), was put into service. Its 7.5 mile route connects downtown Las Vegas with Nellis Air Force Base. The BRT service is intertwined with regular bus service. Much of the BRT system serves areas that were already substantially developed at low to modest intensities. The line is owned by the Regional Transportation Commission of Southern Nevada and operated by Veolia Transportation.

Los Angeles, California. Los Angeles opened the Orange Line (rated Bronze) in 2005 to serve the San Fernando Valley north of the City of Los Angeles. It includes 18 miles of exclusive right-of-way. The Orange Line is operated by the Los Angeles County Metropolitan Transportation Authority.

Kansas City, Missouri. Kansas City began operating its Main Street Line in 2005. It connects downtown to the Crown Center Plaza along a six-mile route, nearly four miles of which are dedicated lanes. It is unrated. The system is operated by the Kansas City Area Transportation Authority.

Eugene-Springfield, Oregon. The Emerald Express (EmX) BRT system (rated Bronze) serving the Eugene-Springfield metropolitan area was put into service in 2007. It connects downtown Springfield to downtown Eugene with stops at the University of Oregon and medical centers. One unique feature affecting this metropolitan area is the presence of an urban growth boundary designed to steer jobs away from lower-density areas into more central ones especially those served by transit. EmX was extended in 2011 to connect northward from the east to the Gateway Mall and Sacred Heart Medical Center at River Bend.

Cleveland, Ohio. Cleveland's HealthLine BRT system, started in 2008, is the nation's highest-rated BRT system (Silver). The HealthLine connects downtown Cleveland to the medical centers to the east. Features of the HealthLine include 24 hybrid-electric vehicles, doors on both sides, bike lanes, landscaping/hardscape treatment with 1,500 irrigated trees, and integrated/stand-alone public art. The 36-station, 9.2-mile BRT corridor is operated by the Greater Cleveland Regional Transit Authority.

Bronx, New York. New York City initiated the Fordham Road-Pelham Parkway BRT Line (unrated) in 2008, substantially serving the Bronx Borough. The systems offers transfer opportunities to subway lines and to the Metro-North Commuter Railroad lines. It is operated by the New York City Department of Transportation.

Phoenix, Arizona. In 2008, the Valley Metro Transit serving Maricopa County, the central county of the Phoenix metropolitan area, opened its Main Street Line (unrated). The 11-

mile, 25-station Main Street Line has since been connected to include several other BRTs, including the Arizona Avenue BRT.

West Valley City, Utah. Yet another BRT system initiated in 2008, the MAX (unrated) runs along the Wasatch Front in suburban West Valley City in Salt Lake County, part of the Salt Lake City metropolitan area. The Max line is operated by the Utah Transit Authority and operates in a dedicated guideway separate from regular traffic.

Research Design, Data and Methods

The research reported in this article is a quasi-experimental, pre-post design applied to each BRT line based on two years: 2008, the first full calendar year of the Great Recession and 2011, the first full calendar year of recovery. It includes a unique control feature allowing reasonably objective comparisons between BRT station area performance and pseudo BRT station areas described below and in the technical appendix.

Data come from the Longitudinal Employer-Household Dynamics (LEHD) for 17 of the 20 two-digit North American Industrial Classification Scheme economic sectors. Excluded are the agriculture, mining and construction sectors because those workers do not normally occupy building spaces in urban areas. Data are collected at the census block group level. The study areas are the centroids of block groups within 0.50-mile of BRT stations. For the analysis, the 17 urban-related, space-occupying sectors are combined into eight economic groups in the manner shown in Table 1. This is similar to the combinations used by others (Belzer, Srivastava and Austin, 2011).

Two analytic methods are used: descriptive analysis and shift-share analysis. Descriptive analysis is used to compare changes in jobs for each economic group between 2008 and 2011 of block group centroids within BRT 0.25-mile of BRT stations, as well as for the sum of all groups for the station areas. This radius is based on research by Nelson et al. (2013) and Nelson and Ganning (2015) showing that nearly all change in employment associated with BRT stations occurs within the first 0.25-mile of a BRT station. Z-scores are used to test the null hypothesis proposition that there is no statistically significant difference in job change between the years (where $p < 0.01$). Descriptive analysis is also used to compare outcomes with respect to control areas using the technique summarized below and described in the technical appendix.

Table 1
Allocation of Jobs by Economic Sectors into Economic Groups

Manufacturing
Manufacturing
Industrial
Utilities
Wholesale Trade
Transportation and Warehousing
Retail-Lodging-Food Service
Retail Trade
Accommodation and Food Services
Knowledge
Information
Professional, Scientific, and Technical Services
Office
Finance and Insurance
Real Estate and Rental and Leasing
Management of Companies and Enterprises
Administrative and Support and Waste Management and Remediation Services
Other Services (except Public Administration)
Public Administration
Education
Educational Services
Health Care
Health Care and Social Assistance
Art-Entertainment-Recreation
Arts, Entertainment, and Recreation

Source: Census

Shift-share analysis is also used because it assigns the change or shift in the share or concentration of jobs with respect to the region, the industry mix, and the "local" area. The local area is often a city or county or even state, but it can be any geographic unit that is smaller than the region. Our local areas are those block groups with centroids within 0.25-mile of the nearest BRT station; this is called the BRT Station Area. As shifts in the share of jobs may vary by sector over time because of changes in economic sector mixes, there is also an "economic group mix" based on the economic groups noted in Table 1. Using notations by the Carnegie Mellon Center for Economic Development (undated), the shift-share formula is:

$$\mathbf{SS_i = CC_i + EGM_i + BRT_i}$$

Where,

SSi = Shift-Share

CCi = Central County share

EGi = Economic Group Mix

BRTi = BRT Station Area shift

The CC share measures by how much total employment in a BRT station area changed because of change in the metropolitan area economy during the period of analysis. If central county employment grew by 10 percent during the analysis period, then employment in the BRT station area would have also grown by 10 percent if there is no BRT effect. The Economic Group Mix (EGM) identifies fast-growing or slow-growing economic sectors in a BRT station area based on the CC growth rates for the individual economic sectors. For instance, a BRT station area with an above-average share of the central county's high-growth sectors would have grown faster than a BRT station area with a high share of low-growth sectors. The BRT station area shift, also called the "competitive effect," is the most relevant component; it identifies a BRT station area's leading and lagging sectors. The competitive effect compares a BRT station area's growth rate in a given economic sector with the growth rate for that same sector at the metropolitan area. A leading sector is one where that sector's BRT station area growth rate is greater than its metropolitan area growth rate. A lagging sector is one where the sector's BRT station area growth rate is less than its CC growth rate. However, shift-share analysis by itself does not necessarily ascribe a causal relationship, merely an associative one.

The equations for each component of the shift-share analysis are:

$$\mathbf{CC} = \mathbf{({}_iBRT\ station\ area^{t-1} \bullet CC^{t} / CC^{t}\text{-}1)}$$

$$\mathbf{EGM} = \mathbf{[({}_iBRT\ station\ area^{t-1} \bullet {}_iCC_{t} / {}_iCC^{t-1}) - CC]}$$

$$\mathbf{BRT} = \mathbf{[{}_iBRT\ station\ area^{t-1} \bullet ({}_iBRT\ station\ area^{t} / {}_iBRT\ station\ area^{t-1} - {}_iCC^{t} / {}_iCC^{t-1})]}$$

Where:

iBRT station area^{t-1}	=	number of jobs in the BRT station area sector (i) at the beginning of the analysis period (t-1)
iBRT station area^{t}	=	number of jobs in the BRT station area in sector (i) at the end of the analysis period (t)
CC^{t-1}	=	total number of jobs in the central county at the beginning of the analysis period (t-1)
CC^{t}	=	total number of jobs in the central county at the end of the analysis period (t)
iCC^{t-1}	=	number of jobs in the central county in sector (i) at the beginning of the analysis period (t-1)

iCC^t = number of jobs in the central county in sector (i) at the end of the analysis period (t)

To control for the counter-factual— that is, that development (or lack thereof) would have occurred anyway – we devised an algorithm to identify 10 pseudo BRT station areas having comparable attributes to each existing station. This generates an alternative set of pseudo BRT station areas with which to apply control analysis. The technical procedure is described in the appendix. The control analysis is noted as "pseudo" for control block groups with centroids within 0.25-mile of pseudo BRT stations. Because there are 10 more pseudo BRT station areas than BRT station areas, we normalize by using the means of block groups for both treatment and control areas. We caution that though this improves causal inference, we are conservative in concluding only associative ones. Results and interpretations are reported next.

Results and Interpretations

Descriptive results are reported first, then shift-share results. Interpretations are offered for each.

Descriptive Results

Table 2 reports descriptive results. For all but four of the 11 lines, BRT station areas are associated with better performance relative to counter-factual areas. In some cases, jobs increased in the BRT station areas relative to pseudo BRT station areas—Pittsburgh South and West lines, Bronx Pelham Parkway and West Valley City. These BRT lines serve substantially built-out suburban areas. In other cases both study areas lost jobs overall but the BRT station areas lost less—Kansas City, Eugene-Springfield, and Cleveland. In case of BRT systems located within the Rust Belt metropolitan areas (Cleveland, Pittsburgh, and Bronx), job changes after the Great Recession show that block groups near BRT stations experienced less job loss compared to pseudo BRT block groups. Particularly, block groups near the Bronx Pelham Parkway in New York experienced much higher job growth (39.4 percent) compared to its pseudo block groups (14.1 percent). In all three cases, BRT systems serve downtowns and nearby areas but not suburban ones. In four situations the pseudo BRT station areas gained over BRT station areas—Pittsburgh South line, Las Vegas, Los Angeles and Phoenix. In all cases, BRT lines served principally suburban areas that were especially hard-hit during the recession. However, only in Las Vegas was total job change in the pseudo BRT station areas positive while the total change in BRT station areas negative. One reason may be that the BRT station areas were already more substantially developed than control areas but further investigation will be needed to understand this outcome. Overall, total jobs increased within BRT station areas by 0.7 percent but decreased in pseudo BRT station areas by 1.3 percent, a total difference of nearly 170 jobs per block group.

Overall, five economic groups appear to be more attracted to BRT station areas than to pseudo BRT station areas. These include manufacturing, industrial, office, health care and arts-entertainment-recreation. Pseudo BRT station areas performed slightly better than BRT station areas in the retail-lodging-food and knowledge economic groups. Notably, however, the pseudo BRT station areas did much better than BRT station areas in the education economic group. One reason may be that suburban-dominated educational institutions are dispersed, often away from major highways that may otherwise be attractive locations for BRT stations. Differentiation between types of educational institutions could be the subject of future research.

Results from shift-share analysis are reported next.

Table 2
BRT Station Area Treatment and Pseudo BRT Station Area Control Area Job Percentage Change
Great Recession into Recovery, 2008-2011

Economic Group	**Pitts-burgh South Line BRT Change**	**Pitts-burgh South Line BRT Change**	**Pitts-burgh West Line BRT Change**	**Las Vegas Max Line BRT Change**	**Los Angeles Orange Line BRT Change**	**Kansas City Main Street BRT Change**	**Eugene-Spring-field EmX BRT Change**	**Cleve-Land Health-Line BRT Change**	**Bronx Pelham Park-way BRT Change**	**Phoenix Main Street BRT Change**	**West Valley City Max BRT Change**	**All BRT Systems Change**
BRT Rating	Basic	Bronze	Basic	Bronze	Bronze	Unrated	Bronze	Silver	Unrated	Unrated	Unrated	NA
BRT Station Area Treatment												
Manufacturing	-26.4%	-18.4%	-26.9%	-30.7%	-16.9%	-3.0%	-14.2%	-27.2%	8.6%	-38.9%	10.1%	**-16.7%**
Industrial	-37.1%	5.7%	15.2%	-5.9%	0.0%	2.9%	14.3%	-14.6%	169.3%	-15.8%	-0.7%	**1.7%**
Retail-Lodging-Food	14.5%	18.0%	8.8%	-21.3%	-9.5%	-3.5%	-5.5%	-10.3%	10.8%	-10.3%	-5.6%	-5.9%
Knowledge	-3.2%	5.1%	-10.0%	-11.5%	-2.4%	-11.3%	-8.6%	-28.8%	-9.6%	-47.8%	-5.5%	-9.9%
Office	-4.7%	-5.1%	17.0%	14.3%	-3.6%	-0.4%	-4.1%	-18.1%	-6.6%	-10.3%	38.5%	**4.8%**
Education	-23.5%	-27.3%	38.9%	13.3%	131.0%	0.0%	2.2%	-24.9%	13.1%	-7.5%	11.6%	3.6%
Health Care	-16.1%	31.0%	18.3%	-6.0%	-42.9%	8.5%	9.5%	26.2%	95.8%	24.4%	23.6%	11.7%
Arts-Entertain-Recreation	-24.5%	-2.7%	76.4%	38.2%	17.0%	-9.2%	-11.4%	-39.0%	30.8%	22.9%	23.8%	**18.8%**
Total	-9.3%	**10.1%**	**12.5%**	-5.8%	-4.2%	**-1.9%**	**-1.0%**	**-10.9%**	**39.4%**	-7.9%	**12.2%**	**0.7%**
Economic Group	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**	**Pseudo Change**
Pseudo BRT Station Area Control												
Manufacturing	-7.3%	-14.1%	-13.8%	-17.6%	-5.5%	-28.6%	-34.1%	-32.3%	-23.7%	-8.9%	-17.4%	-22.7%
Industrial	6.7%	-10.1%	-7.0%	-7.6%	-7.4%	-34.1%	-17.2%	-34.3%	11.7%	-16.4%	-12.0%	-13.3%
Retail-Lodging-Food	-12.4%	-0.5%	1.6%	8.3%	-4.6%	-15.6%	-4.5%	-24.8%	15.7%	-18.3%	-13.5%	**-3.1%**
Knowledge	-1.7%	-0.7%	9.8%	2.2%	-5.2%	-14.3%	-5.3%	-39.4%	7.2%	-18.7%	-2.8%	**-6.5%**
Office	17.3%	15.2%	19.5%	-19.2%	-1.7%	-5.0%	-7.7%	-18.3%	10.7%	-1.7%	-3.3%	-2.9%
Education	1.0%	10.2%	11.4%	507.3%	7.8%	-6.4%	6.3%	-27.2%	15.1%	18.3%	-12.4%	**28.8%**
Health Care	0.7%	4.8%	-8.3%	7.5%	-1.7%	-16.3%	14.1%	20.1%	20.5%	24.8%	18.3%	7.9%
Arts-Entertain-Recreation	-72.6%	-8.5%	-14.4%	-7.2%	-1.7%	-21.0%	-16.3%	-33.4%	-4.1%	-7.7%	-3.8%	-11.8%
Total	**-0.9%**	3.5%	3.3%	**15.4%**	**-2.2%**	-14.4%	-8.4%	-18.7%	14.1%	**-4.2%**	-6.3%	-1.3%

Note: Z-scores show that change in total BRT station area jobs is significantly different than change in total pseudo BRT station area jobs with respect to total central county change in jobs at $p < 0.01$with the exception of the Los Angeles Orange Line. Best-performing treatment and control BRT station areas are highlighted in bold, as are best-performing economic groups.

Shift-Share Analysis

Shift-share results are reported in Table 3. While outcomes are mostly similar to those found for the descriptive analysis, there are interesting nuances.

First of all, eight of 11 BRT station areas had better overall performance than pseudo BRT station areas, with the Los Angeles Orange line having slightly better performance. Across all systems, however, BRT station areas performed many times better than pseudo BRT station areas. In particular, where the mean BRT station area lost 7.7 jobs per block group between 2008 and 2011, the mean pseudo BRT station area lost 104.5 jobs during the same period, about 13.5 times more.

While overall BRT and pseudo station areas lost jobs relative to the rest of their central counties, the story is different when looking more carefully at the treatment and control groups. Among the eight BRT station areas that performed better than the pseudo BRT station areas, six showed positive job growth. In contrast, two of the three pseudo BRT station areas that performed better lost jobs relative to their central counties.

Moreover, five of the eight economic groups performed better in the BRT station areas than in the pseudo BRT station areas including: manufacturing, industrial, office, health care and arts-entertainment-recreation. The others—retail-lodging-food, knowledge and education—fared much better in pseudo BTR station areas than the treatment group. Particularly, among 11 BRT station areas, Pittsburgh West Line in Pittsburgh and West Valley MAX BRT in Salt Lake City experienced rapid job growth. Finally, although it is hard to identify the relationship between the quality of BRT systems and job growth, BRT systems with higher grades show better job growth than ones with low or unrated grades. West Valley City MAX BRT in Salt Lake City is the only exception.

Table 3
BRT Station Area Treatment and Pseudo BRT Station Area Control Shift-Share Results[a]
Great Recession into Recovery, 2008-2011

Economic Group	**Pitts-burgh South Line BRT Shift**	**Pitts-burgh South Line BRT Shift**	**Pitts-burgh West Line BRT Shift**	**Las Vegas Max Line BRT Shift**	**Los Angeles Orange Line BRT Shift**	**Kansas City Main Street BRT Shift**	**Eugene-Spring-field EmX BRT Shift**	**Cleve-Land Health-Line BRT Shift**	**Bronx Pelham Park-way BRT Shift**	**Phoenix Main Street BRT Shift**	**West Valley City Max BRT Shift**	**All BRT Systems Change**
BRT Rating	Basic	Bronze	Basic	Bronze	Bronze	Unrated	Bronze	Silver	Unrated	Unrated	Unrated	
BRT Station Area Treatment (figures are mean jobs per block group comprising the analysis area)												
Manufacturing	-6.9	-2.2	-6.3	-1.1	-2.6	2.7	13.2	-2.7	0.4	-9.9	10.3	**-8.8**
Industrial	-15.5	2.0	5.8	0.3	1.2	3.5	28.7	0.4	10.0	-2.8	1.3	**28.6**
Retail-Lodging-Food	10.7	14.9	13.6	-68.5	-11.5	2.4	-2.8	-2.5	-2.0	-9.4	0.5	-61.5
Knowledge	-4.0	2.5	-20.9	0.6	-3.5	3.9	-2.7	-4.0	-0.8	-20.9	-1.5	-55.8
Office	-39.9	-9.9	51.8	49.5	-27.6	-4.8	9.8	-9.8	-4.4	-8.4	72.1	**77.6**
Education	-30.5	-10.6	19.8	0.2	48.7	2.8	-2.7	-7.3	-0.2	-27.7	5.1	-7.1
Health Care	-20.1	32.7	5.1	-5.9	-61.9	-2.3	-9.5	-0.4	37.6	4.5	3.4	**-9.6**
Arts-Entertain-Recreation	-2.5	-2.3	17.4	11.7	1.7	1.8	0.7	-2.8	0.2	1.7	3.8	**28.8**
Total	-108.8	**27.2**	**86.4**	-13.1	**-55.4**	**9.9**	**34.8**	**-29.1**	**40.8**	-72.9	**95.0**	**-7.7**
Economic Group	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**	**Pseudo Shift**
Pseudo BRT Station Area Control (figures are mean jobs per block group comprising the analysis area)												
Manufacturing	0.3	-1.6	-1.7	0.8	6.5	-3.2	-5.2	-5.2	0.0	0.4	-7.7	-50.0
Industrial	1.1	-2.3	-3.7	-0.0	-2.9	-9.6	-3.3	-5.0	0.3	-6.6	-10.9	-52.6
Retail-Lodging-Food	-9.1	-0.4	1.5	67.4	-2.2	-8.8	0.9	-11.4	0.3	-25.2	-18.1	**-9.3**
Knowledge	-0.3	-0.0	6.2	5.8	-19.1	1.1	1.1	-5.2	0.3	-10.7	-2.2	**-16.8**
Office	3.9	5.0	14.7	-33.8	-21.5	-9.5	-3.9	-8.2	0.7	11.6	-9.6	-87.1
Education	-2.4	1.1	1.9	185.5	-12.1	0.1	1.1	-5.8	0.1	7.2	-10.6	**181.6**
Health Care	-1.5	-2.9	-18.3	-2.6	-16.0	-17.9	3.5	-3.4	-5.8	5.5	2.5	-51.6
Arts-Entertain-Recreation	-2.1	-1.6	-3.9	0.5	0.1	0.2	-0.7	-1.5	-0.1	-2.4	-0.5	-18.8
Total	**-10.0**	-2.7	-3.3	**223.5**	-67.2	-47.6	-6.5	-45.8	-4.2	**-20.3**	-57.1	-104.5

a Only the BRT and Pseudo BRT station area ("local") shift-share results are reported for brevity.
Note: Best-performing treatment and control BRT station areas are highlighted in bold, as are best-performing economic groups.

Summary and Implications

Bus rapid transit (BRT) is emerging as a dominant public transit effort. Little is known, however, of their effect on economic development. This study contributes knowledge accordingly.

We find that over a very constrained but interesting period of time—2008 through 2011—that BRT systems appear to attract somewhat more economic development in terms of jobs than the counter-factual case, operationalized here as pseudo BRT systems. Though three years is not much time, the study period begins in 2008 at the height of the Great Recession and extends through 2011, the first full calendar year after the recession. That the BRT station areas performed moderately better than their pseudo BRT station area counterparts during this challenging economic period may be an important finding. Table 4 summarizes our descriptive and shift-share analysis.

Results for individual metropolitan areas may offer insights into planning for new or expanded BRT systems in the future. For instance, though the worst-performing BRT line in our analysis was Pittsburgh's South line, it is also a historically underserved area perhaps with more economic development challenges than other parts of Allegheny County. We note that the other two BRT lines operating in Allegheny County are among the best performers overall and among most economic groups. Similarly, the Las Vegas Max line serves a historically under-invested area that has largely been bypassed by the new economic investment of the past few decades. In addition, the Main Street line in Phoenix serves a substantially built-out, aging suburban area that suffered from the Great Recession perhaps more than the rest of the nation. On the other hand, shift-share analysis shows that the BRT station areas of Kansas City, Eugene-Springfield, Bronx, and West Valley City (in the Salt Lake City metropolitan area) enjoyed substantial, positive performance in contrast to their pseudo BRT station area controls that exhibited substantial, negative performance. Los Angeles' Orange line and Cleveland's HealthLine lost share of jobs during the study period but less so than their central counties as a whole.

Performance of individual economic groups is also interesting. One surprise is that the manufacturing and industrial economic groups performed much better in BRT station areas than in pseudo ones. The manufacturing sector is perhaps the most diverse. For instance, micro-breweries are considered a manufacturing enterprise yet they are popular in downtowns. Other activities include woodworkers, steel fabricators, hardware prototypers, laser printers, coffee roasters, and a host of specialty garment operations. In addition, industrial jobs include those in the utility industry which includes mostly office and clerical workers. That BRT station areas also perform better than pseudo BRT station areas in the office, health care and arts-entertainment-recreation economic groups is not surprising as these activities tend to be attracted to centers with easy transit access. Though initially a surprise that education jobs favored pseudo BRT station areas by a very substantial margin, this may be attributable to the highly dispersed nature of educational facilities, most of which serve dispersed suburban areas. Certainly some types of educational jobs would be attracted to BRT station areas but future research can ascertain this.

We surmise that, on the whole, BRT station areas contribute to economic development. Indeed, that the outcomes reported above are detected over such a short period of time but on the heels of a major economic calamity may help advance ongoing BRT planning and investments. Future research, perhaps adapting the design we used, can benefit from more years of data especially if applied to systems initiated in the 2000s. Such research is important to assure that the billions of dollars being spent or being planned for expenditure will leverage economic development.

Table 4
Summary Results of Descriptive and Shift-Share Analysis of BRT Station Areas (Treatment) and Pseudo BTRT Station Areas, 2008-2011

BRT Line	**Descriptive BRT Station Area Treatment**	**Descriptive Pseudo BRT Station Area Control**	**Shift-Share BRT Station Area Treatment**	**Shift-Share Pseudo BRT Station Area Control**
Pittsburgh South—1977 – Basic	-9.3%	**-0.9%**	-108.8	**-10.0**
Pittsburgh East—1983 – Bronze	**10.1%**	3.5%	**27.2**	-2.7
Pittsburgh West— 2000 – Basic	**12.5%**	3.3%	**86.4**	-3.3
Las Vegas MAX—2004 - Unrated	-5.8%	**15.4%**	-13.1	**223.5**
Los Angeles Orange—2005 - Bronze	-4.2%	**-2.2%**	**-55.4**	-67.2
Kansas City Main Street—2005 - Unrated	**-1.9%**	-14.4%	**9.9**	-47.6
Eugene-Springfield Emerald Express—2007 - Bronze	**-1.0%**	-8.4%	**34.8**	-6.5
Cleveland Health Line—2008 - Silver	**-10.9%**	-18.7%	**-29.1**	-45.8
Bronx Pelham Parkway—2008 - Unrated	**39.4%**	14.1%	**40.8**	-4.2
Phoenix Main Street—2008 - Unrated	-7.9%	**-4.2%**	-72.9	**-20.3**
West Valley City MAX—2008 - Unrated	**12.2%**	-6.3%	**95.0**	-57.1
Mean Total BRT and Pseudo Station Area Change	**0.7%**	-1.3%	**-7.7**	-104.5
Overall best Performance	7	4	8	3

Note: Coefficients are the sum of the BRT Station Area Share of the shift in mean jobs per block group from shift-share analysis comparing change in share of total jobs between BRT station areas and pseudo BRT station areas with respect to change in central county jobs from the Great Recession into recovery, 2008-2011. All differences are statistically significant at $p < 0.01$.

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Technical Appendix

Pseudo BRT Station Area Selection Protocol for Control Analysis

BRT control areas were created as follows. For details, see Kim (2015). Finding the comparable points for each existing BRT station is done through ESRI's ArcGIS Model Builder. The first step is building a BRT database. The General Transit Feed Specification (GTFS) reference provided by Google contains information about public transit systems in the US allowing for existing BRT station points to be assembled in ArcGIS. For BRT station points that are very close to each other, such as a pair of stations on the each side of a major roadway, the center points between these pairs of BRT stations are created and used for analysis. For major road data from the BRT regions, ESRI's major road shapefile for ArcGIS is used and clipped based on each BRT host county boundary.[1] In using ESRI's street map shapefile, we excluded interstate highway segments because no BRT stations can be built in them. Also, we excluded road segments coded as "highway ramp." Census block group GIS shapefiles for BRT regions were prepared so Longitudinal Employer-Household Dynamics (LEHD) data could be populated in them. These census and LEHD datasets are used to calculate values within a 0.25-mile walkshed of both existing and comparable BRT station points later in the process. The 0.25-mile radius is used based on prior research by Nelson et al. (2013) showing that nearly all BRT-related employment effects occur within this distance BRT stations.

Tools using ArcGIS Model Builder were then developed by the research team. The first step was to create potential comparable points throughout major roads within the BRT central county. To do this, a tool for creating random "***pseudo BRT stations***" was used. After running

[1] According to the white paper of ESRI street map report (http://downloads.esri.com/support/whitepapers/ao_/Esri_Data_and_Maps_10.pdf), ESRI uses the 2005 Tele Atlas street datasets for ESRI 10 street map. The street map data is based on the 2005 street Atlas, so there may be some missing major roads compared to the 2015 street map. However, this is the only street map data that the research team can use currently. This research uses the ESRI 10 street map GIS shapefile for finding the top ten comparable BRT station points here.

several ArcGIS Model Builder tools, thousands of pseudo points were produced. Removing overlapping points and excluding random points outside urbanized areas, about 1,000 random pseudo station points within urbanized areas were selected as candidate pseudo BRT stations.

At this stage, pseudo BRT stations do not have any properties. The research team populated 0.25-mile radius ***pseudo BRT station areas*** with census data on population, employment, median household income, the total number of housing units, and total number of households. As needed, areal fraction ratios are calculated by dividing the total area of block groups intersecting with a 0.25-mile walkshed by the areas of parts of block groups that actually intersect with the 0.25-mile walkshed. By using these areal fraction ratios, values for the five measures are estimated for all existing and pseudo points through the iteration model of the processes above.

To select pseudo station points similar to the five properties of existing BRT stations, the quadrance score matching method is used based on the Euclidian distance (metrics). The Euclidian distance is defined as the “straight-line” distance between two points in the hypothetical Euclidian space. For the n-dimensional space, the Euclidian distance is calculated as a straight-line distance based on the simple Pythagorean Theorem (a squared root of a squared sum of difference in each element of the two points). Sometimes, a squared sum of differences between elements of the two points is used. The major advantage of using the Euclidian distance method is that its algorithm is very simple, fast, and easy to apply to identify the pseudo points with similar properties of treatment points compared to other methods like propensity score matching. In this study, we calculated the Euclidian quadrance score based on the five properties of each census block group – total population, the number of employment, median household income, the total number of housing units, and the total number of households within a block group. The formula is as follows:

$$Quadrance^2_{T_n} = \left(Population_{T_n} - Population_{Comp_n}\right)^2 + \left(Employment_{T_n} - Employment_{Comp_n}\right)^2 + \left(MedHHInc_{T_n} - MedHHInc_{Comp_n}\right)^2 + \left(Housing\_Units_{T_n} - Housing\_Units_{Comp_n}\right)^2 + \left(Households_{T_n} - Households_{Comp_n}\right)^2$$

The formula suggests that pseudo points with small quadrance scores have similar values of the five properties of existing BRT station areas. The top ten pseudo BRT station areas with the smallest quadrance score are finally selected. This means that for every existing BRT station there are 10 pseudo BRT stations having comparable demographic and housing features. Because there are thus 10 pseudo BRT station areas for each existing BRT station area, all data were normalized to means for each set of block groups with centroids falling within the 0.25-mile radius.