COMMUTER MOBILITY AND ECONOMIC PERFORMANCE IN US CITIES

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1. Introduction

The economic impact of increased urban mobility is theoretically ambiguous. Transportation research - as well as US transportation policy- has historically focused on the benefit that increased mobility brings to citizens. Clear benefits exist in enabling residents to access a wider set of destinations and expend less time on travel. More recently, urban theory has paid greater mind to the negative consequences of high mobility, such as automobile dependence and urban sprawl. Such modern conceptions of transportation planning point towards supplanting mobility initiatives with the promotion of locational "access."

Despite an apparent change in the urban planning zeitgeist, the amount of capital expended on mobility promoting infrastructure is large and growing. According to public data from the Federal Highway Administration, in 2010 all levels of US government provided a combined capital budget of $100 billion for highway construction, this figure represents an increase in real terms of 22% over 2000 expenditures and 71% over 1990 expenditures (Federal Highway Administration, 2015). Furthermore, particular urban areas in the US continue to promote mobility as central to transportation policy (Grengs et al., 2010).

There have been few attempts to conceptualize and rigorously measure mobility such that the consequences of mobility might be estimated. This paper will first put forward a novel measure of mobility, attempting to measure the rate with which a commuter can traverse urban space. Subsequently, this paper will demonstrate that high urban mobility generates negative consequences for local employment outcomes, while failing to contribute to economic growth. By controlling for fixed metropolitan characteristics and applying an instrumental variable (IV) method to estimating the impact of mobility on a series of metropolitan economic outcomes this study will provide causal estimates of the economic consequences of mobility.

2. Related Research

Inhibited urban mobility is the topic of much public consternation. The Texas Transportation Institute has provided annual urban mobility reports for US metropolitan areas (Schrank et al., 2015). The reports use data on vehicle congestion to approximate the level of commuter mobility, arguing that the costs of congestion represent an enormous weight on the US economy due to lost time and productivity. If analysis is limited to the first order effects of mobility it is clear that barriers to mobility burden metropolitan economies. However, the higher order consequences of mobility such as changes to urban form, home-work locational choice and travel mode choice make the true economic effects of mobility unclear.

Increasing the capacity of road networks to increase mobility is a solution that has exerted considerable influence over policy discourse (Fields et al., 2009; Schrank et al., 2012; Staley and Moore, 2009). Though many authors have investigated the mechanics of vehicle congestion (Meyer, 1959; Walters, 1961; Lindley, 1987), limited work has been undertaken to determine the broad economic impacts of mobility. Boarnet (1997) was able to show a relationship between reductions in road congestion and economic growth across counties in California. However, Boarnet (1997) found no direct relationship between the expansion of road infrastructure and economic growth. Prud'homme and Lee (1999) investigated the impact of commuter speed on urban productivity. Similar to the current study, Prud'homme and Lee (1999) calculated speed using "as the crow flies" distance divided by total commute time, as opposed to simply using ground speed. This method is able to account for "the availability of roads and bridges as well as the topography of the area" (Prud'homme and Lee, 1999). In the context of France, the study estimated that a 10% increase in urban transport speed is related to a 2.9% increase in city-wide productivity; however, the study stressed the necessity of limiting urban expansion in order for these returns to be realized.

Cervero (1996) questioned the wisdom of promoting urban mobility and suggested an increased focus on accessibility. Cervero (1996) pointed out that mobility may enable access, but it is an unsuitable goal for policy because quick movement does not inherently represent a benefit. Cervero (2001) investigated the impact of mobility and urban form on productivity, characterising the investigation as an attempt to contrast the economic consequences of "sprawl" versus "compact city" development. Cervero (2001) noted the endogenous relationship between growth and mobility, as high growth may spawn an increase in commuting trips, which increases congestion and reduces mobility.

Levine et al. (2012) developed a central theoretical mechanism for considering the relationship between commuter speed and accessibility. Levine et al. (2012) outlined high ground speed's intuitive positive relationship with accessibility; a relationship that holds if speed is exogenously increased for a predetermined urban configuration of origin-destination pairs. However, in a dynamic setting, increased speed enables origins and destinations to exist at greater distances. Levine et al. (2012) examined estimates of point-to-point commute times provided by the Metropolitan Planning Organizations of 38 large metropolitan regions in the US. High travel speed was shown to relate to reductions in the accessibility to jobs, suggesting the dynamic increase in "sprawl" brought about by high speeds overwhelms the intuitive accessibility benefits of mobility. Levine et al. (2012) looked at private vehicle commuting exclusively, pointing out its dominance over commuter mode choice in the US.

With the exception of Kawabata and Shen (2007), very little research has been done to directly investigate the relationship between mobility and economic disparities between urban subgroups. Kawabata and Shen (2007) pointed out that investments which facilitate increased mobility for drivers accrue to those already enjoying the highest mobility levels. Sanchez (1999) put mobility disparities in the context of the US civil rights movement, arguing that the inability to access employment opportunities has been a force for the continued economic underachievement of minority populations. Sanchez (1999) argued that poor residents without access to cars are discriminated against by current transportation policy as they are excluded from the benefits of automobile infrastructure investments.

3. Geodesic Velocity

This paper puts forward a novel method to measure urban mobility. The proposed metric takes the existing built environment as an enabler of mobility and attempts to measure the ease with which an individual overcomes urban space. This study will be concerned with home-work commuting.

Provided individual level observations such that an individual's residence and workplace can be geographically identified, it is possible to calculate the "as the crow flies" distance separating these two locations. "As the crow flies" is meant to refer to the shortest route between two points on the earth's surface, such a route follows a geodesic line. Commuters are limited to travelling through the built transportation network, forcing them to deviate from a geodesic line between origin and destination. The level of commuter deviation from the geodesic is a function of the circuity of the transportation network (Levinson and El-Geneidy, 2009; Giacomin and Levinson, 2015). By using geodesic distance, the current paper will allow for variation in network circuity to impact the measure of mobility (similar to Prud'homme and Lee, 1999). The measurement of the geodesic line between home and work is therefore an intentional abstraction and is not meant to capture the actual route executed. The speed with which an urban resident navigates a given geodesic distance is a function of (1) the average ground speed with which they travel and (2) the extent to which the existing transportation network prompts the commuter to deviate from their ideal geodesic. Metropolitan conditions that enable high ground speeds and direct routes will enable shorter trips and higher mobility. This paper introduces the concept of Geodesic Velocity (GV) to represent the velocity with which a traveller can overcome the distance spanning their origin-destination pair. The GV for an individual is given simply by equation 1:

$$GV_i = D_i \quad / \quad T_i$$

Equation 1: GV_i is the geodesic velocity of individual i, D_i is the geodesic distance between individual i's origin and destination pair, and T_i is the time taken to complete individual i's trip.

GV is a metric related to the technical efficiency that the transportation network provides to a commuter. Averaged over the entire workforce of a region, the metric provides an indication of the regional level mobility provided by the transportation network. This is represented by equation 2:

$$GV = (\sum_{i=1}^{N} GV_i) \quad / \quad N$$

Equation 2: GV is metropolitan level GV, GV_i is the GV of worker i, and N is the number of workers within the metro.

GV need not be specific to a particular mode of transportation. For example, highways may accommodate high ground speed, but may also shunt commuters along routes that are more circuitous than rival modes. Contrastingly, pedestrian travel provides for low ground speed, but may allow the traveller to maintain a more direct route between origin and destination.

The remainder of this study will apply the methods of GV calculation to US metropolitan areas. It will be shown that metropolitan level GV (referred to simply as GV hereafter) displays a high level of variability across US metropolitan areas and across US regions.

Transportation investment in the US has been historically dominated by the accommodation of private vehicles (Giuliano and Dargay, 2006; Grengs et al., 2010). Investment is normally directed towards either creating new roadways that provide more direct access to destinations, or by building out existing roadways to accommodate more traffic at a higher speed. In the context of GV, much of transportation investment in the US can be characterized as an attempt to increase GV, despite the fact it has not previously been considered in these terms.

4. Data

In order to calculate GV the current study aggregates data from multiple sources. Consistent data from all sources is only obtainable for the period of 2006 through 2011, which comprises the period of study. US metropolitan Core Based Statistical Areas (CBSAs) are used as the unit of analysis. This paper makes use of the Longitudinal Employer-Household Dynamics (LEHD) data products, compiled by the US Census Bureau. The LEHD Origin-Destination Employment Statistics (LODES) data set provides located home-work pairs for employees across the US. Home and work locations are identified at the census block level. The LEHD spans all jobs that are covered by unemployment insurance law. LEHD data records approximately 95% of wage and salary employment nationally, notable exclusions are self-employed individuals and US military personnel (Graham et al., 2014). LODES contains incomplete data for the state of Massachusetts and the District of Columbia, any CBSA that falls within these areas is omitted from analysis. 365 metropolitan CBSAs remain, forming a six-year panel. Analysis is limited to within-CBSA commuters. Any CBSA resident who works outside of their home CBSA is dropped from analysis, this applies to less than 1% of the sample.

This paper will also incorporate American Community Survey (ACS) data, which is also collected by

Table 1: Summary statistics

Variable	Mean	Std. Dev.
Geodesic Velocity (km/hr)	31.525	7.683
Median Income ($)	20360.187	3745.583
Unemployment Rate	0.047	0.016
Labor Force Participation	0.612	0.055
On Food Stamps	0.118	0.055
Log Metro GDP	9.406	1.188
Log Population	12.522	1.085
Population Density (persons/km^2)	83.826	95.521
Mean Age	39.643	2.881
White	0.818	0.117
Black	0.092	0.099
Asian	0.026	0.045
Hispanic	0.103	0.144
High School Education	0.858	0.054
College Education	0.255	0.078
Graduate Education	0.095	0.039
Fed Highway Allocation per Capita to State ($)	21.509	15.954
N	2190	

the US Census Bureau. To identify trends through time, one-year estimates are used. The Public Use Microdata Sample (PUMS) provides annual individual level observations for a randomly selected 1% of the US population. Variables are taken directly from the Integrated Public Use Microdata Series data products (Ruggles et al., 2014). The ACS asks workers to report the number of minutes taken to commute one way to work, "door-to-door," which will be used as the measure of commute travel time. PUMS also contains a wide array of individual level demographic characteristics that will be used in analysis.

LODES and ACS data are collapsed to the CBSA level. PUMS observations are identified at the Public Use Micro Data Area (PUMA) and are crosswalked to CBSAs using the Missouri Census Data Center's Geographic Correspondence Engine.

CBSA level population and geographic characteristics are taken directly from the ACS. Annual CBSA GDP figures are taken from the US Bureau of Labor Statistics (BLS). Data on federal highway expenditure for the instrumental variable (as outlined in Section 6) are provided by the US Department of Transportation (USDOT) annual notice of apportionment documents. These documents are posted freely on the USDOT Federal Highway Administration website. The documents contain figures for the "apportionment of funds for the national highway system" that are provided to each state by the federal government in each year. Summary statistics are provided in Table 1.

5. A Recent History of Geodesic Velocity

In 2011, the GV of the average US commuter was 37.4 km/hr; however, this figure displays considerable variation across US Census regions. The road networks and building patterns that make up older metros in the Northeast vary substantially from the urban form of Southwest and west coast metros. Measured GV picks up on this difference in infrastructure. In 2011, the GV of a commuter in the South averaged 40.9 km/hr whereas GV in the Northeast was only 31.0 km/hr. GV for commuters in the Midwest and West regions fall between these markers, at 37.3 km/hr and 37.5 km/hr respectively (Figure 1a).

US commuters have become faster. Between 2006 and 2011 the average GV of a US commuter

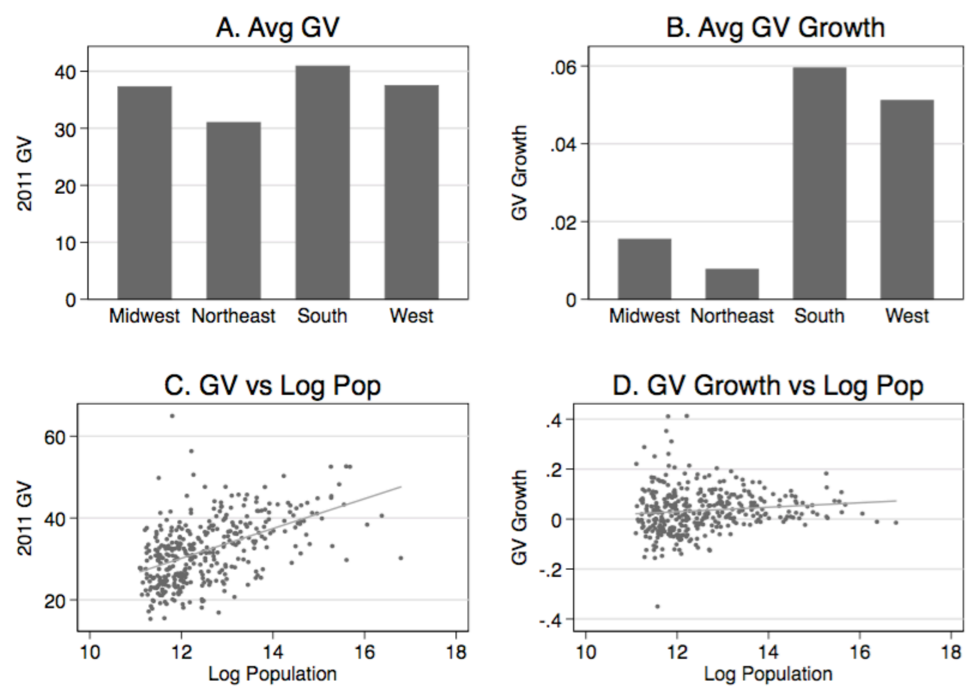

Figure 1: Average Metropolitan GV and GV Growth from 2006-2011. Bar graph data is weighted by CBSA population.

increased from 36.0 km/hr to 37.4 km/hr, an increase of 3.9%. Different census regions of the US have experienced very different rates of growth (Figure 1b). Growth in GV over the period of study has been highest in the South and West regions at 5.9% and 5.1% respectively. Contrastingly, the Midwest and Northeast metropolitan populations experienced GV growth of only 1.5% and 0.8% respectively.

Larger metros have higher GV values on average. For every 100,000 person increase in population, GV was 0.14 km/hr higher on average in 2011 (Figure 1c). Despite a clear relationship between city size and GV, population is only able to explain 7% of the variation in GV. There is no clear relationship between metro size and GV growth over the period of study (Figure 1d).

6. Identification Strategy

This study is concerned with estimating the impact of metropolitan workforce mobility (captured by GV) on metropolitan economic performance. Inferring a causal relationship between mobility and economic performance must overcome two major econometric hurdles. Firstly, omitted variable bias is likely to contaminate results. Idiosyncratic characteristics of metros may simultaneously influence both economic performance and the travel behaviour of workers. Several papers are able to explain travel behaviour through observed metro characteristics (see, for example Cervero and Kockelman, 1997 or Schwanen and Mokhtarian, 2005). Although some metropolitan characteristics may be directly controlled for, some remain unobserved, such as the cultural disposition of the metro with respect to private vehicle ownership or neighborhood form preferences. The current study overcomes this barrier by leveraging the panel format of the data. Omitted variable bias can be handled by including metropolitan level fixed effects in all regressions, and basing estimation on variation that occurs within metropolitan areas, across years. This method removes the omitted variable bias for all time invariant properties of CBSAs.

A second barrier to identification arises due to the possibility that economic changes through time and changes in observed mobility are endogenous (for discussion see Cervero, 2001). Increases in economic activity may generate congestion, which lowers mobility. Alternatively, a fall in economic activity may free up transportation infrastructure, which could lessen congestion and increase mobility. Higher order effects may also be in play, such as economic growth causing more congestion, which in turn galvanizes public pressure for the expansion of transportation infrastructure. The current study seeks to estimate the effect of mobility on economic performance, and must therefore remove the endogenous causation described above, this will be achieved through the use of an instrumental variable.

To be valid the chosen instrument must influence the endogenous variable (mobility), but cannot wield influence on the dependent variable (economic performance) other than through mobility. This paper proposes using random variation in lagged federal capital investment in highways as an instrument for mobility.

Investment in new highway infrastructure has an intuitive relationship with GV. Increasing the capacity of highway infrastructure within metropolitan regions facilitates increased commuter mobility through several mechanisms. Firstly, expanding highways creates an incentive to car ownership, reducing a commuter's need to rely on alternative modes of transportation, which typically operate at lower speeds. Secondly, building new highways may lower the circuity of particular routes. Thirdly, increased road capacity may reduce congestion, increasing ground speed. The mechanism by which the instrument affects GV is not relevant to the identification strategy, provided the effect is significant and the instrument does not impact economic performance in ways other than through GV.

The U.S. Department of Transportation (DOT) allocates highway capital funds to states through annually provided "National Highway System Program Funds," these funds are a consequence of federal highway legislation and the amount allocated to each state is set by acts of congress. The formula for allocation is complex, and includes many so-called bonuses to particular states. Additionally, a portion of funds are set aside for "high priority" projects. Such additional funds are often subject to specific rules. The complexities of allocation have led to criticisms of the apparent arbitrary and politically capricious nature of allocations "that have little or nothing to do with a state's transportation needs" (Cooper and Griffith, 2012). Much of the variation in fund allocation between states is derived from the state's relative population, and geographic size. However, year-to-year variation in funding is considerable, and is typically the result of annual political negotiations, pet projects of politicians and other arbitrary bureaucratic factors. Because of the inclusion of metropolitan fixed effects as well as metropolitan-year controls for population and other demographic characteristics, the variation preserved in the instrument represents the year-to-year vagaries in state allocation, independent of changing demographic needs.

The logged value of federal allocation to each metro's "home state," lagged three years, is used as the instrument. Three years is used as an estimation of how long it takes for the provision of highway funding to be transformed into a usable project. In cases where a CBSA spans multiple states, the state in which the highest portion of the CBSA population resides is considered as the "home state."

7. Economic Impacts of Mobility

OLS estimation of mobility's effect on economic outcomes may be biased due to endogeneity and attenuation bias. Metropolitan fixed effects only control for time invariant characteristics; however, many time varying properties of metros are observed and can be controlled for directly. Regressions control for the log population and population density of the CBSA. Additional demographic controls are added, including mean age, the racial and ethnic make-up of the metro, and the level of education.

This study generates a causal estimate of mobility on economic performance through use of an instrumental variable. The first stage regression (not shown) demonstrates that variation in federal highway fund allocation to a metro's home state three years prior, exerts a statistically powerful influence on the current level of mobility. A 10% increase in lagged log per capita highway capital investment, results in an increase in current GV of 0.40 km/hr. The impact is statistically significant at the 1% level. The Wu-Hausman test for endogeneity is performed on IV regressions and rejects the null hypothesis that mobility is an exogenous variable, confirming the necessity of instrumentation.

Table 2 presents IV results. Column 1 shows the estimated impact of mobility on metropolitan median income. This study finds a positive impact of increased mobility on median income: a 1 km/hr increase in GV is associated with a $597 increase in median income. It is not clear that this large and significant

Table 2: Impact of GV on the Metropolitan Economy: IV Regressions

	Median Inc	Unemployment	LF Partic	Food Stamp	Log GDP
	(1)	(2)	(3)	(4)	(5)
Geodesic Velocity	596.535**	.004**	-.005**	.012**	-.001
	(159.359)	(.001)	(.002)	(.003)	(.005)
Log Population	-2796.486	.061**	-.122**	.237**	.558**
	(2135.746)	(.017)	(.022)	(.043)	(.063)
Population Density	-110.467**	.0004*	.0007**	-.0002	-.002*
	(22.789)	(.0002)	(.0002)	(.0005)	(.0007)
Mean Age	-252.356**	.002**	-.010**	.009**	-.009**
	(57.418)	(.0005)	(.0006)	(.001)	(.002)
White	9562.395**	-.031	.085**	-.036	.119
	(2421.755)	(.019)	(.025)	(.049)	(.071)
Black	-23440.310**	.159**	-.209**	.780**	-.229
	(4437.899)	(.035)	(.047)	(.090)	(.130)
Asian	-26409.140**	-.003	.099	-.231	.361
	(9831.933)	(.078)	(.103)	(.199)	(.288)
Hispanic	-13417.930**	.232**	.025	.564**	-.286*
	(3917.993)	(.031)	(.041)	(.079)	(.115)
High School Education	26680.960**	.138**	.214**	.137*	-.330**
	(3434.570)	(.027)	(.036)	(.069)	(.101)
College Education	22361.930**	.076*	.151**	-.0002	-.304**
	(3899.175)	(.031)	(.041)	(.079)	(.114)
Graduate Education	-4601.431	.071	-.199**	.326**	.211
	(6114.311)	(.048)	(.064)	(.124)	(.179)
Const.	24094.540	-1.148**	2.387**	-3.788**	3.244**
	(23491.830)	(.185)	(.246)	(.475)	(.689)
Metro Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y
Obs.	2190	2190	2190	2190	2190

Significance levels: $*$: 5% $**$: 1%. Standard errors in parenthesis.

effect is caused by an increase in productivity, as subsequent tests of economic outcomes will show.

The IV estimate of the effect of GV on the metropolitan unemployment rate is displayed in column 2. For every 1 km/hr increase in GV the metropolitan unemployment rate increases by 0.4 percentage points. Furthermore, column 3 shows that workforce participation decreases by 0.5 percentage points for every 1 km/hr increase in GV. These estimates represent a substantial shift in worker behaviour in response to a modest change in mobility. This finding is consistent with the transportation mismatch literature which suggests that the expansion of high mobility policy leads to a decline in the ability of some workers to access employment (Baum, 2009; Kawabata, 2003; Ong and Miller, 2005; Taylor and Ong, 1995). If those who would otherwise earn a low income disproportionately experience negative employment effects, the estimated increase in median income may simply represent a bias in terms of who dropped out of the workforce, or became unemployed.

A testable consequence of mobility's apparent impact on employment outcomes is a rise in the uptake of social programs due to an inability to secure stable employment. Column 4 shows the impact of GV on the proportion of the population collecting food stamps. Increased GV has a statistically significant relationship with food stamp uptake: a 1 km/hr increase in GV leads to a 1.2 percentage point increase in the population share on food stamps.

Higher GV is empirically linked to a higher portion of commuters choosing to commute by private vehicle. This paper maintains, in the US context, auto-dependency is an attribute of a high mobility environment and should therefore not be controlled for when estimating the effect of increased mobility on economic outcomes. A rival viewpoint may purport that auto-dependency and mobility are separable. In the spirit of the latter viewpoint, IV regressions are repeated with controls for the modal composition of metropolitan commuting (not shown). Controlling for mode share has almost no effect on the central results of this paper, this suggests the reported effects of mobility are largely independent of shifts in commuter mode choice.

Despite the apparent beneficial impact of mobility on median income, high mobility exerts a strongly negative effect on metropolitan employment conditions. As an indicator for the impact of mobility on overall metropolitan economic expansion, column 5 displays the effect of mobility on logged metropolitan GDP. This study finds mobility to have no significant effect on logged metropolitan GDP. The regression was repeated with non-logged GDP and similarly no significant effect was found.

8. Conclusion

Rival schools of thought disagree on the impact increased mobility has on metropolitan economic performance. New Urbanist contributions to the discussion typically downplay the supposed benefits, emphasising the drawbacks of autodependency that often accompany increases in mobility. The current study adds to this debate by demonstrating that increased mobility inflates metropolitan median income, while imposing negative consequences for several measures of metropolitan workforce performance, and no clear impact in terms of economic growth. Findings suggest that the benefit to society of marginal mobility investment may well be negative.

Prior to this paper, a metropolitan level estimate of mobility's causal effect on economic and labor market outcomes had not been attempted. Future research should explore the apparent workforce outcomes more deeply and at the neighborhood or individual level in order to identify which subpopulations are impacted most strongly by increases in urban mobility. In spite of the potential for further research there is now strong evidence in the literature demonstrating that capital investment in the pursuit of urban mobility is above the efficient level. The imagined economic benefits of mobility investment have no clear empirical basis.

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