Transportation and Land Use across US and Mexican Cities and Megaregions

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16. Abstract
This report compares the socioeconomic factors, urban locations, and commute patterns of urban workers in the United States and Mexico. The US dataset contains information on 3.5 million commuters over 4 years of the ACS PUMS, representing 98 million workers in total in the 100 largest metropolitan areas. The Mexican dataset contains information on 2.9 million commuters, representing 32 million workers in Mexico's 59 metropolitan areas and next largest 41 urban areas. The hundred largest urban areas account for roughly 65% of the employed population in the US and 85% in Mexico. Chapter 1 introduces the motivation for the study. Chapter 2 describes in detail the data sources and variables used to compare households, urban areas, and commutes. Chapter 3 and 4 describe the main differences in commuters and urban areas across the two samples. Chapter 5 then presents an analysis of how different measures of urban form covary across urban areas in the US and Mexico. These analyses flow into three analytical chapters that focus on the relationship between urban form and mode choice, the commute patterns of the working poor, and predictors of cycling.

In Chapter 6, we find that urban residents living in housing types associated with more centrally located housing in more densely populated urban areas with less roadway are less likely to commute by private vehicle than similar residents in other housing types and other urban areas in both countries. In addition to some differences in the strength, significance, and sign of several predictor variables, we find large differences in elasticity estimates across contexts. In particular, the US's high rates of driving and generally car-friendly urban form mean that even dramatic shifts in urban form or income result in only small predicted changes in the probability of commuting by private vehicle. We conclude with two important limitations to our findings and a discussion for the need for more research into the relationships between urban form and travel behavior from outside of the US.

Chapter 7 focuses on the commuters from the poorest fifth of households in each county and, like Chapter 6, finds common relationships on each side of the border, despite substantial socioeconomic and urban differences across the samples. For example, low-income workers with higher incomes and higher educational attainment are more likely to drive to work and less likely to use active modes. We also find that urban form and road networks are strongly and significantly associated with low-income commuter mode choice and travel time. Collectively the statistically significant measures of urban form and transportation have about a five times stronger relationship to the probability of driving to work by car than does income in both the US and Mexico. In terms of public policy, we find that efforts to reduce driving or promote compact development are more likely to reduce driving and more likely to be pro-poor in Mexico than in the US. High rates of driving and auto-oriented urban form make policies to reduce driving particularly likely to be regressive in US metropolitan areas.

The final chapter focuses specifically on cycling, a mode that gets combined with walking in earlier chapters. In both national contexts, men in relatively poor households are likeliest to cycle. The similarities in cycling commuters generally stop with these two commonalities, however. The archetypal US bike commuter is a recent college graduate, lives by himself in a centrally located apartment in a moderate-to-high density city, like Portland, OR, and commutes to work in a relatively low-paying service sector job for a college graduate, perhaps at restaurant or not-for-profit. The archetypal Mexican bike commuter, by contrast, is in his mid-thirties, has only a few years of formal education, lives with a large family in a house in the suburbs of a large dense metropolitan area, like Mexico City, and commutes to a relatively low-paying agriculture, construction, or manufacturing job. Local context matters and the most effective public policies to promote urban cycling will almost certainly vary across national borders. For example, our analysis suggests that suburban cycling investments will likely do a lot more to support Mexican cyclists than US ones. We conclude that there is a need for studies that include comparable measures of cycling infrastructure, local built environments, and non-work trips in different national contexts.

17. Key Words	18. Distribution Statement
Commute patterns, mode choice, urban form, working poor, US, Mexico, bicycling	No restrictions.

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Chapter 1. Introduction

Megaregions inherently cross borders, often national ones. Of the eleven emerging US megaregions identified by the Regional Plan Association in its seminal work, three include Mexican cities (Figure 1.1). Moreover, cross-border commutes, tourism, and economic flows are important components of local and metropolitan economies and cultures in places like San Diego, Tijuana, El Paso, and Juarez. According to the 2015 Intercensus (INEGI 2015), around 5-10% of Mexican commuters from border cities and municipalities work in the United States (Figure 1.2). Even in many central parts of Mexico, a sizable fraction of the workforce commutes to the United States.

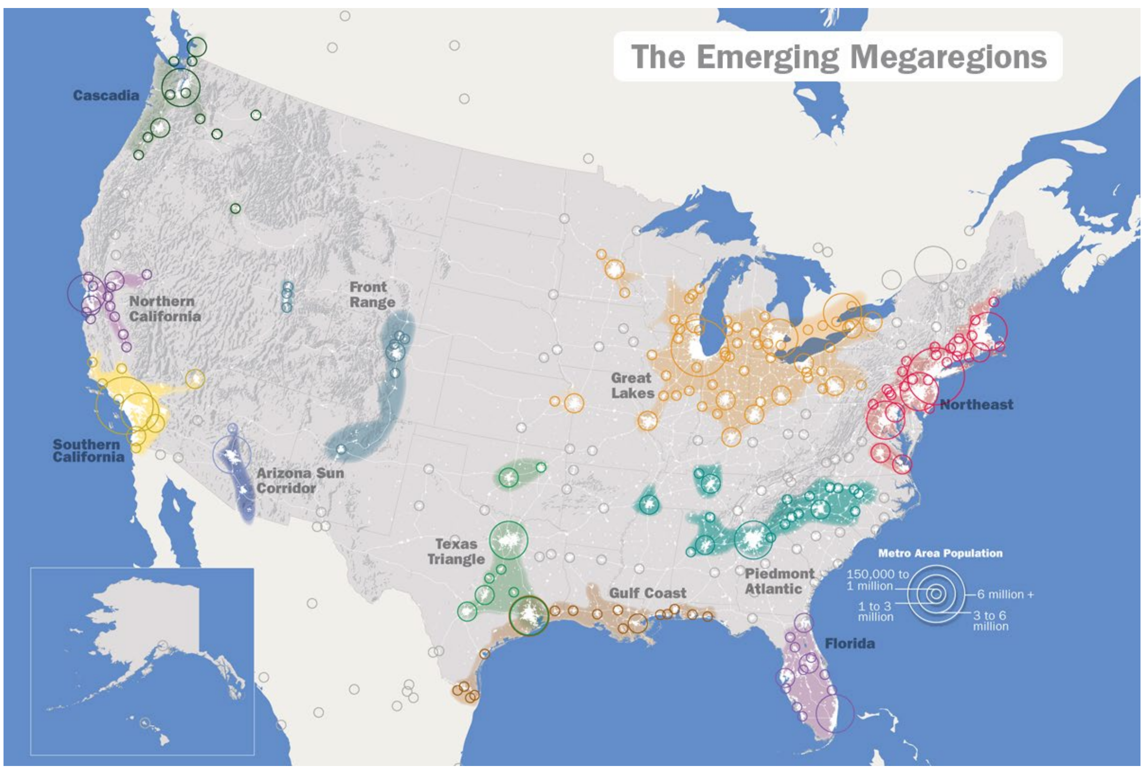

Figure 1.1 Regional Plan Associations map of emerging megaregions

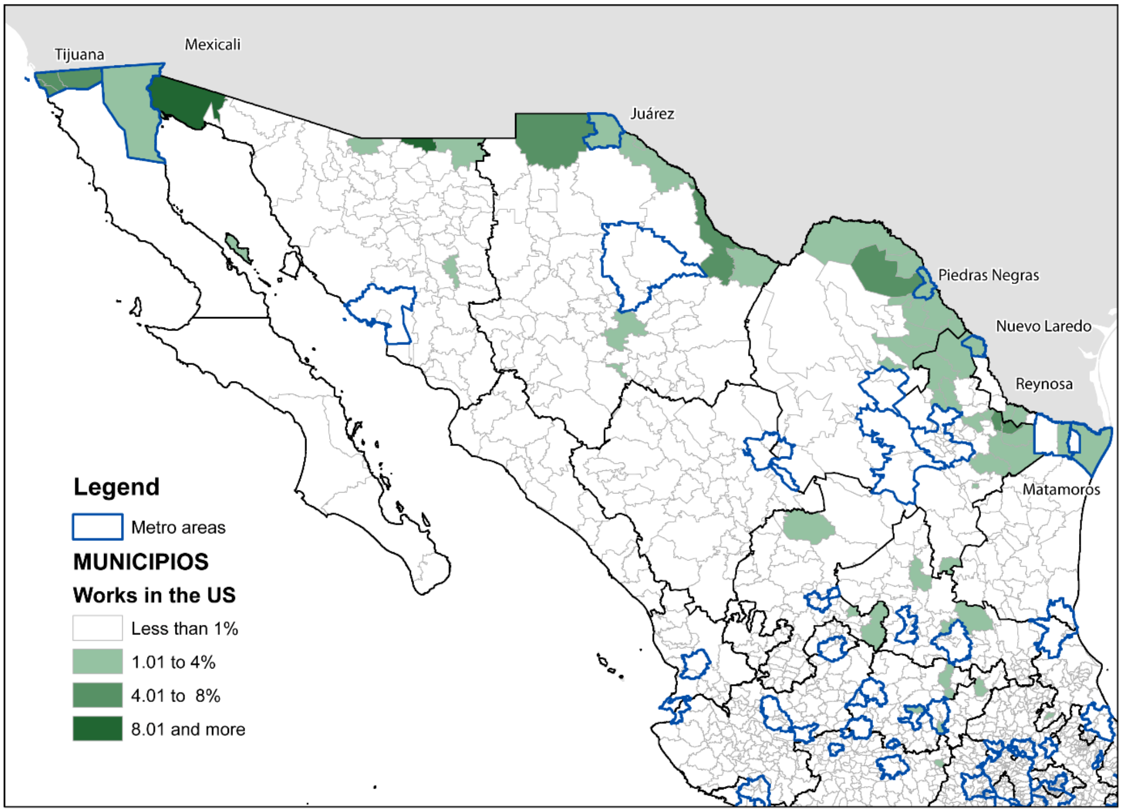

Figure 1.2 Percent of commutes to the United States by Municipality.

Studying the relationship between land use, socioeconomic, and commute behavior across multiple regions in multiple countries can help shed light on the strength and relative importance of different relationships, as well as their consistency and the role of regional and social contexts. Of interest are questions about the relative importance of transportation supply, household income, and the built environment in determining the radically different commute patterns seen on each side of the border. Figure 1.3 plots the percent of commutes to work by transit, car, and non-motorized modes (walking/biking) in the 100 largest metropolitan areas in Mexico and the United States in 2015. Mexican cities are highly multimodal with substantial and continuous variation in modal importance. Even in the most car-reliant city, La Paz, 40% of commuters walk, bike, or take transit. In the US, by contrast, nearly everyone drives to work, with just a few individual cities that have less than 90% of commutes by car.

Socioeconomic and urban differences almost certainly both play a role. Mexican commuters have average household incomes that are around eight times lower than American commuters. In Mexico, residents live in neighborhoods that are five times denser than in US ones.

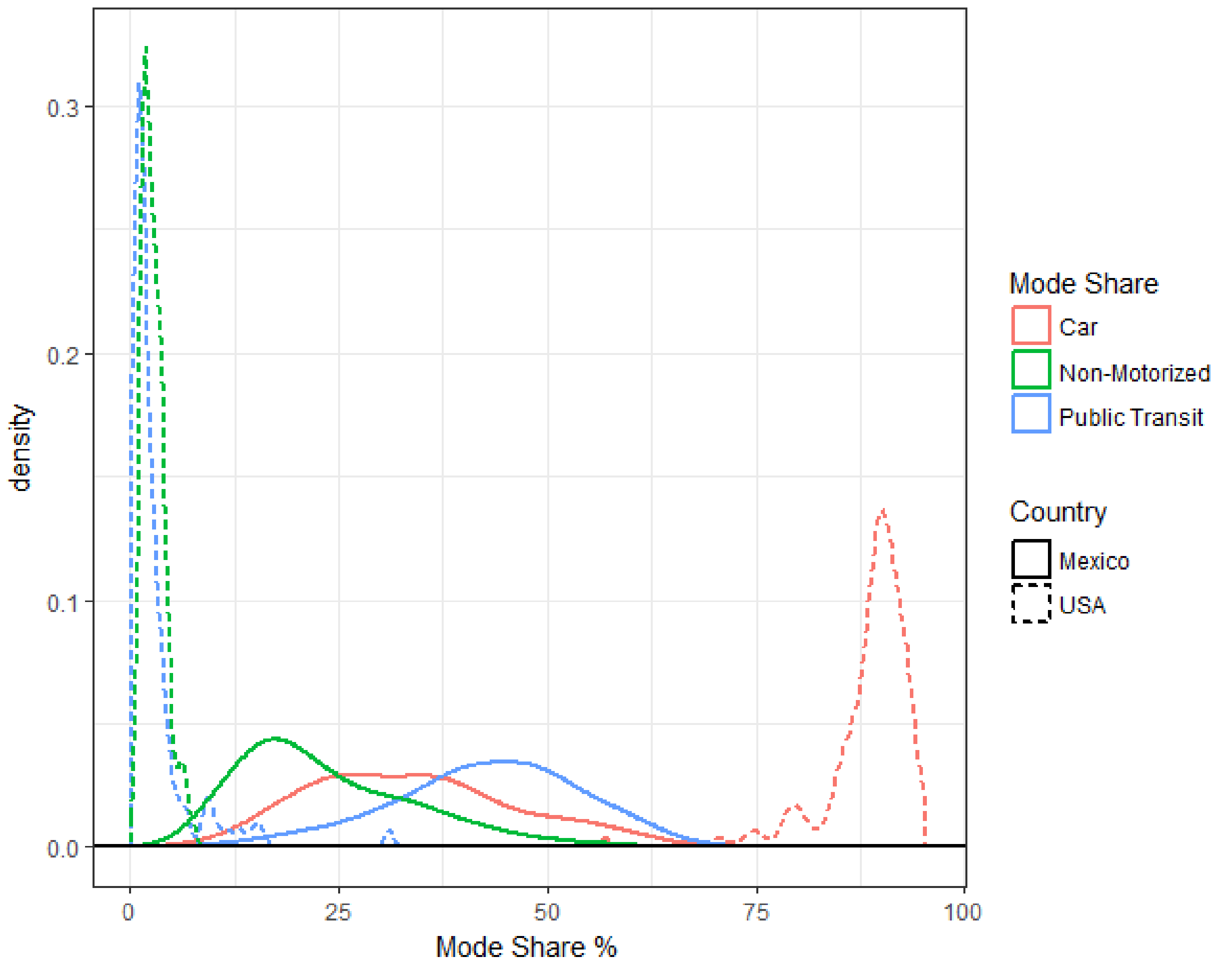

Figure 1.3 Distribution of mode splits across 100 largest urban areas in Mexico (top) and the United States (bottom)

This report is organized as follows. Chapter 2 describes in detail the data sources and variables used in this study. Chapter 3 describes the main differences in commuters across the two samples, while Chapter 4 focuses on differences across urban areas. Chapter 5 then presents an analysis of how different measures of urban form covary across urban areas in the US and Mexico. These analyses flow into three analytical chapters that focus on the relationship between urban form and mode choice, the commute patterns of the working poor, and predictors of cycling. Each of these Chapters 6, 7, and 8 are meant to stand alone and have their own introductions, literature surveys, and data descriptions. As such, there is a fair amount of overlap and repetition across several of the sections of this report. Each analysis relies on slightly different data samples, specifications, and modeling frameworks. Although commute patterns and urban form tend to be more similar within megaregions than outside of them, key findings relate to differences in commute patterns and metropolitan measures of urban form. These findings are presented at the conclusions to chapters 6, 7, and 8 with an emphasis to the contributions on the literatures on (1) the relationship between urban form and travel behavior, (2) the commute patterns of low income workers, and (3) the predictors of cycling.

Chapter 2. Data sources and data sample

We group the primary source data into (1) data on individual households and workers in the 100 largest urban areas in the US and Mexico, (2) data on urban form and transportation networks in urban areas, and (3) data on cross-border flows. The principal focus is on the creation of comparable measures across the two countries, though in some comparisons, such as those involving bus service, this was not possible.

2.1. Household and commuter data

Household and commuter data from the 2015 Mexican Intercensal Survey and four years of the American Community Survey (ACS) Public Use Microdata Sample (PUMS) One Year Data (2012-2015). Both are nationally representative surveys conducted by each country's primary Census agency, sampling from approximately 10% of the Mexican population and 1% of the US population, respectively. The US dataset contains data on 3.5 million commuters over 4 years of the ACS PUMS, representing 98 million workers in total in the 100 largest metropolitan areas. The Mexican dataset contains data on 2.9 million commuters, representing 32 million workers in Mexico's 59 metropolitan areas and next largest 41 urban areas. We use the terms metropolitan area and urban area interchangeably throughout the remainder of the text. The hundred largest urban areas account for roughly 65% of the employed population in the United States and 85% in Mexico. Both datasets contain information on persons employed by the armed forces. Each data set provides information on household characteristics and commuting patterns, which we aggregated into comparable categories (e.g., for educational attainment) or values (e.g., for household income.)

2.1.1. Mexico: 2015 Intercensal Survey

The individual-level data for Mexico come from the 2015 Intercensal Survey conducted by the national statistics agency (Instituto Nacional De Estadistica Y Geografia 2015). This nation-wide survey provides a sample-based snapshot of population and household composition and distribution between 2010, the year the last full survey was conducted, and 2020, the year when the next full survey would be conducted. It is the first national survey to provide information on the commuting patterns of Mexican residents and the most up-to-date, nationally representative survey of households and individuals. In our data sample, individuals represent an average of 11 other residents, with a range of 1 to 467 represented residents.

The main components of the survey include information on housing units (unit size and use, accessibility to various civil utilities, etc.) and individual and household socio-economic attributes (age, marital status, ethnicity, education, employment and migrant history, etc.). The data set provides household location at the municipal level and for urban districts containing more than 50,000 inhabitants, which we matched to the public urban area designation system (SUN).

2.1.2. United States: American Community Survey (ACS) Public Use Microdata Sample (PUMS)

For US individual-level data, we rely on four years of the PUMS (United States Census Bureau 2018a). The PUMS data set shows information regarding housing units and individual and household characteristics collected through the community survey questionnaire. It provides the largest publicly available, nationally representative microdata about US residents. A single year of data contains a one percent sample of the US population. We combined data from four years of the PUMS (2012 to 2015) to make the sample size roughly comparable with the data from the Mexican Intercensus. In addition to housing and socioeconomic data, the PUMS provides data on workers' typical commutes includes the commuting behavior of American residents. Data are available at the Public Use Micro Area (PUMA) geography, which we matched to Metropolitan Statistical Areas.

2.1.3. Combining the datasets

Table 2.1 summarizes key variables from the two data sets, and briefly describes the transformations needed to make the values comparable. For example, due to differences in the dataset, we combine taxi users with other forms of public transit and combine motorcycle commutes with commutes by car. For household income, we provide data in the original currency, 2015 USD, and 2015 USD in purchasing power parity. For consistency we combined occupational data into three overarching categories of services, agriculture/extraction, and manufacturing/construction. Given the 3-digit and 4-digit employment codes, a summary of the aggregations does not fit conveniently into Table 2.1. Instead, we can provide a full reclassification table on request. Other variables, such as gender and age, did not require transformation and are not included in the table. For car ownership, the Mexican Intercensus only reports whether the household has one or more vehicles, while the US Census reports on the number of vehicles. Of note, the Mexican Census, Intercensus, and other surveys provide certain data by household (hogar) and by dwelling (vivienda), since households sometimes share living quarters. All household-level statistics are provided by household, rather than dwelling unit, which is more consistent with the US dataset. The final datasets drop commuters that did not report a commute mode to work or car ownership.

Table 2.1 Individual-level variables in Mexico and US datasets

Variable	*US measurement*	*Mexico measurement*	*Combined Measure Description*
Commuting time	Continuous variable, transformed to categorical variables consistent with the Mexico data set	Categorical variable ((<15, 15-30, 30-60, 60-120, >120, Unit: minutes)	Categorical variable, travel time between home and workplace (<15, 15-30, 30-60, 60-120, >120, Unit: minutes)
Mode choice to work	Public transit (bus or trolley bus, streetcar or trolley car, carro publico in Puerto Rico, subway or elevated, railroad, ferryboat, taxicab); Car (car, truck, or van; motorcycle); bicycle, walk, work at home, others (other method)	Public transit (truck, taxi, combi or colectivo; metro, metrobus or light rail; worforce transport); car (private vehicle, including car, truck or motorcycle); bicycle, walk, work at home (does not move), other	Categorical variable, travel mode choice between home and workplace (transit, car, bicycle/walk, other, works from home)
Household income	Income (USD)	Adjusted annual household income transformed to USD according to current	Continuous variable, annual household income (Unit: USD)

Variable	*US measurement*	*Mexico measurement*	*Combined Measure Description*
		exchange rate/purchasing power parity	
Occupation	4-digit industrial classification	3-digit industrial classification	Combined into 3 generally consistent classifications
Educational attainment	24 qualitative classifications	16 qualitative classifications	Combined into 4 generally consistent classifications
Housing unit type	10 qualitative classifications	10 qualitative classifications	Combined into 4 generally consistent classifications of housing type

2.2. Metropolitan data

We also collected data on urban form and transportation supply at the metropolitan level in both countries. To create urban variables that require more spatially resolved data, we rely on the 2010 Population Census and 2009 Economic Census in Mexico. These two surveys aggregate data by Ageb, which is roughly equivalent to a US Census tract. Urban areas are defined by the Mexican Population Council's National Urban System, including all of the major cities and surrounding suburbs (Consejo Nacional de Población 2018). The 59 largest urban areas are equivalent to Mexico's 59 officially designated metropolitan areas. The US metropolitan data come primarily from the US Census and the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) and area aggregated to the MSA. The United States Office of Management and Budget delineates MSAs, of which there are nearly 400 (United States Census Bureau 2018b). The largest Mexican urban area, Mexico City and its suburbs, has 20.9 million residents; the hundredth largest, Guanajuato, has 76 thousand residents. The largest in the US, New York, has 20.0 million, while the hundredth largest, Spokane, WA, has 537 thousand residents.

One important difference between the US and Mexican Economic data is that, although data both come from form-based surveys, a much larger share of employment is not captured by form-based surveys in Mexico. We estimate that over half of the employed residents in Mexico's hundred largest urban areas work in informal employment that is not captured in the economic Census (Guerra et al. 2018a). This share, moreover, varies by city and by region. For example, a higher share of employment is formal in the industrial cities of Northern Mexico while a much lower share of employment is formal in the South. Measures of job density and distribution should therefore be interpreted with caution.

Land area

We estimate land area as the total reported land area in the Census tracts and Agebs within each metropolitan area. There are substantial differences in the assignment and reporting of geographic units. Figure 3.1 maps the land area of Mexico and the US's largest consumers of land, the Mexico City metropolitan area and the sprawling Inland Empire (Riverside-San Bernardino-Ontario Metropolitan Area.) The sum of the land area in all Census tracts in Riverside consumes more than twice as much land as the hundred largest Mexican metropolitan areas combined. However, the maps reveal that the two measures are hardly consistent. Mexico City's agebs are non-contiguous and exclude mountains and other non-urbanized land. Inland Empire's Census tracts, by contrast, include Joshua Tree, a three-thousand square kilometer National Park. As a result of these large inconsistencies, our study does not use or report total land area or other metrics constructed with total land area, such as metropolitan population density.

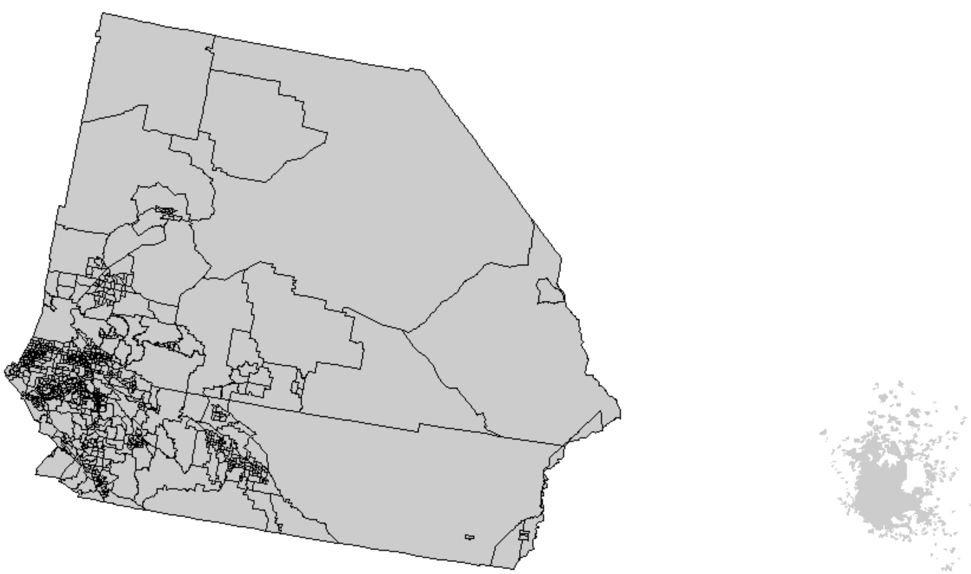

Figure 3.1. Census tracts/Agebs in Riverside (left) and Mexico City (right) Metropolitan Areas at equal scales.

Population Density

We estimated the population density of each Census tract and Ageb within the 100 largest metropolitan areas in Mexico and the United States. Due to the substantial differences in land area measures on the two sides of the border, we exclude gross metropolitan density from our measures.

Instead, we primarily rely on a measure of population density within each Census tract and weight it by the number of people living in the tract. This is equivalent to a measure of the average neighborhood density of the population using micro data. We also supplement this measure with measures of the average, 90th, and 75th percentile population density across Census tracts. The distribution of population density likely has a relationship with travel behavior since below a certain threshold density, walking, biking, and transit may be unattractive alternatives.

Jobs Concentration

We used two types of measures to estimate how concentrated jobs are within a metropolitan area. We expect a high concentration of jobs to support transit use since transit works best in places with concentrated destination patterns that are conducive to fixed-route services. The first measures of job concentration are the 90th and 75th percentile job densities across Census tracts and Agebs. The next measure is a Gini Index of the proportion of land and the proportion of jobs across Census tracts and Agebs. A score of one indicates a perfectly monocentric city with all jobs located in a single Census tract, while a score of zero indicates an even spread of jobs across census tracts. Due to differences in land areas, we estimated the Gini coefficients in US metropolitan areas after alternatively excluding Census tracts with land areas two standard deviations above the median value and excluding those above a standard interquartile range. These two approaches respectively removed 1.8% and 15.5% of Census tracts before calculating the Gini coefficients for each US metropolitan area.

Job-Population Imbalance (Gini Index)

Following Bento et al. (2005), we estimate jobs-population imbalance using a Gini coefficient, based on the percentage of residents and percentage of jobs in each Census tract. A score of zero indicates perfect balance with an equal distribution of jobs and people across all tracts, while a score of one indicates perfect imbalance. The Gini coefficient is a common measure of inequality and frequently applied to measure urban spatial structure (Tsai 2005; Burt, Barber, and Rigby 2009). Urban areas with a better balance of jobs and residents across neighborhoods are likely to facilitate short, non-motorized trips by foot or bike.

Transit Supply

We generate two variables to serve as proxies for the quality and quantity of transit supply in Mexico's urban areas. The first is an estimate of the total kilometers of high-capacity transit—metro, light rail, commuter rail, and BRT—per capita in each urban area. Just seven Mexican metropolitan areas had a high-capacity transit system in March of 2015. We exclude one potential system in Villahermosa because this system is missing various BRT features. Since then, additional lines have opened in Acapulco, Pachuca, and Tuxtla Gutiérrez. The three largest metropolitan areas (Mexico City, Guadalajara, and Monterrey) have a rail and/or metro system in addition to BRT. Since so much transit use occurs on buses, minibuses, worker shuttles, vans, and taxis, we also wanted to construct estimates of the quality and quantity of lower capacity transit supply. We were unable to find consistent data on fleet size by urban area. Instead, we rely on an estimate of the share of workers employed as drivers, transportation operators, or drivers' assistants using the Intercensus. These estimates include truck drivers as well as minibus drivers and transit firms. Parameter estimates should therefore be interpreted with caution.

In the United States, we rely on the National Transit Database (NTD) for measures of high capacity transit and bus supply after matching the NTD database to our metropolitan areas. For high-capacity transit we take the total directional route miles of heavy rail, light rail, commuter rail, trolley, and exclusive bus lanes. For greater consistency with the Mexican data, we divide directional route miles by two and convert to kilometers. For bus service estimates, we include vehicle revenue hours and vehicle revenue miles of bus service.

Road Networks

For consistent road supply data, we rely on OpenStreetMap (OSM), which provides georeferenced roadways and road-types, which we matched to urban areas and combined into consistent roadway types. Our final dataset aggregates roads into arterials, highway, and local roads. For transit data, we relied on the US National Transit Database (NTD) and a previously collected database of high-capacity transit in Mexican urban areas (Guerra et al. 2018a).

2.3. Cross-border flows

Finally, we collected data on cross-border flows of workers and goods. Commute data come from the 2015 Mexican Intercensal Survey and the 2009-2013 5-Year American Community Survey

Commuting Flows. Data for exports and imports was obtained from USA Trade Census page (United States Census Bureau 2018c), which provides the inflation-adjusted dollar value of imports and exports in each HS (Harmonized System) classification between a given US port and a foreign country. Due to a lack of spatial resolution, we do not report findings on cross-border flows. For context, approximately 0.004% of commuters in the hundred largest US urban areas commute to work in Mexico. A similar share commute from Mexican urban areas to the US. Due to a lack of spatial resolution, our final analysis largely excludes data on cross-border flows.

Chapter 3. Differences in commuters and commutes

Table 4.1 summarizes the processed data on commuters from Mexico and in the United States' 100 largest urban areas. On average, US commuters' households earn 11.5 times more than Mexican ones. Accounting for Mexico's cheaper goods and services through purchasing power parity halves this income disparity. Workers in Mexican urban areas also tend to be younger and are more likely to be male than workers in US metropolitan areas. Less than half live in a household with one or more cars, compared to 95% in our US sample. Workers in Mexican urban areas tend to be less well-educated and are more likely to work in manufacturing than in the US urban areas. Nevertheless, most urban residents on both sides of the border work in services. In terms of residence, most workers live in single-family homes. A higher share of US workers lives in multiunit buildings than in Mexico, where row homes are more common.

Table 4.1 Descriptive statistics of sample of commuters in the US and Mexico's hundred largest urban areas

	Mexico				**United States**			
Statistic	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Monthly household income								
Local currency	12,951	17,282	0	999,998	9,105	8,192	0	175,692
2015 USD	799	1,107	0	64,756	9,166	8,244	0	175,692
Purchasing power parity USD	1,484	2,056	0	120,285	9,166	8,244	0	175,692
Income unreported	0.05				0.00			
Male	0.65				0.52			
Age	37.3	12.7	12	110	43.1	14.1	16	97
Maximum educational attainment								
Secondary school	0.31				0.06			

High school	0.23				0.44			
Bachelor's degree or equivalent or higher	0.24				0.48			
Household has one or more cars	0.48				0.95			
Occupation								
Agriculture/extraction	0.05				0.01			
Manufacturing/construction/transport	0.29				0.18			
Services/military	0.65				0.82			
Missing	0.01				0.00			
Primary mode of transport to work								
Transit	0.42				0.07			
Walk	0.15				0.03			
Bike	0.05				0.01			
Car or motorcycle	0.24				0.84			
Work from home	0.09				0.05			
Other	0.01				0.01			
One-way commute time (excludes works from home)								
< 16 minutes	0.27				0.36			
16 - 30 minutes	0.32				0.37			
31 - 60 minutes	0.24				0.22			
61 - 119 minutes	0.10				0.03			
> 120 minutes	0.03				0.01			
Housing type								
Single-family	0.74				0.68			
Single-family attached	0.16				0.07			
Apartment	0.09				0.21			
Other	0.01				0.02			
Unreported					0.02			
Observations	2,487,538				3,304,006			

In terms of commute mode to work, the plurality of urban residents in our sample commute to work by transit (42%), followed by car (24%), foot (15%), bike (5%), while those working from home made up 9%. In the US, 84% of our sample commute to work by car. Seven percent commute by transit and another 4% commute by foot or bike. Due in part to modal differences, commute times are a bit shorter for US urban residents who work outside of the house: a much larger share of Mexico’s commuters has a one-way commute time over an hour (13% compared to 4% in the US). Nearly half of these Mexican commuters live in the Mexico City Metropolitan Area, whose suburbs are notorious for time-consuming work commutes (Guerra 2014b; 2017a).

Table 4.2 summarizes the commute time to work by mode. In both countries, commute times tend to be higher by transit than by car or non-motorized modes. Across countries, a higher share of Mexico's urban residents has shorter commutes than in the US. This likely relates to the high share of US transit use coming from the New York City metropolitan area which tends to have long commutes by all modes. In both countries, pedestrians and cyclists have the shortest duration, and by extension, shortest distance commutes.

Table 4.2 Travel Time to Work by Mode in Mexico and US

	One-way commute time			
Mexico	< 16	16 - 30	31 - 60	> 60
Transit	0.11	0.33	0.35	0.21
Car	0.34	0.38	0.20	0.08
Non-motorized	0.59	0.31	0.08	0.02
United States				
Transit	0.07	0.25	0.47	0.20
Car	0.37	0.39	0.21	0.03
Non-motorized	0.73	0.20	0.06	0.01

Chapter 4. Differences in urban form and transport supply

Mexico's metropolitan areas are generally smaller and denser than their US counterparts, with less roadway and high-capacity transit, and more concentrated job centers, but with less separation between where people work and live. With the exception of transit supply and total size, most of these features are associated with greater transit use and more non-motorized transport use. Table 5.1 presents summary statistics for the largest 100 metropolitan and urban areas in the US and Mexico.

Table 5.1 Urban form and transport supply descriptive statistics by urban area

	The US				**Mexico**			
Statistic	Mean	St. Dev	Min	Max	Mean	St. Dev	Min	Max
Job-population imbalance Gini Index (0~1)	0.46	0.05	0.34	0.61	0.24	0.09	0.09	0.49
Total job (million)	3.26	3.63	0.72	21.18	0.32	0.91	0.03	8.80
Total population (million)	2.10	2.72	0.54	19.98	0.77	2.17	0.08	20.89
Share of road length by highway	13.3%	3.9%	5.4%	31.1%	7.7%	3.1%	0.0%	18.6%
Share of road length by arterial	8.4%	2.1%	3.3%	16.5%	11.0%	4.6%	1.2%	23.6%
Share of road length by local road	78.3%	4.9%	59.0%	90.8%	81.4%	5.3%	66.2%	92.3%
90 percentile of job density (job/hectare)	14.0	8.3	4.6	56.1	27.6	10.7	3.4	79.2
90 percentile of population density (people/hectare)	21.0	19.7	6.6	156.4	130.5	35.8	58.8	273.1
Population weighted density (people/hectare)	14.9	13.4	4.1	117.1	74.9	20.7	29.5	161.3
Job-area imbalance Gini Index (0~1)	0.33	0.09	0.05	0.51	0.46	0.06	0.36	0.67
Total roadway per capita (m/person)	21.6	11.1	0.1	59.7	3.1	1.3	1.3	10.0
Total MRT per capita (m/1000 person)	13.4	27.7	0	121.4	1.2	4.4	0	24.0

Although the Mexico City metropolitan area has almost a million more residents than the New York City metropolitan area, Mexico's smallest urban areas in the sample have many fewer residents than the smallest US metropolitan areas in the sample. The mean population size of Mexican urban areas is 0.77 million, roughly one-third of the average size of the 100 MSAs. The difference in the number of jobs is even larger at around one quarter of the US average. It is worth noting that this estimate of the number of jobs comes from the population Census, rather than the Economic Census, and thus includes informal employment. Thus, the difference likely reflects Mexico's larger household sizes and younger population.

In terms of population density, residents of Mexico's metropolitan areas live in neighborhoods that are five times dense than US metropolitan areas on average. The US has a range from 4 to 117 people per hectare, while in Mexico the range is from 29.5 to 161 people per hectare. When measured with a Gini coefficient or via an analysis of the densest Census tracts, Mexico's metropolitan areas's employment appears more concentrated in particular tracts. The difference would likely be accentuated if these measures included informal employment in Mexico.

Excluding the informal sector, Mexican metropolitan areas have a greater mix of jobs and people within each Census tract. Some urban areas in Mexico have an almost perfect job-residence balance with job-population Gini index close to 0.1. On the contrary, the lower bound in US metropolitan areas can be as high as 0.34. This suggests that it is easier for Mexican residents to access nearby shops and other employment destinations without motorized transport. Including the informal sector would strengthen this difference.

In general, US metropolitan areas have much greater road and transit supply than Mexico's. The average per capita road length of the MSAs is seven times as high as that of the Mexican urban areas. Even for New York and Mexico City, whose population sizes are close, the former has a per capita road supply six times as high as the latter. There is a greater supply of highway in the US; the share of highways in road composition ranges from 5.4% to 31.1% in the US and from 0.0% to 18.6% in Mexico. Accordingly, arterials and local roads play a greater part in Mexican urban road supply.

The average per capita supply of high-capacity transit in the US MSAs is more than 10 times higher than in Mexico's. In fact, only seven Mexican metropolitan areas, including Chihuahua, Guadalajara, Juárez, León, Monterrey, Puebla-Tlaxcala and Valle de México, have high-capacity transit systems, and the types and scales of transit systems of these seven metropolitans could be different. Mexico City has the most extensive transit system in both scale and type of transit. The other six metropolitan areas have much smaller systems ranging between 20 and 40 km. The smallest transit system of any metropolitan area in Mexico is the BRT of Guadalajara. At 16 km, it is just one-tenth of Valle de México's system's size. Only three metropolitan areas, Guadalajara, Monterrey, and Mexico City have rail systems. Although Mexico City has substantially more mass rapid transit than any other Mexican urban area in absolute terms and per capita, it has only a fifth of the rapid transit of New York. Additionally, Boston and Philadelphia have more fixed guideway transit than Mexico City, despite having a quarter of the residents.

Chapter 5. Characterizing urban form and transportation supply

This section aims to explore the covariance in urban form and transportation supply across US and Mexican metropolitan areas. We first present and discuss correlation tables before estimating principal components and describing the types of urban areas in each country. The focus is to reduce the final number of urban variables used in our prediction models. Although the dataset includes observations from millions of commuters in the US and Mexico, we only have 100 urban areas on each side of the border. To conserve space, we refer to variables using name codes in our final dataset. Table 6.1 defines each variable name. The result of this characterization of urban form is a selection of six relatively uncorrelated measures of urban form and transportation supply within and across the US and Mexico.

Table 6.1 Table of urban form variables.

Variable	Name code	Variable	Name code
Job-population imbalance Gini Index (0~1)	Gini_JP	90 percentile of job density (job/hectare)	jph.90th
Total job	jobs.ic	90 percentile of population density (people/hectare)	pph.90th
Total population	POP_TOT	Population weighted density (people/hectare)	wmean_den
Share of road length by highway	ShareHighway	Job-area imbalance Gini Index (0~1)	JobAreaGINI
Share of road length by arterial	ShareArterial	Total roadway per capita (km/person)	Road_pc
Share of road length by local road	ShareLocal	Total MRT per capita (km/person)	MRT_pc

Across US urban areas, we find strong positive correlations between population density, total population, total number of jobs, and the densest Census tracts (Table 6.2). Total roadway and MRT are also positively correlated, though we find modest inverse correlations between population density ad per capita measures of transportation supply. The urban areas with the highest concentration of jobs in a smaller amount of land also tend to have the least balance between jobs and population within neighborhoods. Unsurprisingly, the share of local roadway is inversely correlated with the share of highways and the share of arterial roadway. In Mexico, the largest urban areas also tend to be the densest and have the highest concentration of jobs (Table 6.3). Unlike in the US, urban areas with more balanced jobs and housing tend to have more centralized job centers, though the correlation is just -0.14. Given that only the largest urban areas have any mass rapid transit, we also find a relatively strong correlation between MRT per capita, total population, and total jobs.

Table 6.2 Correlation table for 100 US metropolitan areas

	Gini_JP	jobs.ic	POP_TOT	ShareHighway	ShareArterial	ShareLocal	jph.90th	pph.90th	wmean_den	JobAreaGINI	Road_pc	MRT_pc
Gini_JP	1.00											
jobs.ic	0.39	1.00										
POP_TOT	0.34	0.98	1.00									
ShareHighway	-0.24	-0.01	-0.02	1.00								
ShareArterial	0.08	0.16	0.16	0.25	1.00							
ShareLocal	0.15	-0.06	-0.05	-0.91	-0.64	1.00						
jph.90th	0.38	0.58	0.63	0.02	0.09	-0.05	1.00					
pph.90th	0.31	0.66	0.74	0.01	0.20	-0.09	0.92	1.00				
wmean_den	0.30	0.71	0.81	-0.05	0.16	-0.04	0.88	0.96	1.00			
JobAreaGINI	0.61	0.48	0.46	-0.15	-0.20	0.20	0.36	0.28	0.34	1.00		
Road_pc	-0.22	-0.43	-0.40	-0.22	-0.47	0.38	-0.41	-0.44	-0.42	0.02	1.00	
MRT_pc	0.14	0.37	0.38	-0.08	0.04	0.05	0.43	0.40	0.44	0.20	-0.26	1.00

Table 6.3 Correlation table for 100 Mexican urban areas

	Gini_JP	**jobs.ic**	**POP_TOT**	**ShareHighway**	**ShareArterial**	**ShareLocal**	**jph.90th**	**pph.90th**	**wmean_den**	**JobAreaGINI**	**Road_pc**	**MRT_pc**
Gini_JP	1.00											
jobs.ic	0.02	1.00										
POP_TOT	0.02	1.00	1.00									
ShareHighway	-0.02	0.04	0.04	1.00								
ShareArterial	-0.02	0.05	0.05	-0.09	1.00							
ShareLocal	0.03	-0.07	-0.07	-0.51	-0.82	1.00						
jph.90th	-0.23	0.22	0.21	0.08	0.22	-0.24	1.00					
pph.90th	0.02	0.52	0.52	0.11	0.09	-0.14	0.50	1.00				
wmean_den	0.05	0.55	0.54	0.02	0.13	-0.12	0.53	0.96	1.00			
JobAreaGINI	-0.14	0.02	0.02	0.24	-0.04	-0.11	0.16	0.03	-0.04	1.00		
Road_pc	0.31	-0.15	-0.16	-0.28	0.00	0.17	-0.42	-0.31	-0.28	-0.01	1.00	
MRT_pc	0.06	0.58	0.58	0.03	-0.03	0.00	0.15	0.34	0.37	0.04	0.01	1.00

Combining the urban areas from both countries produces even stronger correlations across many of the measures of urban form (Table 6.4). For example, the Mexican cities are systematically denser and more balanced then US metropolitan areas. By contrast, the correlation between city size and density disappears, since the sample of US cities tend to be more populous but substantially less dense than the Mexican sample.

Table 6.4 Correlation table for 200 metropolitan areas

	Gini_JP	jobs.ic	POP_TOT	ShareHighway	ShareArterial	ShareLocal	jph.90th	pph.90th	wmean_den	JobAreaGINI	Road_pc	MRT_pc
Gini_JP	1.00											
jobs.ic	0.49	1.00										
POP_TOT	0.29	0.88	1.00									
ShareHighway	0.47	0.31	0.17	1.00								
ShareArterial	-0.28	-0.10	-0.02	-0.18	1.00							
ShareLocal	-0.20	-0.19	-0.13	-0.72	-0.56	1.00						
jph.90th	-0.50	-0.01	0.17	-0.33	0.33	0.05	1.00					
pph.90th	-0.71	-0.26	0.02	-0.53	0.35	0.20	0.75	1.00				
wmean_den	-0.68	-0.21	0.08	-0.55	0.35	0.21	0.76	0.99	1.00			
JobAreaGINI	-0.47	-0.06	0.05	-0.43	0.16	0.25	0.54	0.63	0.63	1.00		
Road_pc	0.60	0.14	0.00	0.38	-0.38	-0.05	-0.60	-0.75	-0.74	-0.50	1.00	
MRT_pc	0.28	0.46	0.40	0.14	-0.09	-0.06	0.05	-0.16	-0.12	-0.08	0.07	1.00

5.1 Principal component analysis

To better understand the correlations across all variables, we conducted PCA for the two countries combined. The first two PCs account for over 60% of the data variation and the next two PCs account for another 20%. Plotting PC1 against PC2 shows systematic differences in urban form in the U.S. and Mexico (Figure 6.1). The Mexican metropolitan areas have consistently higher PC1 scores, which correspond with higher job and population densities, better spatial job-population balance, and less roadway per capita (Table 6.5). Only one US urban area, New York, has any overlap with Mexican urban areas along PC1. In short, Mexican and U.S. urban areas have systematically different and non-overlapping urban form and transportation supply along the dimension that best explains the variance across all our measures of urban form. Meanwhile, the several very low scores on PC2 in the U.S. imply very large metropolitan areas, while the only counterpart in Mexico is Valle de México with a PC2 score of -7.5.

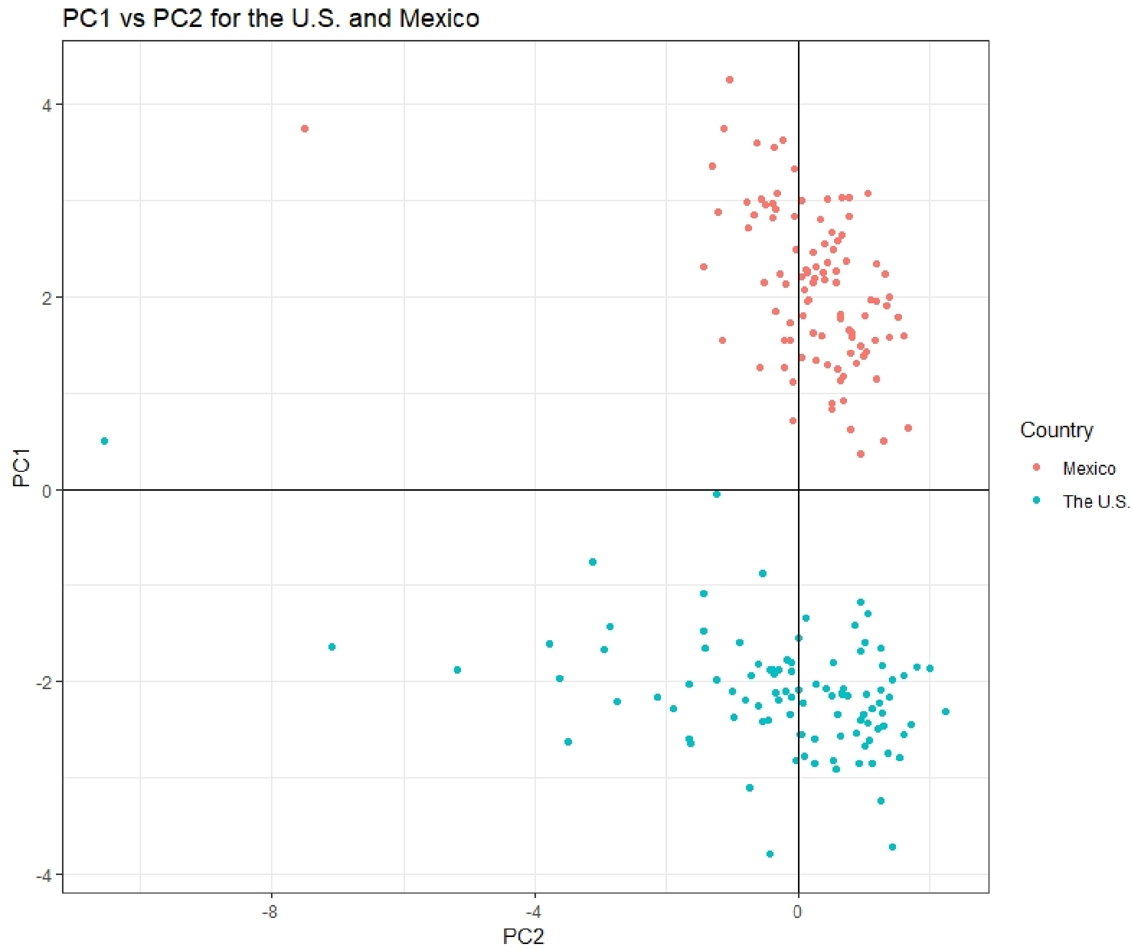

Figure 6.1 PC1 vs PC2 for the U.S. and Mexico

We further plotted other pairs of the first 4 PCs (Figure 6.2). The urban forms of the two countries are not distinctly different in terms of PC3, which captures the composition of different road hierarchies. The U.S. has quite a few low scores on PC4, indicating very high per capita transit supply. These urban areas include Stockton-Lodi, Salt Lake City, Albuquerque, and Baltimore-Columbia-Towson.

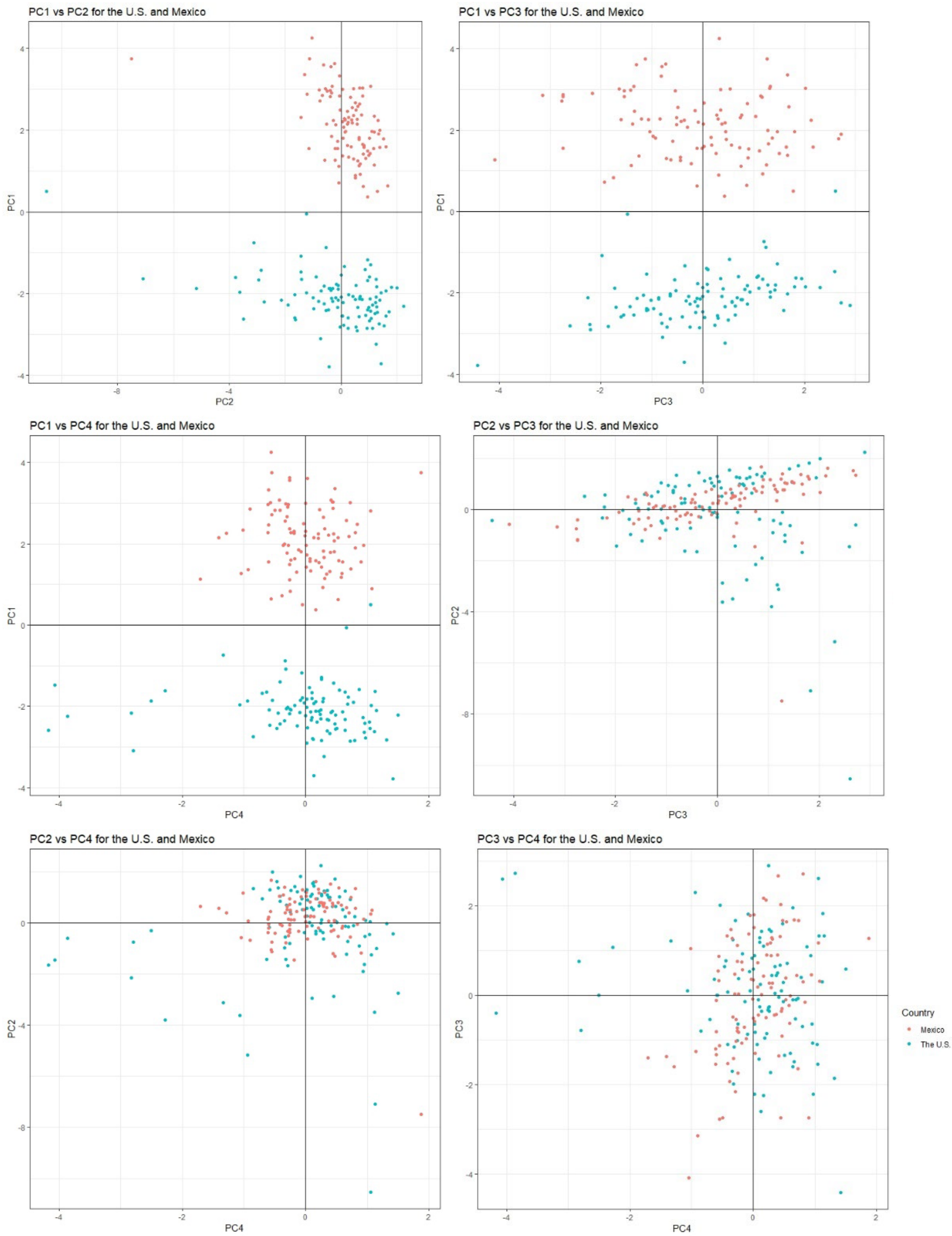

Figure 6.1 PC1 vs PC2 for the U.S. and Mexico

Table 6.5 PCA results for the two countries

	Interpretation	Variable	Loading
PC1	Difference between densities and job-population imbalance and per capita road supply	Gini_JP	-0.36
		Road_pc	-0.35
		jph.90th	0.34

		pph.90th	0.42
		wmean_den	0.42
PC2	Metropolitan size	jobs.ic	-0.54
		POP_TOT	-0.57
		MRT_pc	-0.37
PC3	Road structure- local road	ShareArterial	-0.54
		ShareLocal	0.67
PC4	Per capita transit supply	MRT_pc	-0.77
PC5	Transit and highway supply	ShareHighway	0.56
		ShareArterial	-0.53
		MRT_pc	0.42
PC6	Job-area imbalance	JobAreaGINI	0.88

Chapter 6. Urban form and mode choice

Abstract: This chapter examines empirical relationships between commuters' mode choice, metropolitan urban form, and socioeconomic attributes in the hundred largest urban areas in both the United States and Mexico. Fitting multinomial logit models to data on over five million commuters and their home urban area, we find several consistent relationships and several important differences in relationships between urban form and travel behavior. In both countries, urban residents living in housing types associated with more centrally located housing in more densely populated urban areas with less roadway are less likely to commute by private vehicle than similar residents in other housing types and other urban areas. In addition to some differences in the strength, significance, and sign of several predictor variables, we find large differences in elasticity estimates across contexts. In particular, the US's high rates of driving and generally car-friendly urban form mean that even dramatic shifts in urban form or income result in only small predicted changes in the probability of commuting by private vehicle. We conclude with two important limitations to our findings and a discussion for the need for more research into the relationships between urban form and travel behavior from outside of the US.

6.1. Introduction

Although empirical research tends to emphasize the identification of generalizable relationships, the effects of transportation and land use policies vary across people, place, and time. Geographic, social, and economic context shapes the outcomes of transportation policies and influences the relationships between urban form, transportation infrastructure, and travel behavior. While aggregate comparisons across cities and countries are common (Ingram and Liu 1999; McIntosh et al. 2014; Newman and Kenworthy 1989; Pucher, Dill, and Handy 2010), empirical studies of the relationship between the built environment and travel behavior at the correct ecological unit of analysis—the household or individual—tend focus on just one metropolitan area or a single wealthy country, such as the US or the Netherlands (for an overview, see Ewing and Cervero, 2010, 2001; Stevens, 2017). The single metropolitan areas, moreover, are most likely to be large, dense metropolitan areas, like San Francisco, Los Angeles, Mexico City, Hong Kong, or Boston. In Latin America, studies outside of the largest capital cities are particularly rare (de Vasconcellos 2005; Guerra et al. 2018b; Jaramillo, Lizárraga, and Grindlay 2012). Studies across smaller metropolitan areas in multiple countries are even rarer.

In this chapter, we examine empirical relationships between commuters' mode choice, metropolitan urban form, transportation infrastructure, and socioeconomic attributes for a sample of more than five million commuters in the hundred largest urban areas in both the United States and Mexico. Together, these workers represent roughly two-thirds and four-fifths of all commuters in the US and Mexico. Better understanding the relationship between urban form, socioeconomic attributes, and workers' commute behavior across multiple urban areas in multiple countries can help shed light on the strength and relative importance of factors correlated with commuter mode choice, as well as their consistency and the role of regional and social context. We focus our analysis and discussion on the relative importance of transportation supply, household income, and urban form in shaping the radically different commute patterns seen across the US and Mexico. Mexican urban areas, for example, are highly multimodal with substantial and continuous variation in modal importance (Figure 6.1). Even in La Paz, the most car-reliant urban area, 40% of commuters walk, bike, or take transit. In the US, by contrast, nearly everyone drives to work, with just a few metropolitan areas where less than 90% of commutes are by car. Income almost certainly plays a role in national differences as well. Mexican commuters have average household incomes that are around 8 times lower than American commuters (6 times lower after accounting for purchasing power parity.) So does the built environment. Residents live in neighborhoods that are five times denser in Mexican urban areas than in US ones.

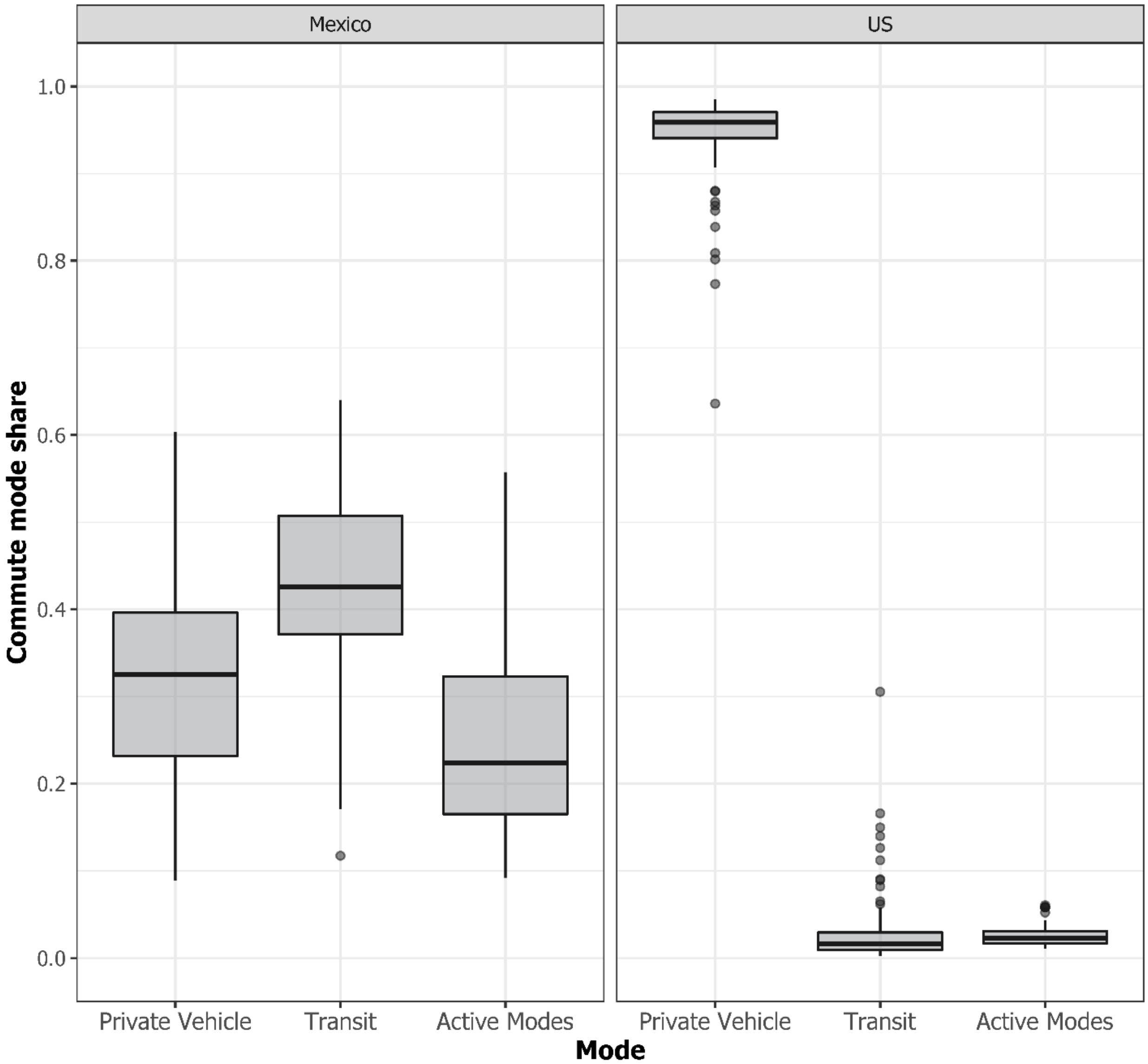

Figure 6.1 Distribution of commute mode share in the 100 largest urban areas in both the US and Mexico

Our study makes three primary contributions to the land use and transportation literature. First, it is one of only a handful of papers to examine individual-level travel behavior across multiple cities in more than one country. Individuals make choices about travel behavior and are thus the correct unit of analysis for studying how differences in urban form, transportation infrastructure, and social context contribute to differences in travel behavior. Findings thus contribute to the growing body of empirical research on the relationship between urban form, transport supply and travel behavior across cities within a country (Bento et al. 2005; Ewing et al. 2014; Guerra et al. 2018b; Sun et al. 2017; 2016; J. Yang et al. 2012; Zhu et al. 2017) and how these relationships may vary across cities and regions in different countries (Feng et al. 2013; Giuliano and Dargay 2006a; Giuliano and Narayan 2003; Tana, Kwan, and Chai 2016; Zhang 2004).

Second, our study offers insight into the nature of the relationship between socioeconomic variables, urban form, and travel behavior. If relationships between income, urban form, and commute patterns are consistent across urban areas and commuters in two substantially different contexts, then they are likely consistent across a variety of contexts. Where relationships are inconsistent, findings provide insight into how context helps to shape relationships between urban form, commuters, and commute patterns. For example, Mexico's urban commuters may be substantially more likely to change travel behavior in response to differences in income, urban form, or transportation supply than in the US. A large share of Mexico's urban population commutes by transit (50.3%), private vehicle (31.2%), and active modes (18.4%). This suggests that the attractiveness of the different modes of travel are relatively close and that small changes in the cost or convenience of any given mode can potentially have large impacts on travel behavior. In the US, where 90% of workers commute by car, even radical changes to the attractiveness of any mode will likely only have small impacts on aggregate mode choice. Doubling the numbers of workers who walk or bike to work, for example, would only reduce driving by around 3.6%.

Third, by providing a consistent analysis across two substantially different contexts, our study helps shed light into the transferability of transportation and land-use policies across contexts. Despite the US's somewhat exceptional commute patterns and urban form—only a handful of other countries look like the US in this respect—a disproportionate amount of research into land use and transportation comes from US urban areas. For example, just five studies from the 62 included in most cited literature review on the relationship between travel behavior and the built environment (Ewing and Cervero 2010) use data from outside of the US. Just one of these studies, an earlier conference paper of Zegras' (2010) study of Santiago de Chile, is from a Latin American context. None are from smaller Latin American cities. If relationships vary substantially across national boundaries, however, drawing on a US-dominated body of literature to shape public policy may be ineffective.

The remainder of the chapter organized as follows. First, we describe our general research approach, data sources, and hypotheses. Second, we present the results the results of four commute mode choice models. Next, we present the results of several simulations to demonstrate the collective relationship between multiple measures of urban form and commute mode choice. Last, we conclude with a discussion of our main takeaways, study limitations, and opportunities for future research.

6.2. Data and research approach

Table 6.1 present our data sources, definitions, and expected relationships with workers' commute mode choice. As described in Chapter 2, , we rely on four years (2012-2015) of the American Community Survey Public Use Microdata Sample 1-year data and the 2015 Mexican Intercensal Survey (INEGI 2015) for individual and household level data. Each survey asks workers about their typical commute mode per week. We aggregate modes into three consistent categories across the two national samples: private vehicle (including drivers and passengers of cars, trucks, vans, and motorcycles); transit (including metro, bus rapid transit, light rail, trolley, subway, worker shuttles, and taxicabs); and active travel (walking and cycling). We exclude other and unreported modes of travel, which account for less than 1% of commutes in both countries.

Table 6.1 Data description and expected relationships with commute mode choice

Variables	Description	Expected relationship with commute choice
Individual-level measures[1]		
Commute mode choice	Primary means of transportation to work by private vehicle (driver and passengers of cars, trucks, vans, and motorcycles), transit (metro, bus rapid transit, light rail, trolley, subway, worker shuttle, and taxicabs) or active modes (walking or cycling).	
Household income	Log-transformation of monthly household income in US dollars adjusted by purchasing power parity. A dummy variable indicates missing income data.	Low income groups are more likely to commute by transit or non-motorized modes.
Household size	Number of persons in household	Offsets household income, but larger households may also have more complicated travel patterns better served by private vehicle.
Vehicle availability	Whether the worker's household has a car, van, or light-duty truck	Vehicle availability indicates preference for driving and makes private vehicle commute easier.
Gender	Male or female	Men are more likely to commute by private modes including vehicles and bicycles.
Age	Worker's age	Younger people are more likely to take transit, walk or bike.
Occupation	Worker's occupation (in agriculture, manufacturing, or service industry)	Occupations better served by transit, such as services in the US, are more likely to have transit commuters. Suburban-oriented occupations are more likely to indicate private vehicle commutes.
Highest education attainment	Worker's highest education attainment (less than middle school, middle school, high school, college and above)	Highest education attainment is positively associated with people's likelihood to drive.
Housing type	The type of housing the worker's household lives in (single-family detached, single family attached, apartment, and other)	Housing type is considered as a proxy for local built environment and relates to commute mode choice in that single-family detached housing is mostly likely associated with driving while apartment is more likely associated with commuting by transit, walking or biking.
Urban-level measures[2]		
Population density	Number of people per hectare weighted by the number of people in each census tract within that urban area	Transit and active commutes are higher in denser urban areas.
Jobs-population imbalance (Gini)	Gini index of the percentage of jobs relative to the percentage of population in each census tract within that urban area; 1: perfect imbalance, 0: perfect balance.	Jobs-population imbalance is positively associated with more driving and less active commuting since commute distances will tend to be longer.
Jobs-area imbalance (Gini)	Gini index of the percentage of jobs relative to the percentage of land area in each census tract within that urban area; 1: perfect imbalance, 0: perfect balance.	Jobs-area imbalance is positively associated with higher rates of transit since more concentrated job centers more easily served by transit.
Share of road length by arterial	Percentage of road length in that urban area that is arterial	Roadway supply is positively associated with car use. The share of commuting by private vehicle is higher in urban areas with more roadway per resident and a higher share of arterials and highways. Greater roadway supply and higher shares of arterials may also be conducive to transit use.
Share of road length by highway	Percentage of road length in that urban area that is highway	
Roadway length per capita	Kilometers of all roadway (highway, arterial, and local roads) divided by total population	

Notes: 1. Commute mode choice, demographic, and household variables from American Community Survey (ACS) and Mexican Intercensal Survey. 2. Measures of urban form calculated from 2010 US and Mexico Decennial Censuses, 2015 US Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics, 2009 Mexican Economic Census, and OpenStreemap

We then converted variables, such as income and highest educational attainment, into consistent units across the two national samples. We introduce quadratic terms to age in order to account for shifts in modal preference as workers' age and take the natural log of household income to reduce skewness and account for the long right-tail of wealthy households in both countries.

Urban-level measures are calculated from the 2010 US Census, 2010 Mexican Census, 2015 US Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics, 2009 Mexican Economic Census, and OpenStreetMap. Population density reflects the census-tract-level population density for urban residents on average. Jobs-population imbalance measures the distribution of jobs relative to that of people across all census tracts as a Gini coefficient. A score of one indicates a perfect imbalance with all jobs and residents occurring in different tracts. A score of zero indicates that jobs and people are proportionately distributed across census tracts. The jobs-area imbalance Gini coefficient measures the spatial concentration. A score approaching one indicates a monocentric city with all jobs in just a few small census tracts. A score of zero indicates that jobs are equally spread by land area across census tracts. In the US, the hundred largest urban areas are the 100 most populous metropolitan statistical areas. In Mexico, the urban areas include all 59 of the country's metropolitan areas and the 41 next largest officially designated urban areas (CONAPO 2018).

Our final dataset emphasizes consistency across measurements and the avoidance of multicollinearity in measures of urban form. For example, we do not include measures of ethnicity or national origin. Although common in studies from the US (Blumenberg and Pierce 2014; Hu 2014), equivalent measures are rare in Latin American contexts and generally excluded from travel behavior models (Guerra et al. 2018b; Suárez, Murata, and Delgado 2016; Suárez and Delgado 2009). Similarly, we exclude measures of whether someone works in the informal sector, despite featuring in studies that predict travel behavior in Mexico (Suárez and Delgado 2009; Guerra et al. 2018b; Suárez, Murata, and Delgado 2016). In terms of collinearity, we exclude measures of urban form with relatively high correlations with other variables. For example, we do not include job density or total population, because they are strongly correlated with population density in one or both countries. Despite the substantial number of commuters in the dataset, each country only has one hundred measures at the scale of the urban area. Thus, we choose a parsimonious and relatively uncorrelated set of urban-scale measures to avoid over-fitting models to the data.

6.2.1. Data summary

Table 6.2 summarizes the final data sample used in our models predicting commuter mode choice in the hundred largest urban areas in the US and Mexico. Workers from Mexico's urban areas tend to rely on a far greater mixture of transportation modes to get to work than those in US urban areas. In our Mexico sample, 28% of workers commute to work by private vehicle, 49% by transit, and 23% by foot or bike. In the US sample, by contrast, fully 90% commute to work by car, 7% by transit, and just 3% by foot or bike. Relative to US workers, Mexico's workers are more likely to be male, have lower educational attainment, work in manufacturing or agriculture, and be less wealthy. Accounting for purchasing power parity, workers in the Mexico sample live in households with six times lower incomes and 42% more family members than workers in the US sample. Workers in the Mexico sample also tend to live in urban areas that are more densely populated with substantially less roadway per capita, less spatial separation between jobs and residents, and more strongly concentrated job centers. The average neighborhood population density for residents in Mexican urban areas is three times higher than for residents in US urban areas. In terms of transportation supply, US urban areas have much more substantial road networks than Mexican ones with six times as much highway, arterial, and local roadway per capita.

Table 6.2 Summary statistics

Variables	Mexico (N=2435133) Mean	Mexico (N=2435133) Std. Dev.	US (N=3276640) Mean	US (N=3276640) Std. Dev.
Commute mode share				
Private vehicle	27.70%		89.80%	
Transit	49.30%		7.10%	
Non-motorized	22.90%		3.10%	
Individual-level measures				
Monthly household income (USD PPP[1])	1,480	2,047	9,170	8,234
Income unreported[2]	4.60%		0%	
Household size	4.4	2.2	3.1	1.6
Gender				
Male	64.30%		52.20%	
Age	38	13	43	
Occupation				
Manufacturing/construction/transport	28.90%		18.00%	
Services/military	65.50%		81.50%	
Agriculture	5.10%		0.10%	
Unreported/missing	0.60%		0.00%	
Highest education attainment				
Less than middle school	29.10%		2.40%	
Middle school	31.30%		6.30%	
High school	23.20%		43.50%	
College degree or higher	23.5		47.80%	
Housing type				
Single-family detached	73.60%		68.40%	
Single-family attached	16.00%		7.20%	
Apartment	9.30%		22.00%	
Other housing type	1.00%		2.50%	
Urban-level measures				
Population density (people per hectare)	99.17	39.47	29	30.74
Jobs-population imbalance (Gini)	0.24	0.08	0.48	0.05
Jobs-area imbalance (Gini)	0.47	0.04	0.38	0.08
Share of road length by arterial	0.12	0.04	0.09	0.02
Share of road length by highway	0.08	0.02	0.13	0.03
Roadway length per capita (km per 100 p	0.26	0.1	1.58	0.87

Notes: 1. Mexican pesos converted to US dollars using exchange rate and accounting for purchasing power parity. 2. For individuals with no income or occupation data, we set income to zero and add dummy variables indicating missing data.

6.2.3. Model specification

We estimate multinomial logit models in the mlogit package (Croissant 2019) in R (R Core Team 2018) to predict workers' commute mode choice as a function of metropolitan urban form, road supply, and the individual attributes of commuters in the 100 largest urban areas in both the US and Mexico. We also estimate average individual elasticities using sample enumeration (Train 2009, chap. 2.6.1) to account for sample weights and provide consistent estimates of the magnitude of the relationship between urban form, income, and commute mode choice across the two data samples.

Socioeconomic and household-level attributes vary by commuter, while measures of urban form vary by urban area. This general estimation framework is common in studies of urban form and travel behavior across multiple cities in one or more countries (Bento et al. 2005; Giuliano and Dargay 2006a; Guerra et al. 2018b; Sun et al. 2017; L. Yang et al. 2017). Although we do not explicitly account for residential self-selection beyond a robust set of socioeconomic control variables—for a review of the problems and potential empirical solutions, see (Cao, Mokhtarian, and Handy 2009; S. Handy, Cao, and Mokhtarian 2005; Mokhtarian and Cao 2008)—workers are far more likely to choose residential locations within a metropolitan based on travel preferences than to choose across metropolitan areas. Note that, unlike many studies of commute mode choice, our estimates do not include estimates of the travel time or travel cost of alternative modes. Thus, our estimates of the relationships between urban form, socioeconomic variables, and commute mode include any intermediary relationships that may occur through relationships to travel times and travel costs. For example, denser urban areas likely decrease car speeds and increase the probability that homes and workplaces are close enough for a walking commute. Similarly, wealthier and better educated commuters are more likely to be able to select into home-work pairs that are suited to their preferred travel mode in terms of travel time and cost.

To account for correlated error terms within urban areas, we present Liang and Zeger (1986) clustered standard errors. We also estimated models using binary logit models of each mode against the reference mode (private vehicle). This Begg and Gray (1984) approximation produces more conservative estimates of standard errors than a multinomial logit model, allowed us to introduce random intercepts for each urban area using a multilevel modeling structure. This procedure produced consistent results with the reported multinomial logit models with clustered standard errors.

6.3. Results

Table 6.3 presents the results of the models predicting the probability of commuting by transit and non-motorized modes relative to commuting by private vehicle in Mexico (Model 1) and the US (Model 3). We discuss Model 2 and Model 4, which include a dummy variable for whether the household has a private car, truck, or van available to the household, in Section 3.3. We converted several predictor variables so that the statistically significant parameter estimates are closer to one or negative one. This facilitates model convergence and makes it easier to read the model outputs. For example, population density is presented in terms of hundreds per hectare and Gini coefficients range from 0 to 100 instead of 0 to 1. Coefficient estimates have direct interpretations in terms of the utility associated with each mode. For example, a one unit increase in hundreds of people per hectare is associated with 0.373 and 2.088 increase in the utility of commuting by transit in Mexico and the US. Taking the exponent of the coefficient makes the coefficient interpretable as an odds ratio. For an average commuter in Mexico and the US, the increases in utility correspond with a 43% and 707% increase in the odds of choosing transit over a private vehicle.

Neither utility nor odds ratios are directly comparable across the samples, however, and depend on the relative attractiveness of the alternative modes and the distributions of the dependent and independent variables. For example, increasing population density by 100 people per hectare roughly doubles population density in the Mexico sample and roughly quadruples it for the US sample. Applying Ewing and Cervero's elasticity formula (2010, 273) to the average commuter, a doubling of population density corresponds with a 19% increase in the probability of commuting by transit in Mexico and 56% increase in the US. Applying the same estimate to the probability of commuting by private vehicle, the elasticity shifts to -0.27 in Mexico, where more workers travel by transit than car, and -0.06 in the US, where nine in ten workers commute by car. We report parameter estimates in terms of utility instead of odds-ratios to avoid possible misinterpretations about the relative strength of parameter estimates across the two national samples. Section 4 presents more directly comparable elasticity estimates.

Table 6.3 Multinomial logit model predicting commute mode to work (reference category: commute by private vehicle)

	Mexico (Model 1)		Mexico (Model 2)		US (Model 3)		US (Model 4)	
	By transit	By foot or bike	By transit	By foot or bike	By transit	By foot or bike	By transit	By foot or bi
Socioeconomic Attributes								
Monthly household income (natural log)	-0.600 ***	-0.815 ***	-0.307 ***	-0.529 ***	-0.085	-0.252 ***	0.067	-0.119 ***
	(0.016)	(0.021)	(0.017)	(0.020)	(0.056)	(0.030)	(0.059)	(0.041)
Income data missing	-4.638 ***	-6.028 ***	-2.508 ***	-3.975 ***				
	(0.156)	(0.195)	(0.158)	(0.189)				
Household size	0.124 ***	0.156 ***	0.138 ***	0.171 ***	0.017 **	0.005	0.046 ***	0.027
	(0.004)	(0.004)	(0.003)	(0.004)	(0.008)	(0.016)	(0.011)	(0.018)
Male	-0.661 ***	-0.668 ***	-0.659 ***	-0.660 ***	0.018	0.327 ***	0.028	0.335 ***
	(0.034)	(0.051)	(0.035)	(0.049)	(0.021)	(0.046)	(0.022)	(0.043)
Age	-0.101 ***	-0.138 ***	-0.081 ***	-0.120 ***	-0.016 ***	-0.081 ***	-0.019 ***	-0.085 ***
	(0.003)	(0.004)	(0.003)	(0.004)	(0.006)	(0.005)	(0.006)	(0.005)
Age squared (divided by 1000)	0.948 ***	1.436 ***	0.802 ***	1.302 ***	0.102	0.806 ***	0.140 *	0.847 ***
	(0.030)	(0.034)	(0.029)	(0.038)	(0.078)	(0.056)	(0.075)	(0.052)
Highest educational attainment (reference category: less than junior high school)								
Junior high school (Secundaria)	-0.222 ***	-0.544 ***	-0.008	-0.331 ***	-0.238 ***	-0.029	-0.180 **	0.004
	(0.017)	(0.019)	(0.018)	(0.018)	(0.070)	(0.082)	(0.077)	(0.087)
High school	-0.538 ***	-1.186 ***	-0.138 ***	-0.791 ***	-0.608 ***	-0.522 ***	-0.435 ***	-0.393 ***
	(0.029)	(0.038)	(0.025)	(0.036)	(0.092)	(0.098)	(0.109)	(0.097)
College degree or higher	-1.355 ***	-2.352 ***	-0.77 ***	-1.774 ***	-0.423 ***	-0.386 ***	-0.213	-0.209 *
	(0.054)	(0.055)	(0.050)	(0.049)	(0.117)	(0.114)	(0.134)	(0.116)
Occupation (reference category: agriculture)								
Works in manufacturing/construction/transport	1.183 ***	-0.142	1.156 ***	-0.168	-0.003	-1.219 ***	-0.023	-1.238 ***
	(0.113)	(0.096)	(0.103)	(0.106)	(0.092)	(0.165)	(0.086)	(0.170)
Works in services/military	0.679 ***	-0.73 ***	0.687 ***	-0.720 ***	0.582 ***	-0.597 ***	0.568 ***	-0.612 ***
	(0.123)	(0.120)	(0.116)	(0.126)	(0.111)	(0.157)	(0.101)	(0.161)
Occupation data missing	0.807 ***	-1.076 ***	0.879 ***	-1.002 ***	1.035 ***	-0.140	0.846 *	-0.255
	(0.118)	(0.152)	(0.110)	(0.158)	(0.351)	(0.536)	(0.505)	(0.548)
Housing type (reference category: single-family detached)								
Single-family attached	0.334 ***	0.44 ***	0.111 ***	0.223 ***	0.940 ***	0.697 ***	0.875 ***	0.644 ***
	(0.031)	(0.032)	(0.026)	(0.034)	(0.130)	(0.105)	(0.117)	(0.095)
Apartment	0.409 ***	0.368 ***	0.165 ***	0.123 ***	1.428 ***	1.377 ***	1.114 ***	1.173 ***
	(0.068)	(0.050)	(0.045)	(0.038)	(0.163)	(0.139)	(0.099)	(0.095)
Other housing type	0.082 ***	0.141 ***	0.028	0.090 ***	-0.201	0.225 ***	-0.290 ***	0.186 ***
	(0.026)	(0.026)	(0.025)	(0.028)	(0.142)	(0.068)	(0.108)	(0.057)
Vehicle availability			-2.389 ***	-2.352 ***			-2.766 ***	-2.488 ***
			(0.030)	(0.035)			(0.045)	(0.076)
Urban-form Measures								
Population weighted density (100s per hectare)	0.382 ***	-0.057	0.503 ***	0.063	2.082 ***	1.427 ***	1.777 ***	1.193 ***
	(0.133)	(0.151)	(0.124)	(0.133)	(0.450)	(0.210)	(0.426)	(0.226)
Jobs-population imbalance (Gini 0-100)	-0.006	-0.024 ***	-0.007 *	-0.024 ***	-0.014	-0.005	-0.010	-0.001
	(0.004)	(0.005)	(0.004)	(0.005)	(0.028)	(0.015)	(0.027)	(0.015)
Jobs-area imbalance (Gini 0 -100)	0.054 ***	0.047 ***	0.043 ***	0.035 ***	0.006	-0.008	0.006	-0.008
	(0.011)	(0.013)	(0.009)	(0.012)	(0.017)	(0.009)	(0.016)	(0.009)
Transportation Supply								
Share of road length by arterial	-0.005	-0.01	-0.002	-0.006	-0.194 ***	-0.117 ***	-0.196 ***	-0.121 ***
	(0.011)	(0.012)	(0.009)	(0.009)	(0.058)	(0.033)	(0.056)	(0.033)
Share of road length by highway	-0.005	-0.018	0.01	-0.003	-0.011	0.015	-0.016	0.011
	(0.017)	(0.020)	(0.014)	(0.017)	(0.034)	(0.011)	(0.032)	(0.011)
Roadway length per capita (km per 100 people)	-2.056 ***	-3.577 ***	-1.208 ***	-2.714 ***	-0.607 **	-0.080	-0.643 ***	-0.087
	(0.462)	(0.654)	(0.378)	(0.545)	(0.239)	(0.061)	(0.225)	(0.061)
Intercept	4.731 ***	9.311 ***	3.391 ***	8.002 ***	0.298	2.037 **	1.401	3.127 ***
	(0.559)	(0.728)	(0.484)	(0.670)	(2.116)	(0.818)	(2.030)	(0.813)
Log-Likelihood:		-2170100	-1989700		-1069500		-989150	
McFadden R^2:	0.144		0.216		0.167		0.23	

*Notes: *p<0.1; **p<0.05; ***p<0.01; Cluster robust standard errors in parentheses.*

6.3.1 Socioeconomic attributes and commute mode choice

In the US and Mexico's largest urban areas, higher income, higher educational attainment, and smaller household sizes tend to be associated with a higher probability of commuting by private vehicle and a lower probability of commuting by transit or active modes. The relationship between income and commuting by transit instead of private vehicle, however, is not statistically significant in the US. This may reflect the relatively wealthy rail commuters that make up a substantial share of transit commuters in large US urban areas. The probability of commuting by private vehicle follows a similar pattern with age in both countries. In the US, men are more likely than women to commute by active modes, while in Mexico the opposite relationship holds. In terms of employment, service-sector workers in both the US and Mexico are more likely to commute by transit or active modes relative to agricultural workers. In Mexico, working in manufacturing is positively associated with workers' likelihood of taking transit, whereas in the US it is negatively associated. This may reflect the greater availability of workplace transit shuttles, better suburban transit services, or denser concentrations of manufacturing in Mexican cities than US ones.

Thus, while we tend to find commonality in the many of the mode choice predictors in terms of the direction and statistical significance of socioeconomic predictor variables, there are several notable differences that may relate to culture or geography. In the US, for example, higher income is not statistically significantly associated with differences in the probability of commuting by transit relative to private vehicle. In Mexico, women appear to have less opportunity to commute by private vehicle than men. In Mexico, existing transit services appear to do a relatively decent job of serving manufacturing and construction jobs.

6.3.2. Urban form and commute mode choice

As with socioeconomic attributes, there are several notable similarities between how measures of metropolitan urban form correlate with commute mode choice in both US and Mexican urban areas. Across national borders, urban residents are less likely to commute to work by private vehicle in densely populated urban areas with less roadway per capita. Workers living in attached homes and multifamily buildings are also less likely to commute by private vehicle than workers living in detached single-family homes. Although somewhat of a crude proxy for location within an urban area, this finding suggests that workers living in more central locations with higher neighborhood densities are more likely to get to work by transit or active modes than those living in more suburban neighborhoods.

There are also several notable differences in the relationship between urban form and commute mode choice. At the metropolitan scale, jobs-population imbalance and jobs-land imbalance are statistically associated with mode choice in Mexico but not in the US. In Mexico, this finding suggests that more diverse land uses and more monocentric urban form lend themselves to greater use of transit and active modes. In the US, these features do not appear to covary with mode choice at the metropolitan scale, though the literature suggests that land use diversity likely relates to mode choice at the neighborhood level.

Another notable difference is that population density is significantly correlated with workers choosing active modes over private vehicles in the US, but not in Mexico. In Mexico, utilitarian walking and cycling occur frequently in suburban and rural environments and may be less responsive to differences in metropolitan form. Nevertheless, active commuting does decrease in urban areas with more roadway per capita. Finally, living in an apartment or an attached home has a similar relationship to commute choice in Mexico, but parameter estimates for living in an apartment are nearly twice as strong as parameter estimates for living in an attached home in the US. This may suggest that the most central locations are particularly important for commuter mode choice in US cities. Since housing type corresponds differently to different neighborhood types across and within national and metropolitan boundaries, however, results should be interpreted with caution. For example, many of Mexico City's suburban neighborhoods are as dense and diverse as more centrally located ones (Guerra 2014b; 2014a).

6.3.3. Automobile availability

Workers with a private vehicle in the household are less likely to commute by transit or active modes than workers without a private vehicle in the US and Mexico. Including controls for vehicle availability tends to reduce the strength and statistical significance of socioeconomic predictors such as income and educational attainment. For example, including vehicle availability in the Mexico models roughly halves the strength of the relationship between household income and the probability of commuting by car instead of transit from -.600 (Model 1) to -.307 (Model 2.) In terms of urban form, the strength of the predictor variables remains relatively consistent, with no parameter estimates changing by more than a standard error after including vehicle availability. Wealthier and better educated commuters are more likely to have access to a private car, but the relationship between metropolitan measures of urban form and commute patterns appear to be generally consistent regardless of car availability. In the US a similar trend holds between housing type and commute patterns, although the strength of the relationship between commute mode housing type weakens substantially and significantly in Mexico after including vehicle availability.

For example, a typical Mexican commuter in an apartment has 50% higher odds of commuting by transit instead of car relative to a typical commuter in a single-family home (Model 1). Including vehicle availability weakens the strength of this relationship to 18% higher odds (Model 2.)

6.4. The strength of the relationship between urban form and commute mode choice

To better understand the relative and absolute strength of the relationships between measures of urban form and commuting behavior in the US and Mexico, we simulate a series of behavioral responses to changes in urban form based on our model results.

6.4.1. Elasticity estimates

Table 6.4 presents a series of elasticity estimates generated by increasing the values of continuous predictor values by 10% and estimating the sample-weighted shifts in commuters' average probability of commuting by private vehicle, transit, or active modes. We focus on three main takeaways about the absolute and relative strength of urban form in large urban areas in the US and Mexico.

Table 4 Elasticity with respect to the probability of commuting to work by private vehicle

	Mexico			US		
Variable	Private vehicle	Active mode	Transit	Private vehicle	Active mode	Transit
Monthly household income	0.42	-0.31	-0.13	0.01	-0.22	
Population density	-0.20	-	0.21	-0.12	0.29	0.50
Jobs-population imbalance	0.19	-0.39	-	-	-	-
Jobs-area imbalance	-1.59	0.46	0.83	-	-	-
Roadway per capita	0.43	-0.48	-0.11	0.05		-0.86
Share of road length by arterial	-	-	-	0.17	-0.83	-1.44

Notes: The table only includes elasticities of variables with statistically significant parameter estimates at the 95% confidence level. Estimates based on model (1) and (3) that do not control for vehicle availability.

First, urban form is a relatively strong, though not always consistent, predictor of commute mode choice and more strongly associated with mode choice than household income in both the US and Mexico. In Mexico, a doubling of household income is associated with an average 42% increase in commuters' probability of commuting by car. A similar strength relationship exists with the amount of roadway per capita and the collective relationship of the other four statistically significant urban form variables. In the US, a doubling of household income is associated with a paltry 1% increase in the average probability of commuting by private vehicle. This is a substantially weaker relationship than any of the three measures of urban form associated with commuter mode choice. In a country, where most people commute to work by car, regardless of income, metropolitan urban form appears to matter a great deal more than income.

Second, there are some substantial differences in the strength and statistical significance of urban form variables in the US and Mexico. The concentration of jobs appears particularly strongly correlated with commute patterns in Mexico but not in the US. Similarly, the share of the road network that is an arterial road is strongly associated with commute patterns in the US but not in Mexico. Only the relationships between population density, roadway per capita, and the probability of commuting by transit or active modes appear to be generally consistent across the models. This finding suggests care be taken when generalizing results from one context to another. Neither the strength nor the statistical significance of predictor variables holds across our national samples even if the results point to the general finding that denser urban areas with less roadway tend to have less commuting by private vehicle.

Third, elasticity estimates depend substantially on the share of commuters choosing a mode and are not likely to be consistent across contexts or even modes. This is most apparent in the US sample where most commuters get to work by private vehicle. Although a doubling of residential densities in a metropolitan area corresponds with a 50% higher probability of commuting by transit and a 29% higher probability of commuting by active modes, this corresponds with a much weaker 12% decrease in the probability of commuting by private vehicle. In the case of income, although higher incomes are strongly related to a decreased probability of commuting by active modes (elasticity of -.22), the probability of commuting by active modes is so low that the relationship to the probability of commuting by private vehicle is extremely weak (elasticity of 0.01). In Mexico, by contrast changes in income and urban form are relatively strongly and consistently associated with shifts in the probability of commuting by different modes. This suggests that aggregate mode share will be much more responsive to shifts in policy or other external factors in Mexico than in the US.

6.4.2 Commute mode choice across urban areas

In order to examine the collective predictive strength of urban form on commuter mode choice, we simulate moving our sample of residents to different urban areas and predicting aggregate commute share in those environments. Table 6.5 predicts aggregate mode share to work if we simulate the entire sample living in a car-friendly, average, and car-unfriendly urban area. In the US, these urban areas correspond to metropolitan Knoxville, Baltimore, and New York. Notably, these simulations leave survey respondents in their existing housing types and thus may underestimate the sum-total predictive power of urban form since New York, for example, has a much higher share of residents living in apartments and row homes than the rest of the country. Nevertheless, moving the entire sample from an average urban area like Baltimore to New York results in a substantial shift in car commuting from 93.2% to 69.7% of total commutes. The decrease comes primarily from a large shift in transit use from 3.9% to 25.0% of the total. This simulated shift provides a counterpoint to findings that individual socio-economic factors play a larger role than land use in determining commute behavior in US contexts (Boarnet and Crane 2001; Ewing et al. 2015; S. Handy, Cao, and Mokhtarian 2006). Residents of metropolitan New York, San Francisco, Chicago, Boston, and Philadelphia do not commute differently from the rest of the US because they are substantially different people but because they live in urban areas with substantially different urban form. Outside of the outlier metropolitan areas that are apparent in Figure 1's boxplot, however, commuter mode share budges only slightly. Moving from an average urban form, like metropolitan Baltimore, to a particularly car-friendly one, like metropolitan Knoxville, results in only a three-percentage point decrease in private vehicle commuting. Across most US metropolitan areas, therefore, socio-economic factors do appear to have a much stronger relationship with commuting than does urban form.

Table 6.5 Simulated mode share based on assigning population sample to specific urban areas

Data Sample	***Urban type***	***Urban example***	***Private vehicle***	***Transit***	***Active modes***
US population	Car friendly	Knoxville, TN	96.40%	1.50%	2.10%
	Average	Baltimore-Columbia-Towson, MD	93.20%	3.90%	2.80%
	Car unfriendly	New York-Newark-Jersey City, NY-NJ-PA	69.70%	25.00%	5.30%
Mexican population	Car friendly	La Paz	37.10%	42.20%	20.70%
	Average	Querétaro	32.10%	48.30%	19.60%
	Car unfriendly	Valle de México	20.80%	57.00%	22.20%

Notes: The estimations are based on Model (1) and (3) estimates that do not control for auto ownership.

In Mexico, we predict the results of shifting the entire data sample from a typical urban area, like Queretaro, to a car-friendly (La Paz) or car-unfriendly (Mexico City) one. As in the US, most of the shift comes from substitution between transit and car and the predicted commute shift from moving the sample from an average urban area to the least car-friendly one is large. Moving the sample from Queretaro to Mexico City results in a 35% (eleven percentage point) drop in commuting by private vehicle. Unlike in the US, urban form appears to continue to play a relatively strong role in predicting commute patterns in more car-friendly urban areas as well. Moving the sample from Queretaro to La Paz corresponds with 16% drop in private vehicle commuting. This is unsurprising since measures of urban form and commute mode share are much more normally distributed than in the US, where just a handful of metropolitan areas account for most transit and walking commutes. Another difference with the US is that car-friendly urban form does not appear as systematically associated with active modes in Mexico's urban areas. Roughly a fifth of the sample commutes by foot in any of the three metropolitan areas, suggesting that socioeconomic characteristics are particularly important for this mode in urban Mexico.

Table 6.6 presents the results of a similar simulation, but we now take each national sample and simulate moving them to urban areas on the other side of the border. To account for differences in the size of urban areas, we weight the probability of assignment to an urban area by population size. For example, a Mexican-survey respondent has a 2.2% chance of getting assigned to greater Boston, which has 2.2% of the total population in the US's hundred largest metropolitan areas. The substantial differences in urban form across the two countries result in substantial differences in predicted commute patterns for both Mexican and US urban residents. Again, this finding suggests that urban form has a relatively important role to play in predicting overall commute patterns. Although Mexican commuters certainly drive less because they have less income, our models predict a massive shift in private-vehicle commuting from 27.7% to 83.3% from moving Mexican residents to US urban areas. Similarly, although US commuters remain substantially wealthier than Mexico commuters, our models predict a fivefold increase in aggregate transit use from moving them to Mexico's urban areas. These results suggest that the US's low densities and substantial road networks contribute substantially to the country's high rates of driving in large urban areas. These differences in urban form across the border are often quite stark. For example, the hundred largest urban areas in the US have nearly ten times as much roadway per capita on average as the hundred largest urban areas in Mexico.

Table 6.6 Predicted commute mode share based on actual and simulated home urban area

Data sample	Urban form	Private vehicle	Transit	Active modes
US population	US cities	89.80%	7.10%	3.10%
	Mexican cities	64.10%	31.70%	4.20%
Mexican population	US cities	83.30%	14.40%	2.30%
	Mexican cities	27.70%	49.30%	22.90%

Notes: The estimations are based on Model (1) and (3) estimates that do not control for auto ownership.

Another notable finding is the shift in active transportation across the two data samples. In the US, where walking and biking represent a relatively niche commuting mode, shifting the population to Mexico's urban areas only increases the share of active commutes from 3.1% to 4.2%. In Mexico, where shifting from the most to the least car-friendly urban area barely affected predicted active commute mode share, shifting the population to US urban areas results in a massive decline in active commute share from 22.9% to 2.3%. The differences in roadway per capita drives this result. Changing just this one variable results in active transportation mode share dropping to just 4.4% of all commutes. Despite the finding that Mexico's active commuters are unresponsive to shifts in urban form across Mexico's urban areas, this general finding does not hold when assigning residents to the US's much less pedestrian-friendly urban areas.

6.5 Conclusion

In this chapter, we examined empirical relationships between commuters' mode choice, metropolitan urban form, and socioeconomic attributes for a five-million-respondent sample representing roughly two-thirds and four-fifths of all work commuters in the US and Mexico. Focusing on how relationships vary across the border, we found several consistent takeaways with regards to urban form. In both the US and Mexico, urban residents living in housing types associated with more centrally located housing in more densely populated urban areas with less roadway are less likely to commute by car than similar residents in other housing types and other urban areas. Moreover, the strength of these relationship tends to be as strong or stronger than relationships to income or other household level attributes. Consistent with the existing literature, higher income, higher educational attainment, smaller household sizes, and greater automobile availability tended to be associated with a higher probability of commuting by private vehicle. Including automobile availability in models tended to attenuate the relationships between commuting and associated variables, like household income or educational attainment, but have less of an influence on the strength of relationships between housing type, urban form, and commute mode.

We also found several important differences across urban areas on either side of the US-Mexico border. Notably differences in socioeconomic attributes, urban form, and commute patterns have important implications for elasticity estimates. In particular, the US's high rates of driving and generally car-friendly urban form mean that even dramatic shifts in urban form or income resulted in only small predicted changes in the probability of commuting by car. From this finding, we draw three primary inferences for research into the relationship between urban form and travel behavior. First, despite being a convenient way summarize findings for meta-analyses (Ewing and Cervero 2010; Stevens 2017), elasticities are not necessarily comparable across places, particularly where there are substantial differences in size and distribution of the independent and dependent variables. For example, the estimated income-elasticity with respect to commuting by private vehicle is forty times stronger in Mexico than in the US. Second, despite a literature dominated by findings form US cities, elasticities estimated from US data are unlikely to hold outside of the US, where the distances and share of trips accomplished by private vehicle are unusually high. Even in the largest urban areas, which tend to be the densest and best served by transit, 90% of US commuters use private vehicles to get work. This share barely budges by income group or urban form in all but the most densely populated metropolitan areas. Third, there remains a need for studies into the strength and direction of relationships between urban form and travel behavior from a wider variety of contexts. Academic understanding of the relationship between socioeconomic factors, urban form, and travel behavior is disproportionately weighted by findings from an extreme outlier, the United States.

In addition to the magnitude of elasticity estimates, we found several contextual differences in results from the US and Mexico. For example, women are more likely than men to commute by private vehicle in US urban areas, but substantially less likely in Mexico's urban areas. Manufacturing workers are more likely to use transit than service workers in Mexico but less likely in the US. In terms of urban form, jobs-population imbalance and jobs-land imbalance are statistically associated with mode choice in Mexico but not in the US. Overall these results show that contextual differences likely have an important role in shaping relationships between socioeconomic factors, urban form, and travel behavior. Again, this suggests a need for great care when applying results for one context, such as the US, to another, such as Mexico.

In terms of public policy, we generally find that denser urban areas with less roadway are more likely to have a higher share of workers commuting by transit or active modes. While these relationships are relatively strong, implications for public policy are more limited, particularly in the United States, where just a handful metropolitan areas contain most of the transit and active commuters. Neither Knoxville nor Baltimore are likely to become much more like New York or San Francisco in terms of urban form. Moreover, the herculean policy efforts that would be needed to shift Knoxville's urban form to resemble Baltimore's would likely only have a small impact on overall commute mode share. In Mexico, making La Paz a bit more like Queretaro in terms of urban form, appears less of a physical challenge and more likely to result in greater shifts in mode share. Perhaps the most notable policy takeaway is that shifting Mexico's urban form to more like US urban form will likely result in substantial losses in the share of workers commuting by transit or non-motorized modes, despite Mexico's lower household incomes. In this context, it is particularly worrisome that 80% to 90% of federal and state transportation spending goes to road investments in Mexico's largest urban areas and only 7% to 11% of investments go to transit, pedestrian, or cycling investments (ITDP 2017).

6.5.1. Limitations and areas for future research

This chapter relied on two large national datasets with limited spatial resolution in order to collect consistent data on commuter behavior in two different national contexts. We only know what urban area a commuter lives within, but do not know where they reside or work within that urban area. As a result, our models do not include variables related to commuters' local built environments or features, like travel cost or time, that are associated with different commute modes. Both variables are commonly included in studies of the relationship between urban form and travel behavior. While our study has offered insight into how commute patterns and metropolitan urban form vary across national contexts, we have little to say about the importance of local built environments, beyond housing type as a proxy, or the role of relative travel times and costs by different modes. Future research that can address these limitations across national contexts would make an important contribution to the literature and understanding of how the relationships between urban form and travel behavior vary across national contexts.

Chapter 7. Commute patterns of the working poor

Abstract: This chapter examines the how urban form, housing type, and socioeconomic factors covary with individuals' commute mode choice and commute times for 1.2 million low-income workers in the US and Mexico. We find many common relationships on each side of the border, despite substantial socioeconomic and urban differences across the samples. For example, low-income workers with higher incomes and higher educational attainment are more likely to drive to work and less likely to use active modes. We also find that urban form and road networks are strongly and significantly associated with low-income commuter mode choice and travel time. Collectively the statistically significant measures of urban form and transportation have about a five times stronger relationship to the probability of driving to work by car than does income in both the US and Mexico. In terms of public policy, we find that efforts to reduce driving or promote compact development are more likely to reduce driving and more likely to be pro-poor in Mexico than in the US. High rates of driving and auto-oriented urban form make policies to reduce driving particularly likely to be regressive in US metropolitan areas.

7.1 Introduction

Access to work is critical for finding and keeping income-earning opportunities. With households around the world spending an average of half of their earnings on housing and transportation, accessibility may be the most important urban resource (Duranton and Guerra 2016). Low-income residents, who have less money to spend on housing and transportation, are generally least able to choose the housing or transportation options that provide the best access to work and other opportunities (El-Geneidy et al. 2016). Local and national governments, therefore, have an incentive and arguably a moral obligation to improve access to employment for low-income households. For a review of the transportation justice and equity literature, see (Beiler and Mohammed 2016; Cui et al. 2019; Deboosere and El-Geneidy 2018; Foth, Manaugh, and El-Geneidy 2013; Bocarejo and Oviedo 2012).

In this chapter, we examine how socioeconomic factors, urban form, road supply, and housing type (a proxy for local built environments) covary with individuals' commute mode choice and average one-way commute time for 1.2 million low-income workers in the hundred largest urban areas in each of the United States and Mexico. We emphasize how predictors of commute mode choice differ in the two countries and what these differences mean for public policies to support low-income commuters in each country. Better understanding the commute patterns of low-income residents, and how these patterns relate to demographic profiles, urban structure, and transportation supply can help inform public policies to improve commutes for low-income workers.

We emphasize three specific contributions to the existing literature. First, we add another individual-level analysis of the determinants of commuter mode choice and commute time for low-income workers. While there is a substantial literature on the relationship between urban form, socioeconomic factors, and daily commutes (for a review, see Horner, 2004; Lin et al., 2015), few studies focus explicitly on low-income households or commuters (Hu and Schneider 2017; Khattak, Amerlynck, and Quercia 2000; Morency et al. 2011; Shen 2000).

Second, due to substantial differences in households' socioeconomic profiles and the urban form of metropolitan areas in the US and Mexico, our study offers insight into the nature of the relationship between socioeconomic variables, urban form, and travel behavior of low-income commuters in dramatically different settings. In our sample, Mexico's poorest fifth of workers earn twelve times less than their US counterparts. Although low-income commuters in the US are more likely than wealthier commuters to live in high-density urban centers served by convenient public transit systems (Hess 2005; Hu 2015; Hu and Wang 2017; Shen 1998), their Mexican counterparts live in urban areas that are nearly four times denser and have substantially better transit service. If relationships between income, urban form, and commute patterns are consistent across urban areas and commuters in these two substantially different contexts, then they are likely consistent across a variety of additional contexts. Where relationships are inconsistent, findings may provide insight into how context helps to shape relationships between urban form, commuters, and commute patterns.

Third, and finally, by providing a consistent analysis across two substantially different contexts, our study helps shed light on the transferability of transportation and land-use policies across national boundaries. In the United States, where sprawling cities and suburbs tend to have long trip distances and absent or unreliable transit services, most poor commuters rely on cars (Blumenberg and Thomas 2014; Boschmann 2011; Giuliano 2005). Those without cars tend to move to job-rich areas with better public transit (Glaeser, Kahn, and Rappaport 2008) or borrow cars from neighbors or friends (Blumenberg and Smart 2014; Lovejoy and Handy 2011; Rogalsky

2010). In this context, providing access to cars may be a particularly important public policy for low-income workers outside of urban centers.

In Latin American and Asian cities, by contrast, many low-income workers live far from urban centers and face long, expensive transit commutes to major job centers, which tend to be centrally located (Day and Cervero 2010; Duren 2018; Fan, Allen, and Sun 2014; Gilbert and De Jong 2015; Guerra 2017b; Guerra et al. 2018b; Guzman and Oviedo 2018; D. Hernandez 2018; D. O. Hernandez and Dávila 2016; Zhou, Wu, and Cheng 2013). Others work in the informal retail economy in small local businesses or street vending in their homes or nearby (Motte et al. 2016; Suárez, Murata, and Delgado 2016; Suárez and Delgado 2009), find housing in job-rich urban centers (Li and Zhao 2018), or rely on inexpensive motorcycles (Ratanawaraha and Chalermpong 2016; Shirgaokar 2016) to save commute time and costs. In this context, decentralizing employment from job-rich areas in central locations to subcenters throughout metropolitan areas or facilitating home-businesses could be particularly relevant.

The remaining parts of this chapter are organized as follows: Section 7.2 summarizes the data, variables, and methods in the study. Section 7.3 and 7.4 demonstrate the regression results. Section 7.5 concludes with a discussion of implications for future studies and public policy.

7.2 Data and research approach

We predict commute mode choice and commute times of low-income commuters as a function of metropolitan urban form, road supply, and the individual attributes of commuters in the 100 largest urban areas in both the US and Mexico. Our final data includes the poorest fifth of commuters in each urban area to account for relative differences in purchasing power and costs of living across countries and urban areas. We also estimate models on the bottom fifth of all workers by country regardless of the urban area and on workers living in households below the poverty line, as defined by US Department of Health and Human Services (2019) and Mexico's National Council for the Evaluation of Social Development Policy (CONEVAL 2018)[i]. Approximately a quarter of Mexican workers and one-twentieth of US workers in our samples lived in households below the national poverty line. In the US, the hundred largest urban areas are the 100 most populous metropolitan statistical areas. In Mexico, the urban areas include all 59 of the country's metropolitan areas and the 41 next largest officially designated urban areas (CONAPO 2018).

7.2.2. Data summary

Table 7.1 provides descriptive statistics about the commutes, demographics, household attributes, and urban areas of residence for 1.2 million low-income workers in the US and Mexico. There is substantial variation in commutes across the two samples. In the US, for example, the car dominates the travel of low-income workers. Fully 80% of the sample commutes to work by private vehicle compared to just 13% in Mexico. The plurality of Mexicans in our sample commutes by transit (44%) with another 30% commuting by active modes and 13% working from home. Just one in ten low-income US commuters in our sample commutes by transit.

US commuters also tend to have shorter average commute times than Mexican ones. Forty percent of the US sample has a typical commute that lasts 15 minutes or less, compared to 29% for the Mexico sample. One percent of the US sample and 3% of the Mexico sample have commutes that last two hours or longer. Mode share appears to explain much of this difference. Mexicans commuting by car have similar travel times to US commuters, though Americans commuting by transit tend to have much longer commutes than Mexicans commuting by transit.

Table 7.1 Descriptive statistics of the commutes, demographic and household attributes, and metropolitan areas of the bottom income-quintile of commuters in the 100 largest urban areas in the US and Mexico.

	United States (N=686947)		**Mexico(N=532139)**	
	Average	**Std. Dev.**	**Average**	**Std. Dev.**
Commute mode				
Transit	0.10		0.44	
Private vehicle	0.80		0.13	
Active travel	0.05		0.30	
Work at home	0.04		0.13	
Commute time[1]				
<15 min	0.40		0.29	
15-30 min	0.37		0.34	
30-60 min	0.19		0.25	
60-120 min	0.03		0.10	
>120 min	0.01		0.03	
Socio-economic attributes				
Age	41.40	14.90	40.45	14.00
Male	0.47		0.66	
Household income (100 USD per month)	24.32	10.39	4.00	1.62
Household size	2.63	1.56	3.64	1.72

Housing type				
Single-family	0.43		0.71	
Single-family attached	0.08		0.21	
Apartment	0.44		0.07	
Others	0.05		0.01	
Maximum education attainment				
Secondary	0.12		0.37	
High school	0.55		0.19	
College	0.28		0.08	
Occupation				
Agriculture	0.01		0.10	
Manufacturing	0.23		0.10	
Service	0.77		0.81	
Urban form				
Population density (100s per hectare)	0.29	0.31	0.99	0.40
Jobs-housing balance	0.48	0.05	0.23	0.08
Jobs-area balance	0.39	0.08	0.47	0.04
Transport supply				
Roads (meters) per capita	15.77	8.69	2.57	0.99
Share of the arterials	0.09	0.02	0.12	0.04
Share of highways	0.13	0.03	0.08	0.02
Share of the local roads	0.78	0.04	0.80	0.04

1. Excludes workers who worked from home

The two national samples also vary socioeconomically. US commuters tend to live in households that are wealthier and smaller than those in Mexico. Accounting for purchasing power parity, US commuters' households make $2432 per month on average compared to $400 dollars per month in Mexico. The US sample is also relatively more educated than the Mexico sample. More than a third of low-income Mexican workers' highest educational attainment is middle school compared to just one in ten in the US. Nearly 30% of the US sample has a college degree or higher, compared to 8% in Mexico.

Relative to US commuters, low-income Mexican commuters live in substantially denser urban areas with more concentrated job centers, less roadway per capita, and a more balanced distribution of jobs and residents. For example, the average length of roads per capita in the US is 15.77 meters, compared to 2.57 meters in Mexico. Within urban areas, there are also substantial differences in where low-income workers tend to live. Most (71%) Mexican low-income workers live in single-family houses. In comparison, the plurality (44%) of low-income US workers live in apartments with a similar share (43%) in single-family houses. Only 7% of low-income workers live in apartments or condos in our Mexico sample.

7.2.1 Model specifications

We estimate multinomial logistic models of mode choice and ordered logit models of categories of commute time in R (R Core Team 2018), using the mlogit (Croissant 2019) and lrm (Harrell 2019) packages. In both sets of models, socioeconomic and household-level attributes vary by the commuter, while measures of urban form vary by urban area. This general data organization is typical in studies of urban form and travel behavior across multiple cities in one or more countries (Bento et al. 2005; Giuliano and Dargay 2006a; Guerra et al. 2018b; Sun et al. 2017; L. Yang et al. 2017). To account for correlated error terms within urban areas, we estimate Liang and Zeger (1986) clustered standard errors.

We combine reported travel modes into four consistent categories across the two national censuses: private vehicle (including drivers and passengers of cars, trucks, vans, and motorcycles), transit (including metro, bus rapid transit, light rail, trolley, subway, worker shuttles, and taxicabs), active travel (walking or cycling), and working from home. We exclude other and unreported modes of travel, which account for less than 1% of commutes in both countries. Both censuses ask respondents to report the most commonly used commute mode. Driving is chosen as the reference category. We also estimate average individual elasticities using sample enumeration (Ben-Akiva and Lerman 1985) to account for sample weights and provide consistent estimates of the relationship between urban form, income, and commute mode choice across the two data samples. We also estimated models of commute mode choice that control for household vehicle availability (available upon request). Including vehicle availability tends to weaken the relationship between income, some measures of urban form, and commute mode choice but does not alter any of the main findings.

For the ordered logit models, we pool commute times into the five most disaggregate but consistent categories: up to 15 minutes; 16-30 minutes; 31 minutes to an hour; 61-120 minutes; and more than two hours.

7.3. Predictors of mode choice

Table 7.2 presents the results of the mode choice models. Parameter estimates have direct interpretations in terms of utility and, after taking the exponent, as odds ratios. mode. For example, each additional \$100 per month in household income is associated with a 0.196 reduction in the utility of walking or biking to work in Mexico. For an average commuter this corresponds with an 18% reduction in the odds of commuting by an active mode instead of car. Since the average commuter varies so much in the two countries and utility is not directly measured, the magnitude of parameter estimates from the two samples are not directly comparable. We provide comparable elasticity estimates in next section of this chapter.

Table 7.2 Multinomial regression of the commute mode choice (Reference group: private vehicle)

	Model 1-US			**Model 3-Mexico**		
	Transit	Active travel	Work at home	Transit	Active travel	Work at home
Socio-economic attributes						
Age	-0.018***	-0.063***	0.040***	-0.045***	-0.074***	-0.033***
	(0.005)	(0.005)	(0.003)	(0.002)	(0.005)	(0.006)
Age squared/1000	0.134*	0.609***	-0.126***	0.305***	0.686***	0.565***
	(0.054)	(0.053)	(0.032)	(0.027)	(0.045)	(0.060)
Male	-0.101***	0.371***	0.087**	-0.724***	-0.630***	-1.130***
	(0.031)	(0.059)	(0.030)	(0.034)	(0.078)	(0.032)
Household income (100 USD per month)	-0.008	-0.024***	-0.021***	-0.024	-0.196***	-0.289***
	(0.004)	(0.002)	(0.001)	(0.016)	(0.013)	(0.019)
Household size	-0.008	-0.008	0.047***	-0.013*	0.007	-0.013
	(0.009)	(0.031)	(0.008)	(0.005)	(0.007)	(0.008)
Maximum educational attainment (reference group: less than middle school)						
Middle school	-0.08	0.013	0.127*	-0.213***	-0.537***	-0.290***
	(0.073)	(0.066)	(0.056)	(0.020)	(0.025)	(0.029)
High school	-0.414***	-0.328***	0.141*	-0.569***	-1.195***	-0.709***
	(0.088)	(0.075)	(0.064)	(0.038)	(0.037)	(0.043)
College and above	-0.527***	-0.281**	0.649***	-1.455***	-2.428***	-1.524**
	(0.115)	(0.093)	(0.071)	(0.065)	(0.059)	(0.055)
Occupation (reference group: agriculture)						
Manufacturing	0.089	-0.492***	-0.620***	1.236***	-0.481***	0.660***
	(0.141)	(0.145)	(0.154)	(0.158)	(0.124)	(0.113)
Service	0.603***	0.146	0.142	1.034***	-0.577***	0.315***

	(0.159)	(0.140)	(0.151)	(0.122)	(0.107)	(0.110)
Urban form						
Population density (100s per hectare)	1.917***	1.652***	0.683***	0.344*	-0.025	0.062
	(0.288)	(0.190)	(0.134)	(0.137)	(0.142)	(0.136)
Jobs-housing imbalance (0-100)	-0.011	-0.008	0.002	-0.005	-0.021***	-0.010*
	(0.020)	(0.014)	(0.008)	(0.005)	(0.006)	(0.005)
Jobs-area imbalance (0-100)	0.009	-0.011	0.002	0.057***	0.051***	0.061***
	(0.012)	(0.008)	(0.005)	(0.011)	(0.013)	(0.011)
Housing type (reference group: single-family detached)						
Attached single-family	0.940***	0.532***	-0.184***	0.274***	0.369***	0.145***
	(0.158)	(0.084)	(0.025)	(0.047)	(0.031)	(0.032)
Apartment/Condo	1.273***	1.044***	-0.223***	0.429***	0.325***	-0.242***
	(0.131)	(0.089)	(0.064)	(0.048)	(0.056)	(0.045)
Others	-0.436***	0.057	-0.355***	0.043	0.136**	0.052
	(0.134)	(0.060)	(0.043)	(0.053)	(0.051)	(0.064)
Transport supply						
Roads (meters) per capita	-0.041**	-0.005	-0.012**	-0.191***	-0.325***	-0.284***
	(0.014)	(0.005)	(0.004)	(0.044)	(0.060)	(0.050)
Share of arterials*100	-0.090*	-0.091**	-0.063***	-0.003	-0.011	0.004
	(0.035)	(0.029)	(0.017)	(0.011)	(0.013)	(0.012)
Share of the highways*100	0.011	0.021	-0.023**	0.005	-0.002	-0.02
	(0.023)	(0.011)	(0.008)	(0.017)	(0.021)	(0.016)
Intercept	-1.548	-0.334	-3.680***	0.046	3.976***	0.443
	(1.328)	(0.758)	(0.291)	(0.581)	(0.736)	(0.583)
Observations	686947			532139		
Log Likelihood	-424681.6			-605526		

Note: * p<0.05, ** p<0.01, *** p<0.001. All clustered standard errors in parentheses.

Higher household income and educational attainment are associated with a higher probability of commuting by car in both countries. Income also appears less strongly associated with switching from transit to car than switching from non-motorized modes or from working at home to car for the bottom quintile income workers in both countries. Educational attainment follows a similar pattern, but with college-educated US workers more likely to work from home relative to workers with less than a secondary school education.

As commuters age in both countries, their probability of commuting to work by car increases and peaks in the mid-50s and 60s relative to active modes and transit. Relative to women, Mexican men in our sample are more likely to choose private vehicles. In the US, men have a higher likelihood than women of choosing an active mode or working from home, but a lower probability of choosing transit.

In terms of employment, there are substantial differences between employment type and commute mode choice in the US and Mexico. For example, service sector workers are less likely to use an active commute mode than agricultural workers in Mexico. Workers in the manufacturing sector are more likely to work from home than agricultural workers. In the US, both relationships go in the opposite direction.

In both countries, higher population density is associated with a lower probability of commuting by car. For an average US commuter, a 100-person increase in people per hectare is associated with a statistically significant 1.917 increase in the utility of commuting by transit, 1.652 increase for active modes, and 0.683 increase for working for home. In Mexico, higher population density is associated with statistically significant increases in transit use, but not active modes or working from home. In the US, no other measure of urban form is significantly associated with mode choice with anything close to 95% confidence. In Mexico, by contrast, commuters in urban areas with less balanced jobs and population (a GINI coefficient that approaches one) are less likely to use active modes or to work from home. They are also less likely to drive in urban areas where jobs are highly clustered in census tracts as opposed to geographically dispersed.

Within urban areas in both countries, housing type is significantly associated with mode choice. Commuters living in single family homes are more likely to drive than take transit or an active transportation mode relative to commuters living in apartments or attached houses. The effect sizes are also generally as strong or stronger than the effect sizes for other qualitative variables, including gender, educational attainment, and occupation. Roadway per capita is positively associated with driving in both countries, but the shares of different types of roadways are only significantly related to mode choice in the US. In general, more roadway and a higher share of arterials are associated with more driving.

7.3.1. Comparable estimates of the relationship between mode choice, income, and urban form

Table 7.3 presents quantitatively comparable estimates of the relationship between mode choice, household income, and statistically significant urban form variables in the form of elasticity estimates. For interpretation, a 10% increase in household income corresponds with a roughly 1.3% decrease in US commuters' average probability of commuting by transit, 4.9% decrease in the probability of active commuting, and 4.4% decrease in the probability of working from home. Since such a high share of commuters get to work by private, however, this corresponds to just an 0.7% increase in the probability of driving to work. In Mexico, a corresponding 10% increase in income increases the probability of commuting by car by around 4%. For low-income workers, the relationship between household income and commuting by transit instead of car is not significantly different from zero.

Table 7.3 Mode choice elasticity estimates with respect to selected predictor variables in the US and Mexico

	Driving	Transit	Active travel	Work at home
	US estimates from Table 2			
Household income	0.07	-0.13	-0.49	-0.44
Population density	-0.16	0.40	0.32	0.03
Jobs-housing imbalance	-	-	-	-
Jobs-area balance	-	-	-	-
Roads per capita	0.06	-0.56	-	-0.12
Share of arterials	0.16	-0.62	-0.63	-0.40
Share of highways	-0.02	-	0.27	-0.32
	Mexico estimates from Table 2			
Household income	0.38	-	-0.44	-0.81
Population density	-0.18	0.19	-	-
Jobs-housing imbalance	0.22	-	-0.30	-0.03
Jobs-area balance	-2.04	0.40	0.11	0.60
Roads per capita	0.54	0.03	-0.31	-0.20
Share of arterials	-	-	-	-
Share of highways	-	-	-	-

Note: Elasticity estimates are the average predicted change are the sample-enumerated individuals' average probability of shifting commute mode in response to a change in the predictor variable. Sample weights are applied to the estimates.

In terms of urban form, the estimated strength of the relationship between population density and commuting to work by car is surprisingly consistent. It is also quite a bit stronger than estimates from meta-analyses of the relationship between local population density and commuting by car (Ewing and Cervero 2010; Stevens 2017). Density at the metropolitan scale is associated with where workers live within a metropolitan area but also with the general accessibility of that entire metropolitan area relative to other metropolitan areas. Finally, density is positively correlated with other variables such as transit supply. In Mexico, the decrease in driving with density comes almost entirely from increased transit use. In the US, the decrease comes relatively consistently from increased transit use and active travel modes.

Jobs-housing balance and job concentration are both relatively strongly associated with commute mode choice in urban Mexico but not in the US. In Mexico, a 10% greater balance of jobs and residents corresponds with around a 3% increase in the attractiveness of active travel with most of it coming from decreased attractiveness of driving. Job concentration, as measured by jobs-area balance, is surprisingly strongly correlated with commute patterns. A 10% increase in jobs concentration corresponds with an elastic 20% decrease in the probability of driving with increases in transit, active travel, and working from home. We suspect that the unusual strength of this relationship may correspond to regional travel differences and local transit supply. Including these variables weakens the relationship though it remains substantially strong. Looking at just the raw data, low-income commuters with above the median score of job-area balance commute to work by car 17.8% of the time compared to 9.5% for those below the median.

The roadway network also appears to have a somewhat different relationship with commuting. In the US more roadway per capita is associated with a relatively strong decrease in transit use and a more modest decrease in working from home. As with income, however, these decreases only correspond with a weak shift in driving rates, since the share of workers commuting by car is so high. In Mexico, a 10% increase in roadway per capita corresponds with a relatively strong shift in driving, with most of the shift coming from active travel.

7.4. Predictors of commute time

Table 7.4 presents estimates of the relationship between commute times, socioeconomic variables, and urban form variables with and without including commuter mode choice. Parameter estimates again have interpretations in terms of utility and odds-ratios. For example, each $100 increase in monthly income corresponds 0.5% higher odds of being in a higher commute-time category in the US and Mexico.

Table 7.4 Ordered logistic regression of the commute time categories

	Model 1-US	**Model 2-US**	**Model 3-Mexico**	**Model 4-Mexico**
Travel mode (Reference group: private vehicle)				
Public transit		1.915***		2.380***
		(0.055)		(0.148)
Active travel		-1.170***		-1.009***
		(0.050)		(0.154)
Socio-economic attributes				
Age	0.047***	0.048***	0.022***	0.018***
	(0.002)	(0.001)	(0.006)	(0.005)
Age Squared/1000	-0.516***	-0.515***	-0.276***	-0.209***
	(0.017)	(0.015)	(0.058)	(0.047)
Male	0.119***	0.168***	0.192***	0.352***
	(0.009)	(0.009)	(0.039)	(0.015)
Household monthly income (100s USD)	0.005**	0.005***	0.060***	0.005
	(0.002)	(0.001)	(0.015)	(0.010)
Household size	0.003	0.005	0.024***	0.038***
	(0.005)	(0.004)	(0.004)	(0.004)
Maximum educational attainment (Reference group: less than middle school)				
Middle school	-0.117***	-0.108***	-0.143	-0.155***
	(0.016)	(0.022)	(0.026)	(0.020)
High school	-0.107***	-0.06**	0.021	-0.213***
	(0.019)	(0.019)	(0.074)	(0.051)
College and above	-0.016	0.056**	0.036	-0.144
	(0.019)	(0.021)	(0.142)	(0.099)
Occupation (Reference group: Agriculture)				
Manufacturing	0.153	0.121	0.126	-0.653***

	(0.096)	(0.104)	(0.162)	(0.091)
Service	-0.020	-0.094	0.032	-0.705***
	(0.094)	(0.101)	(0.082)	(0.088)
Housing type (Reference group: Single-family detached)				
Attached single-family	0.074	0.002	-0.079**	-0.061**
	(0.044)	(0.027)	(0.030)	(0.021)
Apartment/Condo	0.001	-0.122***	-0.011	-0.107***
	(0.055)	(0.023)	(0.025)	(0.021)
Others	0.146***	0.158***	-0.041	-0.014
	0.032	(0.028)	(0.025)	(0.029)
Urban form				
Population density (100s per hectare)	0.513***	0.011	0.660***	0.611***
	(0.116)	(0.102)	(0.118)	(0.105)
Jobs-housing balance*100	0.007	0.009	0.006	0.001
	(0.006)	(0.006)	(0.004)	(0.004)
Jobs-area imbalance*100	0.011**	0.010***	0.015**	0.012**
	(0.004)	(0.004)	(0.006)	(0.005)
Transport supply				
Roads (meters) per capita	-0.014***	-0.014***	-0.018	-0.060
	(0.004)	(0.004)	(0.048)	(0.046)
Reference: Share of the local roads				
Share of arterials*100	-0.006	-0.004	-0.005	-0.007
	(0.013)	(0.013)	(0.008)	(0.007)
Share of the highways*100	-0.009	-0.011	0.005	0.003
	(0.007)	(0.006)	(0.011)	(0.011)
Intercepts				
<15|15-30	-1.178*	-1.143***	-1.361**	-1.160
	(0.410)	(0.377)	(0.427)	(0.355)
15-30|30-60	-2.844***	-2.950***	-2.840***	-2.015***
	(0.411)	(0.376)	(0.398)	(0.355)
30-60|60-120	-4.884***	-5.166***	-4.297***	-3.669***
	(0.409)	(0.376)	(0.357)	(0.371)
60-120|>120	-5.940***	-6.253***	-5.989***	-5.426***
	0.413	(0.395)	(0.362)	(0.409)
Observations	659,486	659,486	436,393	436,393
Log Likelihood	-780911	-745081	-600121	-541545

Note: * p<0.05, ** p<0.01, *** p<0.001. All clustered standard errors in parentheses.

In both the US and Mexico, transit commuters tend to have significantly longer duration commutes than drivers. Active commuters have substantially shorter duration commutes. Since active modes tend to be the slowest, this finding relates to shorter travel distances. In terms of socioeconomic attributes, gender, age, and income have the same directional relations with commute time in both countries. Males tend to have longer commute times in both countries. People tend to have longer commute times as they age until around 45 when their commute times tend to decrease. Higher income is associated with higher possibilities of being in a longer commute time category in both countries. These findings hold with and without including commute mode.

Commute times tend to be higher for low income workers in denser cities with more concentrated job centers. In the US, however, higher rates of transit use in denser urban areas explain most of this difference. Increased roadway per capita is associated with shorter duration commutes in the US but not in Mexico. Low-income commuters in apartments tend to have shorter commutes, but only after controlling for mode choice in both the US and Mexico. This suggests that more centrally located workers have shorter commutes than more peripherally located workers using the same modes. Across urban geographies, however, differences in mode share offset these modal differences in travel time. For example, transit users are likelier to have shorter duration commutes in the center than on the periphery. Transit trips, however, tend to be longer duration than driving trips and occur more frequently in central locations with more apartment buildings.

7.5. Concluding remarks

In this chapter, we examine how urban form, housing type, and socioeconomic factors covary with individuals' commute mode choice and commute times for 1.2 million low-income workers in the US and Mexico. We find many common relationships on each side of the border, despite substantial socioeconomic and urban differences across the samples. As expected, low-income workers with higher incomes and higher educational attainment are more likely to drive to work and less likely to use active modes. Perhaps surprisingly, wealthier commuters tend to have longer commutes with and without controls for travel mode. This finding may relate to higher income households selecting into neighborhoods with lower job accessibility, low-income workers making tradeoffs between wages and commute distances, or even multi-worker households making housing location decisions that collectively lead to longer commutes. Whatever the reason, wealthier low-income workers do not appear to use higher income levels to purchase greater accessibility. Despite workers tending to shift from active travel modes at higher incomes, active commuters tend to have the shortest commutes.

Another common finding is that the relationships between urban form and commuting behavior modes are collectively as strong or even stronger than the relationship between household income and commuting. Collectively, the statistically significant measures of urban form and transportation have about a five times stronger relationship to the probability of driving to work by car than does income in both the US and Mexico (Table 3). Across national boundaries, commuters are least likely to drive in dense urban areas with less roadway per capita and a lower share of high capacity roads. Including the role of housing type would only strengthen the relative importance of urban form and the built environment. An average low-income US commuter in an apartment, a proxy for living in a denser and more centrally located neighborhood, is six times more likely to use transit than drive compared to an average commuter in a single-family home. In Mexico, where transit use is common throughout metropolitan areas, the commuter is 40% more likely. We also find that apartment-dwellers have similar or shorter duration commutes, suggesting that a reorientation in affordable housing toward city centers will not only tend to shift lower-income workers out of cars, but also shorten their commutes.

We also find important differences in the direction and magnitude of relationships studied in the US and Mexico. Several of these suggest that contextual differences play an important role in behavioral examples. For example, women commuters are more likely than men to drive in the US, but less likely in Mexico. In the US, low-income workers, especially women, benefit from driving private cars as they expand their spatial access to jobs, reduce work commute times, and conduct flexible trips to food shopping locations (Blumenberg 2004; 2016). Conversely, in Mexico, because low-income communities are dense and have vibrant local retail economies, many women, especially informal workers, commute to their jobs, by walking or using public transport. In both contexts, women tend to have shorter duration commutes. This is partly because female workers, especially those with children, use their social contacts to find local jobs near their homes, as observed by Chapple (Chapple 2001; 2002) in San Francisco, and by (Suárez, Murata, and Delgado 2016) in Mexico. Another notable difference is the strong association between manufacturing work and transit commutes in Mexico. This may relate to geospatial differences in the location of manufacturing, but perhaps more importantly to the higher quality of Mexico's suburb-to-suburb transit services, including worker shuttles provided by factories and other large employers. In terms of urban form, we also found several substantial differences. Job concentration, for example, is perhaps the strongest predictor of commute patterns in Mexico but unassociated with commute choice in the US. Our best explanation is that job concentrations are more highly associated with transit supply in Mexico than in the US, but this general finding merits further examination. Greater roadway per capita is associated with shorter duration commutes in the US but not in Mexico.

Another notable difference is how similar changes in income, urban form, and other predictor variables are likely to influence driving patterns in the US and Mexico. Although a 10% increase in income corresponds with a similar reduction in transit use in both countries, this translates to just a 0.7% increase in private vehicle commutes in the US compared to a 3.8% increase in Mexico. In the US, where 80% of low-income commuters commute by car, workers are substantially less responsive to changes in policy or personal circumstances than in places with lower rates of driving. The flip side is that driving rates for Mexico's commuters might increase extremely rapidly in response to changes in income, urban form, or the distribution of household locations throughout an urban area.

These similarities and differences in the relationship between low-income commuters, urban form, and commute patterns have potentially important implications for public policy. First, we find that urban form, housing location, and transportation investments have relatively strong relationships with commute patterns in two substantially different urban contexts. In some instances, such as promoting jobs-housing balance and more centralized housing locations, public policies appear likely to reduce both driving and commute times. In others, such as promoting density, public policy appears likely to discourage driving, but increase average commute times. Similarly, additional roadway investment will almost certainly encourage driving, but—at least in the US—reduce commute times for low-income workers.

Second, the US's low-income commuters are substantially less responsive in terms of mode choice to changes in circumstance than are Mexican commuters. With its already elevated driving rates, low-density urban form, and substantial roadway networks, there is relatively limited scope for public policy to increase or decrease driving rates for low-income US workers in most urban areas. In Mexico, by contrast, urban policy makers have substantially more influence over travel behavior outcomes. In this respect, Mexico's primary national low-income housing policy, which has concentrated low-to-moderate income households in large single-use peripheral housing developments appears particularly misplaced. Low-income commuters are not only likely to shift to driving, they are likely to have longer and more expensive commutes. Given the low current rates of driving to work, moreover, there is substantial room to increase the total amount of driving in Mexico's already congested urban areas.

Third, our findings suggest that different transportation policies are likely to be more effective at supporting low-income workers and achieving other policy objectives in the US and in Mexico. In the US, public policies that improve the quality of cars or access to cars for low income households are likely to be particularly important. For example, a program that reduces the environmental and out-of-pocket costs of driving for low-income workers, would benefit 80% of low-income commuters and generate environmental benefits from a large share of the population. Given the low elasticities, the program would be unlikely to increase work commutes by much. In Mexico, by contrast, the same policy would benefit relatively few workers and also encourage a stronger behavioral shift toward private. Similarly, improving urban walking and cycling conditions will likely do a lot more to benefit low-income Mexican commuters than US ones.

More generally, urban policies to increase the cost of driving in the are substantially more likely to be regressive in US urban areas than in Mexican ones. The lowest income quintile households spend 30% of their income on car-related expenses in the US, compared to just 3% in Mexico (Bureau of Labor Statistics 2018; INEGI 2018). As such, US policy makers should much more carefully consider the equity implications of policies, such as increases to the gas tax, and consider mitigating harmful social effects. In Mexico, by contrast, policies to raise the cost of driving and use revenues to improve transit and non-motorized infrastructure will tend to be pro-poor.

Chapter 8. Predictors of cycling in US and Mexican urban areas

Abstract: In this chapter, we develop comparable multilevel logistic regressions predicting whether a sample of 5.7 million workers commute by bicycle in the hundred largest urban areas in the US and Mexico. In both contexts, men in relatively poor households are likeliest to cycle. The

similarities in cycling commuters generally stop with these two commonalities, however. The archetypal US bike commuter is a recent college graduate, lives by himself in a centrally located apartment in a moderate-to-high density city, like Portland, OR, and commutes to work in a relatively low-paying service sector job for a college graduate, perhaps at restaurant or not-for-profit. The archetypal Mexican bike commuter, by contrast, is in his mid-thirties, has only a few years of formal education, lives with a large family in a house in the suburbs of a large dense metropolitan area, like Mexico City, and commutes to a relatively low-paying agriculture, construction, or manufacturing job. Local context matters and the most effective public policies to promote urban cycling will almost certainly vary across national borders. For example, our analysis suggests that suburban cycling investments will likely do a lot more to support Mexican cyclists than US ones. Last, we conclude that there is a need for studies that include comparable measures of cycling infrastructure, local built environments, and non-work trips in different national contexts.

8.1. Introduction

There is growing policy interest in promoting bicycling as an affordable, healthy, and sustainable means of transportation in cities and countries around the globe. To better understand how to promote cycling, researchers have identified a wide a range of individual and environmental factors associated with higher cycling rates. Knowing which people in which environments are relatively more likely to cycle can help policy makers decide where to target policies, such as new bicycle lanes, most effectively. For example, if wealthy suburban residents in low-density housing developments are unlikely to cycle, policies to promote cycling will tend to bear less fruit in those types of neighborhoods than in high-density urban environments with less wealthy residents. Based on utility theory, changes in the attractiveness of cycling will have the greatest impact on cycling rates in places where more people are on the edge of choosing whether to cycle. In terms of environmental factors, such as the nature of the built environment, direct changes through zoning ordinances and infrastructure investments can potentially increase or reduce the attractiveness of cycling and thus the probability that residents choose to cycle.

Despite an exponentially increasing amount of cycling research, it is difficult to predict which factors are most likely to increase cycling rates (S. Handy, Wee, and Kroesen 2014) and a confluence of factors, such as infrastructure, supportive land uses, pricing, and educational policies may be necessary to achieve substantial increases in cycling rates (Forsyth and Krizek 2010; Pucher and Buehler 2008; Pucher, Buehler, and Seinen 2011). Moreover, there may be substantial contextual variation in how different factors correlate with cycling and by extension which policies are most likely to increase cycling rates. For example, although women are less likely to cycle than men in most cities and countries (Bopp, Kaczynski, and Besenyi 2012; Cervero et al. 2009; Gómez et al. 2005; Heesch, Sahlqvist, and Garrard 2012; Pucher, Buehler, and Seinen 2011; Pucher and Buehler 2010; Rodríguez and Joo 2004; Singleton and Goddard 2016; Trang, Hong, and Dibley 2012; Winters et al. 2007; Zhao 2014), there is little difference in cycling rates by sex in countries with high overall bicycle use, such as Germany, Denmark, and the Netherlands (Pucher and Buehler 2010). The cycling gender gap appears to diminish with the quality of infrastructure (Garrard, Rose, and Lo 2008; Emond, Tang, and Handy 2009; Pucher and Buehler 2008) and Nielsen et al. (2013) find that women have a statistically higher cycling probability of cycling than men in the Netherlands when controlling for other covariates.

Other individual and household predictors of cycling also vary across studies. Although lower income and lower educational attainment are associated with higher utilitarian cycling in some contexts (Cervero et al. 2009; Cervero and Duncan 2003; Trang, Hong, and Dibley 2012; Zhao 2014), cycling is associated with higher incomes (Dill and Voros 2007; Heesch, Giles-Corti, and Turrell 2014) and relatively wealthy central neighborhoods of wealthy cities in other contexts (Pucher, Buehler, and Seinen 2011). Nielsen et al. (2013) find that cycling probability increases with educational attainment but decreases with income in the Netherlands. Across studies, greater age has also been found to have both positive (Zhao 2014) and negative (Cervero et al. 2009; Moudon et al. 2005) associations with cycling. Car ownership is generally associated with a lower probability of cycling (Cervero et al. 2009; Cervero and Duncan 2003; Moudon et al. 2005; Zhao 2014), but is also substantially determined by income and personal preferences (Small and Verhoef 2007), which may play a particularly important role in choosing to cycle (Dill and McNeil 2016; 2013; Dill and Voros 2007) and certainly vary by geography and social context.

In terms of the natural environment, poor weather (Miranda-Moreno and Nosal 2011; Ahmed, Rose, and Jakob 2013) and presence of sloped terrain (Cervero and Duncan 2003; Cole-Hunter et al. 2015; Ma and Dill 2015; Mateo-Babiano et al. 2016; Rodríguez and Joo 2004) are associated with lower cycling within urban areas. Across urban areas, however, these relationships may not hold. For example, Pucher and Buehler (2006) find that urban form and cycling conditions help explain Canada having much higher cycling rates than the US, despite much colder weather. Similarly, San Francisco's hills, Seattle's rain, and Minneapolis' cold do not prevent those cities from having some of the highest rates of cycling in the US. Moreover, the amount of rain that deters a typical cyclist in wet climates, like Seattle or Ho Chi Minh City, is likely much different than the amount of rain that deters a typical cyclist in drier climates, like San Diego or Mexico City. Buehler and Pucher (2012) do not find a statistically significant relationship between aggregate cycling and annual precipitation or the number of cold and hot days per year across 90 of the largest US cities.

There may also be systematic differences in which built environment factors help predict cycling in different global contexts. For example, in contrast with findings from wealthier contexts (Cervero and Duncan 2003; Moudon et al. 2005; Nielsen et al. 2013; Rodríguez and Joo 2004), several studies from Latin America and Asia have found no association or inverse associations between features typically associated with higher cycling rates, like population density, land use mix, and central urban location (Cervero et al. 2009; Parra et al. 2011; Pérez López and Landin Álvarez 2019; Trang, Hong, and Dibley 2012; Zhao 2014). While utilitarian cycling tends to be associated with urban conditions in the United States and Europe, cycling rates are highest among low-income suburban residents in Vietnamese cities (Trang, Hong, and Dibley 2012) and Mexico City (Pérez López and Landin Álvarez 2019). In a study pooling data from fourteen cities in ten countries, Christiansen et al. (2016) find positive associations between population density, intersection density, land use mix, and the probability of cycling. However, the authors do no present whether the findings from the three Latin American cities differ from findings from Australia, New Zealand, or four additional European countries.

Although partly a function of the built environment, shorter trips to locations where parking or transit are more expensive is generally associated with a higher probability of cycling (Buehler 2012; S. L. Handy and Xing 2011). Finally, the presence of cycling infrastructure is generally associated with higher cycling rates (Dill and Carr 2003; Parker, Gustat, and Rice 2011; Krizek and Johnson 2006; Howard and Burns 2001; Broach, Dill, and Gliebe 2012), but the degree to which cyclists cause cycle lanes or cycle lanes cause cyclists remains unclear.

This chapter examines urban, socioeconomic, and other predictors of bicycling across 5.7 million commuters in the hundred largest urban areas in the US and Mexico. Despite close geographic, social, and historical ties, the US and Mexico have substantially different urban contexts, weather patterns, and populations. For example, US commuters come from households that earn eight times more than Mexican ones after adjusting for purchasing power parity. Mexican commuters live in urban areas, where residents' neighborhoods are three times more densely populated than in the US. Better understanding differences in cycling predictors in such different contexts can help shed light on the relative importance of different factors for promoting cycling and how the effects of cycling policy might vary in different contexts.

The remainder of this chapter is organized as follows. First, we present the data and estimation strategy used to model cycling commutes to work. Next, we present a summary of the study findings with an emphasis on who cycles to work and where commuters are most likely to cycle. Last, we conclude with a summary of the key takeaways, policy implications, limitations, and opportunities for future research.

8.2. Data and research approach

We predict whether commuters cycle to work as a function of metropolitan urban form, road supply, and the individual attributes of commuters in the hundred largest urban areas in the US and Mexico. In addition to data presented in earlier chapters, we rely on NOAA global station climate data on precipitation and the number of degrees that a day's average temperature is above and below 65 degrees Fahrenheit aggregated annually and averaged from 1980 to 2000 (National Oceanic and Atmospheric Administration n.d.). While out of date, these data provide consistent cross-sectional data on annual climate variation across the two hundred urban areas in our study.

8.2.1 Data summary

Table 8.1 provides summary statistics on the demographic attributes, household attributes, and urban areas of cyclists and other commuters in our sample. We exclude workers who worked from home from the sample. On average, urban Mexican workers are nearly eight times more likely to commute to work by bicycle than urban US workers. A higher share of Mexican workers is male, has low educational attainment, and works in manufacturing or agriculture than the share of US workers. Mexican workers also tend to live in poorer households with lower car availability. In terms of geography, urban Mexican workers are more likely to live in single-family homes in much denser and warmer urban areas with less roadway and MRT than their US counterparts. Mexican urban workers also live in urban areas with more concentrated job centers and higher mixes of jobs and residents in Census tracts as measured by Gini coefficients. A Gini coefficient that approaches

100 (on a 0 to 100 scale) for jobs and land area indicates that all jobs are concentrated in a single Census tract that includes a small share of total land area. A Gini coefficient that approaches 100 (on a 0 to 100 scale) for jobs and population indicates that jobs and population are completely segregated across Census tracts.

*Table 8.1 Data summary for cyclist commuters and other commuters in the hundred largest urban areas in Mexico and the US**

	Mexico cyclist	Mexico other		US cyclist	US other
Share of commuters	5.2%	94.8%		0.7%	99.3%
Monthly income (2015 PPP USD)	1005	1504		8672	9169
(St. Dev.)	(1134)	(2083)		(8657)	(8241)
Age	39	38		38	43
(St. Dev.)	(14)	(13)		(13)	(14)
Male	93%	63%		71%	52%
Maximum educational attainment					
-Jr. high school	39%	31%		8%	6%
-High school	15%	24%		32%	44%
-BA or higher	4%	25%		57%	48%
-Less than Jr. high school	43%	21%		3%	3%
Occupation					
-Agriculture/extraction	16%	5%		1%	1%
-Manufacturing/construction/transport	52%	28%		14%	18%
-Missing	0%	1%		0%	0%
-Services/military	32%	67%		86%	81%
Vehicle available to household	27%	49%		78%	95%
Number of people in household	4.88	4.41		2.93	3.13
(St. Dev.)	(2.41)	(2.13)		(1.66)	(1.61)
Housing Type					
-Single family	76%	73%		45%	68%
-Attached single family	19%	16%		9%	7%
-Apartment / Condominium	4%	10%		44%	22%
Other	1%	1%		2%	2%
Population per hectare in residents' Census tracts	92	100		32	29
(St. Dev.)	(38)	(39)		(28)	(31)
Jobs-population Gini (0-100)	21.7	23.6		49.1	48.3
(St. Dev.)	(8.10)	(8.20)		(4.40)	(4.50)
Jobs-land area Gini (0-100)	47	47.1		39.7	38.5
(St. Dev.)	(3.90)	(4.10)		(6.70)	(7.70)
Kilometers of MRT per 100,000 people	1.69	1.76		7.79	7.35
(St. Dev.)	(2.04)	(2.05)		(11.55)	(11.85)
Kilometers of roadway per 1,000 people	1.82	1.80		10.32	105.7
(St. Dev.)	(1.54)	(1.53)		(6.07)	(6.29)
Share arterial	11.5	11.5		8.4	8.9
(St. Dev.)	(4.0)	(3.5)		(2.1)	(2.0)
Share local	80.2	80.4		78.7	77.9
(St. Dev.)	(4.4)	(3.9)		(3.6)	(3.6)

Share highway	8.3	8.1		12.9	13.3
(St. Dev.)	(2.5)	(2.2)		(2.6)	(2.9)
Annual degrees above 65F	1,373	1,321		671	759
(St. Dev.)	(898)	(911)		(577)	(580)
Annual degrees below 65F	315	354		2,072	2,177
(St. Dev.)	(285)	(306)		(1195)	(1153)
Annual precipitation (mm)	1,011	1,058		947	973
(St. Dev.)	(642)	(708)		(384)	(382)
Number of observations	127,683	2,332,697		22,045	3,281,961

*Categorical variables presented as percentage. Continuous variables presented as mean and standard deviation.

In terms of the cyclists, both US and Mexican cyclists are less wealthy on average than their non-cycling compatriots. US cyclists are more likely to have earned at least a bachelor's degree (BA), whereas Mexico's urban cyclists are generally less well-educated than other urban commuters. US cyclists are likelier to live in an apartment building than other US commuters, while Mexican cyclists are less likely to live in an apartment building. In terms of employment, Mexican cyclist are more likely to work in agriculture or manufacturing, while US cyclists are more likely to work in services. Differences between the urban form and weather patterns in urban areas where cyclists reside do not appear to be substantially different from urban areas where non-cyclist commuters reside.

8.2.2. Model specification

Our final model specifications estimate the probability of commuting by bicycle using multilevel logistic regression with random intercepts and random slopes for housing type, vehicle availability, and income by urban area in the lme4 package (Bates et al. 2015) in R (R Core Team 2018). Multilevel specifications allow us to include data that vary at the individual level, such as age and sex, and urban area, such as population density and roadway per capita (Gelman and Hill 2007). We prefer to allow variation in slope by urban area since we expect substantial variation in these variables by type of urban area. For example, car ownership is likely a much stronger predictor of non-cycling in urban areas that are poorly suited to cycling due to long trip distances or poor infrastructure. The relationship between housing type is almost certainly different since there is so much variety in housing stock by urban area and how the type of housing correlates with other unobserved predictors, such as how far a commuter lives from downtown or the quality of local cycling infrastructure. Models that allowed variation in slope and intercept also produced better model fits—as measured by the Akaike information criterion, Bayesian information criteria, and log-likelihood—than models that allowed no multilevel variation or only allowed varying intercepts.

Written formally, the probability of a commuter cycling to work is:

$$y_j = \frac{e^{\beta 0 + \beta_i X_{ij} + \mu_{iz} X_{ij} + \mu_z 0}}{1 + e^{\beta 0 + \beta_i X_{ij} + \mu_{iz} X_{ij} + \mu_z 0}} \quad \text{(eq. 1)}$$

Where:

- y_j is the probability of commuter *j* cycling to work.
- $\beta 0$ is a fixed constant.
- β_i is a vector of fixed parameter estimates for all predictors X_i included in the model.
- X_{ij} is the data value of *i* for each commuter *j*.
- μ_{iz} is the zero-centered, normally distributed random parameter for the subset of parameters β_i that vary by urban area *z* (housing type, income, and car ownership).
- $\mu_z 0$ is the zero-centered, normally distributed random intercept for each urban area.

We also estimated multilevel models that excluded data from New York and from Mexico City, two potential urban outliers. We discuss the small differences that these specifications produce in the findings section, but do not report the full summary tables due to space constraints. All specifications are available upon request. Following Nielsen et al. (2013), we present models that include and exclude car availability for US and Mexican commuters. Although car availability is endogenous to mode choice, including the variable sheds light into how the decision to purchase a car intervenes in relationships between cycling, urban form, and socioeconomic variables.

8.3. Results

Table 8.2 presents the results of the multilevel models predicting whether commuters cycle to work in the hundred largest urban areas in the US and Mexico. Unless explicitly stated otherwise, all text refers to Models 1 and 3, which exclude vehicle availability from the model specifications. While having access to a private vehicle is a strong predictor of mode choice, vehicle access depends also on income, urban form, and personal preference. Continuous and categorical variables have interpretations as odds ratios. For example, in Mexican urban areas an average commuter living in an attached home has about 16% higher odds of cycling than one living in a single-family home. In US urban areas, the corresponding increase in odds is around 48%. Since the prevalence of cycling is so different across samples, however, the strength of odds-ratios are not directly comparable across the US and Mexico models. Switching from a single-family home to an attached-home is associated with a higher percentage point increase in the probability of cycling in Mexico (0.78) than in the US (0.30) for average commuters, despite the higher odds-ratio in the US models. Variables that enter the model non-linearly—income, age, and population density—require additional transformation for easy interpretation, which we provide in the text below.

Table 8.2 Odds-ratios of multilevel binomial logit model predicting the probability of commuting to work by bicycle in the hundred largest urban areas in the US and Mexico (95% confidence intervals in parentheses)

	Mexico		US	
	Model 1 (excludes vehicle)	Model 2 (includes vehicle)	Model 3 (excludes vehicle)	Model 4 (includes vehicle)
Male	6.24***	6.58***	2.55***	2.53***
	(6.21, 6.26)	(6.56, 6.60)	(2.52, 2.58)	(2.50, 2.56)
Age/10	1.09***	1.19***	0.60***	0.60***
	(1.07, 1.12)	(1.16, 1.21)	(0.55, 0.66)	(0.55, 0.66)
Age squared/1000	0.88***	0.83***	1.35***	1.36***
	(0.85, 0.91)	(0.80, 0.85)	(1.28, 1.42)	(1.29, 1.43)
Natural log of monthly income	0.97***	0.98***	0.77***	0.85***
	(0.96, 0.98)	(0.97, 0.99)	(0.72, 0.81)	(0.81, 0.89)
Maximum educational attainment (Reference: Less than junior high school)				
-Junior high school	0.70***	0.74***	0.84***	0.89***
	(0.68, 0.71)	(0.73, 0.76)	(0.75, 0.93)	(0.80, 0.98)
-High school	0.40***	0.47***	0.57***	0.66***
	(0.38, 0.42)	(0.45, 0.48)	(0.49, 0.65)	(0.58, 0.74)
-BA or higher	0.12***	0.17***	0.93+	1.12**
	(0.09, 0.15)	(0.13, 0.20)	(0.85, 1.01)	(1.03, 1.20)
Occupation (Reference: Agriculture)				
-Manufacturing/construction/transport	0.76***	0.74***	0.98***	1.05***
	(0.74, 0.78)	(0.72, 0.76)	(0.79, 1.17)	(0.86, 1.24)
-Services/military	0.43***	0.43***	1.48***	1.53***
	(0.41, 0.45)	(0.41, 0.45)	(1.29, 1.67)	(1.34, 1.72)

Number of people in household	1.02***	1.02***	0.95***	0.97***
	(1.01, 1.02)	(1.02, 1.02)	(0.94, 0.96)	(0.96, 0.98)
Housing type (Reference: Detached single family)				
-Attached single family	1.16***	1.09**	1.48***	1.41***
	(1.10, 1.22)	(1.03, 1.15)	(1.35, 1.60)	(1.29, 1.53)
-Apartment / Condominium	0.75***	0.68***	1.91***	1.59***
	(0.66, 0.85)	(0.59, 0.77)	(1.82, 2.00)	(1.50, 1.68)
-Other	0.93*	0.93*	0.94	0.92
	(0.87, 1.00)	(0.86, 0.99)	(0.78, 1.10)	(0.76, 1.08)
Vehicle available to household		0.43***		0.17***
		(0.36, 0.49)		(0.05, 0.28)
Population per hectare / 100		0.43***		0.17***
		(0.36, 0.49)		(0.05, 0.28)
Population per hectare squared / 10000	0.96*	0.96+	1.08***	1.08***
	(0.92, 1.00)	(0.92, 1.00)	(1.05, 1.11)	(1.05, 1.11)
Jobs-population Gini (0-100)	1.00***	1.00***	0.98***	0.98***
	(0.98, 1.02)	(0.98, 1.02)	(0.95, 1.01)	(0.95, 1.02)
Jobs-land area Gini (0-100)	0.98	0.98	1.01	1.01
	(0.94, 1.03)	(0.94, 1.02)	(0.99, 1.02)	(0.99, 1.03)
Kilometers of MRT per 10000 people	0.03	0.04	0.98	0.99
	(0.00, 6.07)	(0, 8.56)	(.73, 1.31)	(-0.74, 1.33)
Kilometers of roadway per 1000 people	0.82*	0.88	1.00	1.00
	(0.62, 1.02)	(0.68, 1.08)	(0.99, 1.02)	(0.99, 1.02)
Share arterial (0-100)	1.01	1.01	0.89***	0.89***
	(0.96, 1.05)	(0.97, 1.05)	(0.83, 0.95)	(0.82, 0.95)
Share highway (0-100)	0.98	0.98	0.98	0.98
	(0.91, 1.05)	(0.91, 1.06)	(0.95, 1.01)	(0.94, 1.01)
Annual degrees below 65F / 1000	1.15	1.10	1.12	1.14
	(0.92, 1.37)	(0.87, 1.32)	(0.91, 1.33)	(0.93, 1.35)
Annual precipitation (mm)	0.84	0.78+	1.37+	1.35+
	(0.55, 1.13)	(0.49, 1.07)	(1.05, 1.69)	(1.02, 1.67)
Constant	0.85	0.73	0.15	0.28
	(0.07, 11.17)	(0.05, 9.77)	(0.03, 0.77)	(0.05, 1.44)
Observations	2,460,380	2,460,380	3,304,006	3,304,006
Log Likelihood	-403,449.20	-398,174.60	-120,439.30	-117,711.80
Akaike Inf. Crit.	806,976.40	796,441.20	240,956.50	235,515.50
McFadden R-squared	0.196	0.207	0.090	0.111

Notes: + p < 0.1* p < 0.05; ** p < 0.01; *** p < 0.001. Random intercepts and random slopes (income, housing type, and vehicle access) included for the hundred largest urban area in each country.

8.3.1. Who cycles to work more in the US and Mexico?

The probability of cycling to work is statistically significantly associated with lower income and the male gender in the hundred largest urban areas in the US and Mexico. Accounting for income, education, and other factors, men are 2.5 times more likely to cycle than women in the US and a little over 6 times more likely in Mexico. Despite this greater gender imbalance in Mexico's urban cyclists, a slightly higher share of Mexican women commutes to work by bike (0.098%) than the share of US men (0.090%) in our sample. Although a higher share of cyclists are male in Mexico than in the US, a much higher share of women commute by bicycle in Mexico than in the US.

In Mexico, each increase in educational attainment is associated with decreasing odds of cycling. Commuters with a BA, equivalent, or higher degree, are about 90% less likely to cycle than commuters who have not completed secondary school. In the US, by contrast, commuters with a BA are the second most likely to cycle group. They are just 7% less likely to cycle than the small share of US workers who have not completed middle school and this difference is not statistically significant at the 95% confidence level. In the model that controls for vehicle availability, US commutes with a BA have 1.12 times higher odds of commuting by bike than those with less than a junior high school education. Income is more strongly associated with cycling rates in the US than in Mexico in our models. Across the entire sample, reducing income by 10% and predicting the shift in the probability of cycling results in an average 0.03% increase in Mexican cycling and 2.2% increase in US cycling. Allowing variation in parameters by metropolitan area strengthens the relationship between income and US cycling from an odds-ratio 0.84 to the reported 0.77, since cycling tends to be higher in wealthier cities.

Despite popular perceptions of US cyclists being wealthy and well-educated, US commuter cyclists earn much less than those who commute by other modes with similar education levels and working in the same urban area. Education and geography appear to play important roles. Without accounting for educational attainment or urban area, the relationship between income and cycling strengthens in Mexico and weakens in the US. Ignoring all other covariates, Mexican cyclists earn a third less than non-cyclists, while US cyclists earn just 5% less.

Beyond these similarities, there are substantial differences in the socioeconomic and demographic predictors of in the US and Mexico's largest urban areas. In the US, for example, the probability of cycling to work declines continuously but at a decreasing rate with age. Twenty-year-old commuters cycle twice as frequently as 40-year-old commuters. In Mexico, by contrast, the probability of cycling peaks at around 35 and only begins to decrease substantially in the 60s. Twenty-year-old commuters cycle 20% less frequently than 40-year-old commuters. The interested reader can estimate odds-ratio at any age by taking the natural log of the sum of products of age and age-squared (divided by 1000) with the exponent of the corresponding estimated linear and quadratic odds-ratios for age.

Whereas urban cyclists are most likely to cycle to jobs in the service sector in the US, they are least likely in Mexico, instead cycling to jobs in agriculture, manufacturing, and construction. Finally, US cycling commuters tend to come from smaller households, while Mexican ones come from larger households. For an average commuter, a one person increase in household size reduces the odds of cycling by 5% in the US urban areas but increases it by 2% in the Mexican ones.

8.3.2. Where do workers cycle more in the US and Mexico?

We generally do not find statistically significant relationships between metropolitan-level measures of urban form and the probability of cycling. Neither the distribution of jobs and people, the concentration of jobs, nor the amount of mass rapid transit per capita are statistically significantly correlated with cycling in the US or Mexico. We introduced a quadratic term to population density since we expect the convenience of cycling to decrease as density and size increase conflict for road-space with other users and increase trip lengths. As shown in Figure 1, this specification produced nearly inverse relationships between cycling and population density in Mexican and US urban areas. In Mexico, cycling rates have a U-shaped relationship with population density. Accounting for income and other covariates, the lowest probability of cycling occurs in urban areas with around 100 people per hectare in residents' Census tracts. The highest occurs in the largest, densest urban areas like Mexico City, and the smallest and least dense ones. This general pattern emerges in models excluding Mexico City. The US has an almost entirely inverted relationship with the highest cycling rates urban areas with 40 to 80 people per hectare. Dropping New York, whose residents live at far higher residential densities than residents in other metropolitan areas, shifts the inflection point from around 65 people per hectare to 40 people per hectare but maintains the general relationship between cycling and population density. Of note, however, no metropolitan areas had residents living at average densities between 47 (San Francisco) and 117 (New York) people per hectare, the densities with the highest predicted cycling probability in the main model. Moreover, just eight US metropolitan areas have average residents living at population densities above 30 people per hectare, the least densely populated urban area in the Mexican sample.

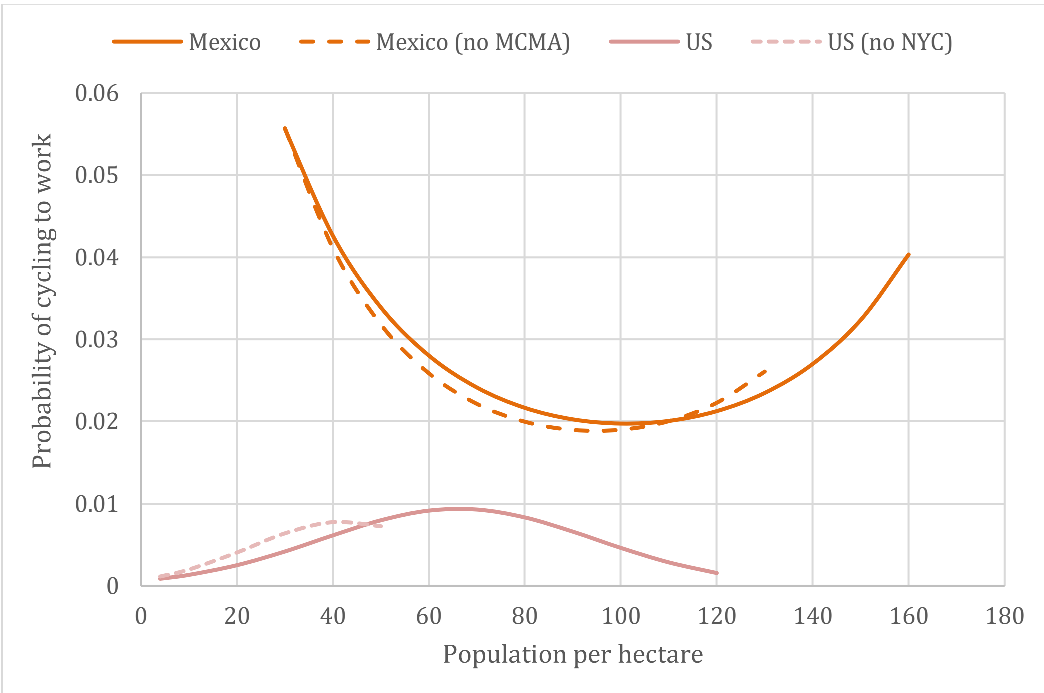

Figure 8.1 Probability of cycling by urban population density for an average worker in the US and Mexico's hundred largest urban areas with and without the New York (NYC) and Mexico City (MCMA) metropolitan areas

Although the relationships are inconsistent, cycling does appear to decrease with more or more substantial roadway in both countries. In Mexico, each additional meter of roadway per capita is associated with 18% lower odds of cycling. In the US, a percentage point increase in the share of the road system comprised of arterials is associated with 11% lower odds of cycling.

Housing type, a proxy for the local built environment (Giuliano and Dargay 2006b), is much more strongly related to cycling to work than metropolitan measures of urban form. As with population density, however, the relationship is substantially different across national borders. In the US, for example, living in an apartment instead of a single-family home is associated with 91% higher odds of cycling and is one of the strongest predictors of cycling. In Mexico, by contrast, the same shift in housing type corresponds to 25% lower odds of cycling. Simulating a shift of the entire sample of commuters from single-family homes to apartment buildings doubles cycling to work from around 0.06% to 1.1% in the US but decreases it from around 5.7% to 4.6% in Mexico. Several contextual differences help explain this finding.

First, Mexican cycling is more suburban than US cycling, which is strongly associated with more central residential locations. In Mexico City for example, commuters in the suburban State of Mexico have three times higher cycling rates than commuters living in the city proper. Second, there are substantial differences between suburban neighborhoods in the US and Mexico. The highest density Census tracts in Mexican urban areas are often in suburban neighborhoods comprised primarily of small, single-family homes. Figure 2 maps the total population per hectare by Census tract in Querétaro, the urban area with the closest to average density in our sample. Third and finally, many Mexican households that we assigned to single-family homes likely live in attached row homes. This style of home is extremely common in Mexican cities and the Census definitions of "*casa única en el terreno*" and "*casa que comparte terreno con otra(s)*" that we used to characterize housing type do not as clearly distinguish between single-family detached and attached homes as do the US Census definitions.

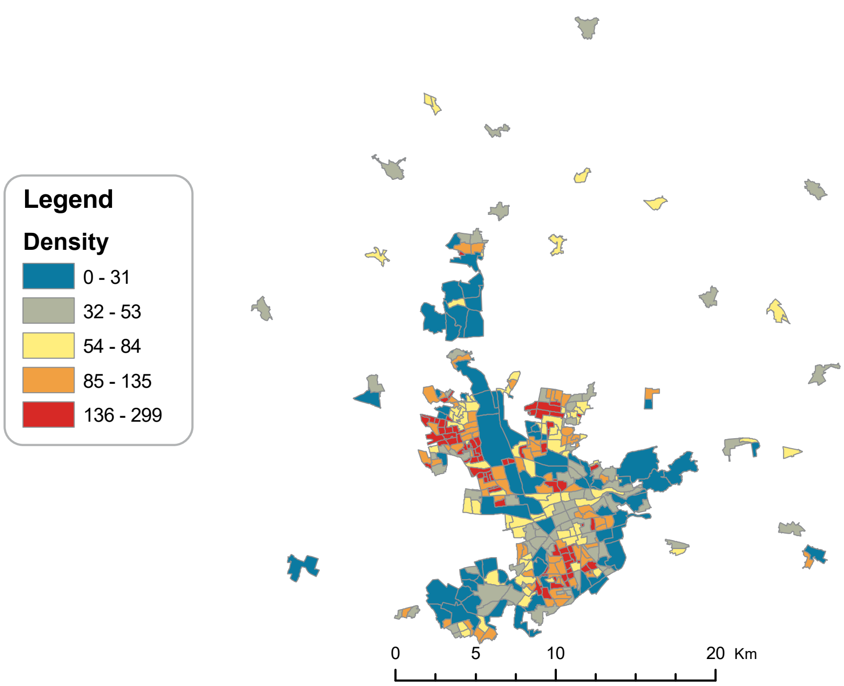

Figure 8.2 Population per hectare by Census tract (Ageb) in Querétaro, Mexico

8.3.2.1 Weather and unobserved urban measures

In our final presented models, we do not find statistically significant relationships between cycling to work and annual cold or hot days. We do find relationships between precipitation and cycling probability, but these relationships are only statistically significant at the 90% confident level. Moreover, we find more cycling in rainier US urban areas and less cycling in rainier Mexican ones. While hot, cold, and rainy weather may affect cycling across days and seasons, the affect does not appear strong enough to show up consistently in our cross-sectional models.

Random intercepts (Appendix A) provide insight into some of the missing variables that are also likely associated with cycling. For example, Guanajuato's large negative intercept is almost certainly associated with the steep terrain that makes cycling particularly challenging. Florida's metropolitan areas, such as Daytona Beach and Jacksonville, tend to have higher cycling rates than the relatively low density and single-family houses would otherwise predict. This may relate to a combination of flat terrain, weather, and other factors.

8.3.3. The role of automobile availability

Commuters from households that have a car are much less likely to commute by bike. An average commuter with access to a car is associated has 83% and 57% lower odds of cycling to work in the US and Mexico. Including vehicle availability primarily weakens the relationship between cycling, income, and education. Once car availability is considered, US commuters with a BA are more likely to cycle than all other groups, including the small share of worker with less than a Jr. high school education. There are also some statistically significant shifts in the relationship between housing type and commuting by cycling. Accounting for car access, for example, living in an apartment becomes less positively associated with cycling in the US and Mexico.

8.4. Conclusion

In this chapter, we develop comparable models predicting whether a sample of 5.7 million workers commute by bicycle in the hundred largest urban areas in the US and Mexico. In both contexts, men in poorer households are likeliest to cycle. The similarities in cycling commuters generally stop with these two commonalities, however. The archetypal US bike commuter is a recent college graduate, who lives by himself in a centrally located apartment in a moderate-to-high density city, like Portland, OR, or San Francisco, CA, and commutes to work in a relatively low-paying service sector job for a college graduate, perhaps at restaurant or not-for-profit. The archetypal Mexican bike commuter, by contrast, is in his mid-thirties, has only a few years of formal education, lives with a large family in a house in the suburbs of either a small city or a large dense metropolitan area, like Mexico City, and commutes to a relatively low-paying agriculture, construction, or manufacturing job. Despite these archetypes, there is a wide range in cycling behavior in the US and Mexico. For example, although men are more than six times to cycle to work than women in Mexico, Mexican women commute to work by bicycle slightly more than US men. Despite the higher cycling rates of poorer workers and stereotypes about workers only cycling out of financial necessity, 2.2% of the wealthiest quintile of urban Mexican workers commute by bicycle.

Taken together, our findings provide several insights for public policy. First, understanding contextual differences is critical to the development of policy to increase cycling. Across the US and Mexico, there are substantial differences in what socioeconomic, demographic, and geographic features are associated with higher rates of cycling. As such, adopting public policies from one context and applying them in another may have unexpected or relatively weak effects. As an example, suburban cycling corridors along major arterials may be particularly effective at improving cyclists' experiences in Mexican urban areas but not in US ones. Given the high share of Mexican cyclists working in agriculture, manufacturing, and construction, encouraging showers and bicycle parking in new commercial office buildings may be less effective at improving cycling conditions in Mexico than in the US. Neither observation suggests that policy makers should ignore low probability cyclists. Targeting policies to the most policy-receptive populations will likely limit the overall attractiveness of cycling in environments where most existing cyclists have different preferences from a majority that is interested in cycling but concerned about safety and comfort (Dill and McNeil 2013; Geller 2006). Nevertheless, the findings suggest that low- and high-probability cyclists vary by context and policies to target either group should also vary.

Since most research into promoting cycling come from European and US cities, there is a need for substantially more work from Latin American, Asian, and other contexts, which may vary substantially. Even within countries, we find substantial differences. For example, living in an apartment building is much more strongly associated with cycling in the Philadelphia region than in the Portland region (Appendix A).

Second, the largescale differences in urban form that help shape car and transit use (Bento et al. 2005; Giuliano and Dargay 2006b; Guerra et al. 2018c) are only weakly and inconsistently associated with cycling. As such, cycling policies may be substantially more effective at municipal or sub-municipal levels of governance as opposed to metropolitan ones. That said, investing in more and higher capacity roadway likely reduces aggregate cycling rates at the margin. In Mexico, a simulated 10% increase in roadway per capita results in an 5% decrease in cycling to work. In the US, a 10% increase in the share of arterial roads corresponds with an estimated 7% reduction in cycling rates.

Last, although this paper contributes to the existing literature by providing a rare cross-national assessment of cycling at the correct ecological unit (the individual) in two substantially different contexts, three major limitations of this study present opportunities for future research into the how the predictors of cycling vary by context and which policies are likely to be more effective in a Mexican urban context than a US one. First, we have no consistent measures of cycling infrastructure across urban areas in the US and Mexico. Given the research and the policy focus on cycling infrastructure, understanding where, how, and what types of cycling infrastructure influences cycling in Mexico is particularly important. Second, the data used in this study have limited spatial resolution. Collecting micro data at a better spatial resolution would allow for study into how cycling measures vary with the local built environment. Based on our findings related to housing type, we expect substantial differences across US and Mexican urban areas. Third and finally, our study provides no insight into similarities and differences in recreational and non-work utilitarian cycling in the US and Mexico. Understanding the determinants of non-work cycling trips is essential to developing public policies to promote cycling. Although national comparisons that address these three limitations are unlikely due to data limitations, there are opportunities to explore the predictors of cycling across larger metropolitan areas with recent and relatively consistent household travel surveys.

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Appendix A. Random intercepts and slops

Random intercepts and slopes for Table 2, model 1, predicting the probability of cycling in the 100 largest urban areas in Mexico

	Intercept	***Income***	***Single-family attached***	***Apartment***	***Other housing***
Acapulco	-1.83	0.12	0.07	-0.44	-0.04
Acayucan	-0.38	0.00	-0.08	-0.16	-0.06
Aguascalientes	0.83	0.00	0.38	0.00	0.16
Apatzingán de la Constitución	-0.69	0.01	-0.11	-0.23	-0.08
Campeche	-0.18	-0.04	0.09	-0.07	-0.01
Cancún	0.13	0.00	0.05	-0.02	0.02
Cárdenas	1.75	-0.05	0.18	-0.07	0.11
Celaya	1.58	0.00	-0.27	0.00	-0.01
Chetumal	0.99	0.01	0.34	0.54	0.20
Chihuahua	-0.10	-0.04	0.19	0.00	0.04
Chilpancingo do los Bravo	-3.43	0.04	0.01	-0.04	-0.15
Ciudad Acuña	-0.90	0.03	0.09	0.20	0.02
Ciudad del Carmen	-0.27	-0.01	0.02	0.26	0.01
Ciudad Guzmán	1.36	-0.03	-0.16	0.11	0.01
Ciudad Lázaro Cárdenas	0.81	-0.05	0.10	-0.08	0.04
Ciudad Obregón	1.42	-0.05	0.01	0.17	0.06
Ciudad Valles	0.44	-0.04	0.10	0.01	0.03
Ciudad Victoria	0.55	-0.01	-0.08	0.16	0.01
Coatzacoalcos	-0.53	-0.03	0.03	-0.01	-0.03
Colima-Villa de Álvarez	-0.52	-0.02	-0.32	0.51	-0.11
Comitán de Domínguez	0.26	0.04	-0.11	-0.17	-0.01
Córdoba	-0.58	-0.03	-0.21	-0.18	-0.13
Cuauhtémoc	-0.44	0.03	0.23	0.25	0.08
Cuautla	-0.65	0.06	0.04	-0.42	-0.02
Cuernavaca	-1.11	0.01	-0.08	-0.18	-0.09
Culiacán Rosales	-0.66	0.00	0.18	0.01	0.03
Delicias	0.84	-0.04	0.06	0.18	0.05
Ensenada	-0.40	-0.02	0.15	0.70	0.06
Fresnillo	1.73	-0.06	0.27	-0.08	0.14
Guadalajara	-0.04	0.03	0.21	0.13	0.09
Guanajuato	-3.03	0.01	0.15	0.04	-0.10
Guaymas	-0.19	0.00	0.34	0.15	0.11
Hermosillo	0.71	-0.06	0.08	0.07	0.04

Heroica Nogales	-2.21	0.02	0.13	0.62	-0.01
Hidalgo del Parral	-1.33	0.00	0.00	-0.04	-0.07
Iguala de la Independencia	0.01	0.00	0.08	0.19	0.04
Irapuato	1.69	-0.04	0.02	0.11	0.08
Juárez	-0.89	-0.02	0.16	0.24	0.01
La Laguna	1.54	-0.05	0.14	-0.30	0.07
La Paz	-1.06	0.01	-0.10	0.01	-0.08
La Piedad-Pénjamo	-0.06	0.06	-0.01	-0.03	0.02
Lagos de Moreno	1.06	-0.02	-0.03	-0.08	0.02
León	1.41	0.02	0.01	0.05	0.08
Los Mochis	1.88	-0.05	-0.11	0.01	0.04
Manzanillo	-0.27	0.02	-0.08	0.27	-0.01
Matamoros	0.26	-0.03	-0.25	0.25	-0.07
Mazatlán	1.69	-0.07	-0.09	0.11	0.02
Mérida	0.89	-0.03	0.29	0.14	0.13
Mexicali	0.04	-0.05	0.06	0.20	0.01
Minatitlán	-0.18	-0.01	0.00	-0.41	-0.04
Monclova-Frontera	-0.44	-0.03	0.03	0.03	-0.03
Monterrey	-0.33	-0.04	0.33	0.20	0.08
Morelia	-1.35	0.08	-0.07	0.00	-0.05
Moroleón-Uriangato	0.65	0.09	-0.27	0.00	-0.01
Navojoa	1.76	-0.11	0.15	0.45	0.11
Nuevo Laredo	0.27	-0.02	0.00	-0.36	-0.02
Oaxaca	0.59	-0.02	0.02	-0.34	0.00
Ocotlán	1.30	0.02	-0.46	0.17	-0.06
Orizaba	-0.33	0.11	0.04	0.14	0.07
Pachuca	-0.20	0.00	-0.14	0.14	-0.05
Piedras Negras	0.61	-0.03	0.14	-0.01	0.06
Poza Rica	-1.82	0.13	-0.04	0.23	-0.02
Puebla-Tlaxcala	1.26	0.00	-0.09	-0.63	-0.01
Puerto Vallarta	-0.59	0.01	-0.10	-0.02	-0.06
Querétaro	-0.68	0.00	0.28	0.08	0.06
Reynosa-Río Bravo	-0.28	-0.04	-0.04	0.16	-0.04
Rioverde-Ciudad Fernández	0.15	0.10	-0.37	-0.10	-0.07
Salamanca	2.22	-0.02	-0.42	-0.52	-0.07
Saltillo	-1.22	0.00	0.40	0.38	0.09
San Cristóbal de las Casas	0.88	0.07	-0.17	-0.02	0.02
San Francisco del Rincón	1.36	0.07	-0.46	0.26	-0.03
San Juan Bautista Tuxtepec	0.44	0.02	-0.03	-0.13	0.02
San Juan del Río	0.58	-0.03	0.53	0.03	0.18
San Luis Potosí-Soledad de Graciano Sánc	1.76	-0.08	0.10	0.03	0.08
San Luis Río Colorado	-0.27	-0.03	0.01	-0.15	-0.04

Tampico	0.03	-0.05	-0.12	-0.51	-0.10
Tapachula de Córdova y Ordóñez	0.02	-0.01	-0.15	-0.31	-0.08
Tecomán	-0.08	0.07	-0.23	0.04	-0.04
Tehuacán	0.77	0.04	0.07	-0.40	0.06
Tehuantepec	-0.61	0.04	-0.16	-0.18	-0.07
Tepatitlán de Morelos	0.10	0.00	-0.02	0.36	0.03
Tepic	-0.94	0.04	-0.26	-0.01	-0.11
Teziutlán	-2.67	0.00	-0.22	-0.21	-0.22
Tianguistenco	-1.26	0.04	-0.34	0.04	-0.15
Tijuana	-1.18	-0.02	0.30	0.05	0.03
Tlaxcala-Apizaco	0.81	-0.03	-0.06	-0.16	-0.01
Toluca	-0.11	0.04	0.14	-0.16	0.05
Tula	-0.04	-0.03	-0.01	-1.20	-0.10
Tulancingo	0.00	0.06	0.05	-0.30	0.03
Túxpam de Rodríguez Cano	0.06	0.01	-0.03	-0.25	-0.02
Tuxtla Gutiérrez	-1.25	0.09	0.37	0.29	0.12
Uruapan	-0.38	0.02	-0.31	0.07	-0.11
Valle de México	0.04	0.00	-0.21	-0.04	-0.07
Veracruz	-0.38	0.01	0.17	-0.16	0.03
Victoria de Durango	1.27	-0.03	0.10	0.17	0.09
Villahermosa	0.35	-0.08	-0.33	-0.67	-0.18
Xalapa	-1.81	0.03	0.21	0.34	0.02
Zacatecas-Guadalupe	-0.44	-0.05	-0.05	-0.20	-0.08
Zamora-Jacona	0.78	0.02	-0.35	0.81	-0.01
Zitácuaro	-1.31	0.01	-0.10	-0.12	-0.10

Random intercepts and slopes for Table 8.2, model 3, predicting the probability of cycling in the 100 largest urban areas in the US

	Intercept	**Income**	**Single-family attached**	**Apartment**	**Other housing**
Akron, OH	1.155	-0.195	0.282	0.153	0.159
Albany-Schenectady-Troy, NY	-0.846	0.059	0.005	-0.182	-0.115
Albuquerque, NM	-0.243	0.141	0.236	-0.036	-0.624
Allentown-Bethlehem-Easton, PA-NJ	0.773	-0.130	-0.184	-0.106	0.245
Atlanta-Sandy Springs-Roswell, GA	-1.621	0.129	-0.054	-0.083	-0.067
Augusta-Richmond County, GA-SC	0.099	-0.061	0.400	0.240	-0.149
Austin-Round Rock, TX	0.804	-0.022	0.279	-0.157	-0.757
Bakersfield, CA	0.634	-0.079	0.045	-0.025	-0.117
Baltimore-Columbia-Towson, MD	-0.574	0.014	0.133	-0.159	-0.242
Baton Rouge, LA	1.395	-0.136	0.066	0.012	-0.095
Birmingham-Hoover, AL	-1.852	0.105	0.043	0.175	-0.022
Boise City, ID	-0.576	0.160	-0.043	0.074	0.197

Boston-Cambridge-Newton, MA-NH	-4.724	0.456	0.552	0.696	-0.464
Bridgeport-Stamford-Norwalk, CT	0.314	-0.109	-0.536	-0.550	-0.041
Buffalo-Cheektowaga-Niagara Falls, NY	1.356	-0.125	-0.140	-0.033	0.260
Cape Coral-Fort Myers, FL	1.278	-0.112	-0.631	-0.209	0.881
Charleston-North Charleston, SC	2.308	-0.168	0.418	-0.104	-0.476
Charlotte-Concord-Gastonia, NC-SC	0.475	-0.116	-0.119	-0.178	-0.106
Chattanooga, TN-GA	0.250	-0.025	0.310	0.173	-0.051
Chicago-Naperville-Elgin, IL-IN-WI	-1.964	0.134	0.044	0.586	0.230
Cincinnati, OH-KY-IN	-0.233	-0.022	-0.022	0.097	-0.039
Cleveland-Elyria, OH	-0.702	0.110	0.344	0.308	-0.134
Colorado Springs, CO	0.708	-0.042	-0.538	-0.472	-0.133
Columbia, SC	0.044	-0.053	-0.088	-0.068	-0.011
Columbus, OH	0.352	-0.025	0.501	0.216	-0.170
Dallas-Fort Worth-Arlington, TX	1.039	-0.182	-0.089	-0.177	0.245
Dayton, OH	0.323	-0.046	0.154	0.032	0.080
Deltona-Daytona Beach-Ormond Beach, FL	2.121	-0.126	0.285	0.494	0.802
Denver-Aurora-Lakewood, CO	0.288	0.022	0.067	-0.231	-0.227
Des Moines-West Des Moines, IA	-1.471	0.181	-0.258	-0.124	-0.105
Detroit-Warren-Dearborn, MI	0.403	-0.114	-0.020	0.131	0.352
El Paso, TX	-0.337	-0.071	-0.240	-0.097	0.283
Fresno, CA	0.069	0.029	-0.246	0.026	0.358
Grand Rapids-Wyoming, MI	0.058	0.002	-0.096	-0.229	-0.166
Greensboro-High Point, NC	2.398	-0.285	-0.092	-0.152	0.316
Greenville-Anderson-Mauldin, SC	2.387	-0.350	-0.054	-0.215	0.063
Harrisburg-Carlisle, PA	0.201	0.005	-0.323	-0.179	-0.037
Hartford-West Hartford-East Hartford, CT	-0.453	0.026	-0.228	-0.208	0.023
Houston-The Woodlands-Sugar Land, TX	-0.233	-0.055	0.082	0.159	-0.022
Indianapolis-Carmel-Anderson, IN	0.824	-0.053	-0.159	-0.104	0.348
Jackson, MS	-1.274	0.057	0.106	-0.031	-0.284
Jacksonville, FL	3.073	-0.260	0.134	-0.301	0.447
Kansas City, MO-KS	-0.383	-0.044	0.097	-0.038	-0.171
Knoxville, TN	-0.772	0.086	0.306	0.252	-0.264
Lakeland-Winter Haven, FL	3.715	-0.399	-0.450	-0.551	0.286
Las Vegas-Henderson-Paradise, NV	-0.854	0.139	0.146	0.320	0.095
Little Rock-North Little Rock-Conway, AR	0.429	-0.141	0.100	0.259	0.487
Los Angeles-Long Beach-Anaheim, CA	-0.042	-0.034	-0.124	-0.063	0.530
Louisville/Jefferson County, KY-IN	0.967	-0.145	0.071	0.141	0.116
Madison, WI	-0.995	0.295	-0.312	0.210	0.026
McAllen-Edinburg-Mission, TX	-1.037	0.023	0.163	0.153	-0.129
Memphis, TN-MS-AR	-0.147	-0.016	-0.345	-0.280	0.023
Miami-Fort Lauderdale-West Palm Beach, FL	0.425	-0.118	-0.544	0.093	0.839

Milwaukee-Waukesha-West Allis, WI	0.761	-0.020	-0.478	-0.174	0.303
Minneapolis-St. Paul-Bloomington, MN-WI	0.394	0.074	-0.856	-0.023	0.578
Nashville-Davidson--Murfreesboro--Franklin, TN	-0.834	0.091	0.023	0.226	-0.050
New Haven-Milford, CT	-2.817	0.324	0.483	0.889	0.083
New Orleans-Metairie, LA	0.583	-0.004	0.811	0.560	-0.051
New York-Newark-Jersey City, NY-NJ-PA	-2.827	0.298	0.458	0.833	0.099
North Port-Sarasota-Bradenton, FL	1.798	-0.148	-0.404	-0.326	0.389
Ogden-Clearfield, UT	1.254	-0.109	-0.155	-0.316	-0.084
Oklahoma City, OK	0.456	-0.099	0.093	0.084	-0.161
Omaha-Council Bluffs, NE-IA	0.276	-0.078	-0.273	-0.276	0.077
Orlando-Kissimmee-Sanford, FL	1.885	-0.135	-0.442	-0.696	-0.081
Oxnard-Thousand Oaks-Ventura, CA	-0.793	0.119	-0.177	-0.133	-0.190
Palm Bay-Melbourne-Titusville, FL	2.270	-0.178	-0.446	-0.327	0.226
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	-2.411	0.163	1.119	0.895	-0.002
Phoenix-Mesa-Scottsdale, AZ	0.713	-0.048	-0.110	0.043	0.365
Pittsburgh, PA	-1.885	0.185	0.587	0.339	-0.313
Portland-Vancouver-Hillsboro, OR-WA	-0.993	0.274	-0.289	-0.478	-0.805
Providence-Warwick, RI-MA	0.033	-0.056	0.146	0.184	0.093
Provo-Orem, UT	-0.474	0.075	0.192	0.055	-0.158
Raleigh, NC	0.495	-0.044	-0.398	-0.417	-0.164
Richmond, VA	1.667	-0.202	0.797	0.525	0.218
Riverside-San Bernardino-Ontario, CA	0.562	-0.095	-0.043	0.015	0.285
Rochester, NY	1.003	-0.036	-0.316	-0.166	0.225
Sacramento--Roseville--Arden-Arcade, CA	0.107	0.093	0.334	0.230	-0.139
Salt Lake City, UT	0.256	0.029	-0.274	-0.575	-0.347
San Antonio-New Braunfels, TX	-1.399	0.073	0.004	-0.074	-0.347
San Diego-Carlsbad, CA	-1.326	0.179	-0.278	-0.148	-0.196
San Francisco-Oakland-Hayward, CA	-2.237	0.277	-0.286	0.144	-0.028
San Jose-Sunnyvale-Santa Clara, CA	-1.279	0.208	-0.090	-0.065	-0.137
Scranton--Wilkes-Barre--Hazleton, PA	-0.919	0.026	0.164	0.243	0.142
Seattle-Tacoma-Bellevue, WA	-2.896	0.393	-0.296	-0.399	-0.812
Spokane-Spokane Valley, WA	0.094	0.015	-0.349	-0.286	-0.163
Springfield, MA	-0.955	0.098	-0.056	0.028	-0.088
St. Louis, MO-IL	-1.836	0.144	0.391	0.455	0.007
Stockton-Lodi, CA	1.988	-0.176	-0.247	-0.263	0.223
Syracuse, NY	1.191	-0.128	0.171	-0.049	-0.126
Tampa-St. Petersburg-Clearwater, FL	2.321	-0.207	-0.146	-0.332	0.357
Toledo, OH	0.346	0.013	-0.046	-0.222	-0.236
Tucson, AZ	1.100	-0.024	0.052	-0.156	-0.275
Tulsa, OK	-0.950	0.033	0.395	0.111	-0.376

Urban Honolulu, HI	0.554	-0.049	0.124	0.089	0.042
Virginia Beach-Norfolk-Newport News, VA-NC	0.913	-0.106	-0.060	-0.092	0.070
Washington-Arlington-Alexandria, DC-VA-MD-WV	-5.526	0.602	0.576	0.366	-0.842
Wichita, KS	-0.044	-0.011	-0.232	-0.227	-0.122
Winston-Salem, NC	1.044	-0.165	0.163	-0.010	-0.048
Worcester, MA-CT	-0.595	0.000	0.330	0.285	0.003
Youngstown-Warren-Boardman, OH-PA	-0.403	0.020	-0.101	-0.027	0.083

[i] Model results are available upon request from the corresponding author.