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Determinants of transport mode choice: a comparison of Germany and the USA

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ABSTRACT

Germany and the USA have among the highest motorization rates in the world. Yet Germans make a four times higher share of trips by foot, bike, and public transport and drive for a 25% lower share of trips as Americans. Using two comparable national travel surveys this paper empirically investigates determinants of transport mode choice in Germany and the USA.

In both countries higher population density, a greater mix of land-uses, household proximity to public transport, and fewer cars per household are associated with a lower share of trips by automobile. However, considerable differences remain: all groups of society in America are more car-dependent than Germans. Even controlling for dissimilarities in socio-economic factors and land-use, Germans are more likely to walk, cycle, and use public transport. Moreover, Americans living in dense, mixed-use areas, and close to public transport are more likely to drive than Germans living in lower density areas, with more limited mix of land-uses, and farther from public transport. Differences in transport policy that make car travel slower, more expensive, less convenient, and alternatives to the automobile more attractive in Germany may help account for the remaining differences.

1. Introduction

Car travel is related to climate change, dependence on fossil fuels, and traffic congestion. In 2006, roughly 30% of all Greenhouse Gas Emissions in the USA came from the transport sector—mainly in form of CO_2 emissions from the burning of fossil fuels (IEA, 2006). Moreover, total CO_2 emissions from the transport sector have increased significantly since 1990—compared to decreases in residential and industrial sectors. In 2001, Americans made 89% of their trips by automobile and 8% on foot, 2% by public transport and less than 1% by bicycle (ORNL, 2005). Reducing the share of trips made by car might help combat oil dependence, global warming, and environmental pollution.

Germany and the USA are similarly wealthy countries with high standards of living, important automobile industries, two of the highest motorization rates in the world, and extensive networks of limited access highways. Yet Germans make 40% of their trips by the so called *green modes*: public transport (8%), bicycle (9%), and foot (23%) (BMVBS, 2004). Reliance on the automobile for most trips contributes to twice as many kilometers of car travel per-capita annually in the USA as in Germany (24,000 vs. 11,000 km). Growth in automobile travel has also been slower in Germany than in the USA over the last decade. Between 1995 and 2005, per-capita vehicle kilometers of car use increased by 5% in Germany compared to 12% in the USA. Similarly, growth in vehicle ownership per-capita was faster in the USA between 1995 and 2005 (BMVBS, 1991–2010; FHWA, 2006).

A higher share of car use in the USA contributes to a less sustainable transport system compared to Germany. In 2005, per-capita CO_2 emissions from transport in the USA were three times the German level (3900 vs. 1300 kg CO_2 per year) (IEA, 2006; ORNL, 2008; UBA, 2005). Similarly, annual transport energy use per-capita was three times higher in the USA than in Germany (58,000 vs. 18,000 MJ) (BMVBS, 1991–2010; ORNL, 2008). The trends are also more favorable in Germany. Between 1999 and 2006, per-capita CO_2 emissions and energy use from transport in Germany declined by 7% and 9%, compared to 2% and 4% increases in the USA.

Traffic fatalities per population and per kilometer of travel are also higher in the USA: 14.7 vs. 6.5 traffic fatalities per capita and 9.0 vs. 7.8 fatalities per billion km of travel (IRTAD, 2008). Walking and cycling are two and four times more dangerous in the USA than in Germany: 5.0 vs. 2.5 fatalities per 100 million km of walking and 11.3 vs. 2.5 fatalities per 100 million km of cycling (Buehler et al., 2009). American households spend a 5% higher share of disposable income on transport than Germans (19% vs. 14%)—which amounts to $2712 higher household transport expenditures annually in the USA (BLS, 2000–2003; DESTATIS, 2003a). Public transport is more financially viable in Germany than in the USA. Government subsidies constitute 25% of public transport operating budgets in Germany compared to 65% in the USA (APTA, 2006; VDV, 2008). Every dimension of transport in Germany analyzed here seems to be more sustainable than in the USA.

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Arguably, differences in socio-economic and demographic factors, spatial development patterns, transport and land-use policies, and culture can help explain international dissimilarities in travel behavior. Using two comparable national travel surveys, this paper investigates the role of these factors in shaping differences in mode choice in Germany and the USA. The majority of this paper is devoted to a bi-variate and multiple regression analysis of the impact of socio-economic factors, spatial development patterns, and transport policy on mode choice. Understanding differences in determinants of travel can help formulating policies that make transport systems more sustainable.

2. Explaining differences in mode choice between countries

International comparative studies of travel behavior vary greatly in methods, data, units of analysis, and explanatory variables. Methodological approaches for comparative studies include descriptive and multivariate statistical analyses. Descriptive studies are generally aggregate case studies of cities, nations, or specific policies over time or at a certain point in time. Units of analysis in multivariate studies range from individuals, households, cities, nations to world regions. Table 1 below provides a systematic overview of studies that compare travel behavior in Western European countries, Canada, and the USA and were published between 1980 and 2007. Table 1 indicates the authors' names, units of analysis, methods employed, countries studied, and if a Germany—USA comparison is a central part of the study. Overall explanatory variables for travel behavior can be categorized as: (1) socio-economic and demographic characteristics, (2) spatial development patterns, (3) policies directly or indirectly affecting travel behavior, as well as (4) national cultures or individual preferences.

The majority of studies rely on a utility based framework to explain international differences in mode choice. These studies assume that: (1) individuals maximize their utility gained from out-of-home activities and that (2) individuals minimize the disutility of travel time and cost to reach these activities. Transport policies and spatial development patterns shape the feasibility, as well as time and out-of-pocket cost of different modes of transport. Individual travel mode choice depends on the attractiveness of different modes of transport, but also on socio-economic and demographic characteristics of the trip maker.

2.1. Socio-economic and demographic factors

Most analyses identify income and automobile ownership as primary determinants for explaining international differences in mode choice (Dargay and Gately, 1999; Ingram and Liu, 1999; Schafer and Victor, 2000). Both variables are closely correlated: increasing incomes make owning and maintaining a car feasible. Additionally, higher incomes increase the opportunity costs of travel time—thus making faster modes of transport, such as the automobile, more attractive. Income and auto ownership have been good predictors for mode choice internationally. However, some scholars speculate that socio-economic factors may be less important in industrialized countries—where most households own an automobile and most growth of travel is for discretionary trips (Kunert and Lipps, 2005). This implies that demographic variables, such as household composition and life cycle, gender, and age may be more relevant determinants of mode choice in wealthy countries. Other studies find that the very young, the elderly, and women make fewer and shorter trips compared to employed males between 18 and 65 (Axhausen et al., 2003; Giuliano and Dargay, 2005; Timmermanns et al., 2003).

2.2. Spatial development patterns

Some studies also include spatial development patterns as determinants of mode choice (see Table 1). Urban form and land-use influence time cost and convenience of different modes of transport (Banister, 2005; Cervero, 1998). For example, low density and spread-out developments make walking and cycling unattractive—due to long distances between trip origins and destinations and often insufficient supply of bicycle and pedestrian infrastructure (CEMT, 2004; Pucher and Buehler, 2006). These settlement patterns encourage use of automobiles—which can cover longer distances faster with lower time opportunity costs. In contrast, higher densities with a mix of land-uses provide for shorter trip distances and offer more opportunities for walking and cycling (Kenworthy, 2002). Residential density also often serves as a proxy for quality, quantity, and convenience of pedestrian facilities and ease of walking and cycling (Boarnet and Crane, 2001; Chatman, 2008). Moreover, car travel tends to be slower and less attractive in dense areas—due to traffic congestion, less parking supply, and higher costs for parking. Additionally, higher densities make the provision of public transport economical (TRB, 2001; Vuchic, 1999).

Spatial development patterns and travel behavior have a mutual influence on each other (Giuliano and Dargay, 2005; Newman and Kenworthy, 1996). A definite causal relationship cannot be determined, since the automobile allows for low-density settlements, but at the same time these kinds of settlements then require the availability of a car for daily activities. Furthermore, there might be a self-selection effect in neighborhood choice (Giuliano, 1999). Individuals, who prefer to cycle, walk, or use public transport may move to denser neighborhoods with a greater mix of land-uses. Overall, studies have found that spatial development and land-use account for less variability in travel behavior than socio-economic and demographic variables (Axhausen et al., 2003; Simma and Axhausen, 2003).

2.3. Transport and land-use policies

Transport policies at all levels of government influence the out-of-pocket and time cost and convenience of transport modes (CEMT, 2003; Pucher, 1988). Most studies that compare transport policies are aggregate descriptive analyses of countries or cities (see Table 1). Costs for automobile travel that are commonly influenced by governments include gasoline and sales taxes, automobile registration fees, tolls, parking costs, and speed limits (CEMT, 2003; Nivola, 1995). Higher automobile operating costs and slower car travel speeds likely result in less automobile travel and a higher percentage of trips by public transport, walking, or cycling.

Governments also play a role in infrastructure supply (Banister, 2005; Ingram and Liu, 1999). More road infrastructure supply in cities can contribute to faster and more convenient car travel. Moreover, land-use policies also influence travel behavior (Nivola, 1999). A greater mix of land-uses and shorter trip distances make trips by bike and foot feasible—while higher densities make public transport economically viable.

Transport policies that promote walking, cycling and public transport; and make car use more expensive, slower, and less convenient may help explain differences in travel behavior and more sustainable transport in Germany compared to the USA:

First, owning and operating a car is more expensive in Germany. In 2006, tax on fuel was nine times higher and sales taxes on new cars were three times higher in Germany than in most American states (EIA, 2008; Federation of Tax Administrators, 2006). Moreover, annual vehicle registration fees are higher in Germany, especially for cars with larger engines (BMVBS, 1991–2010; FHWA, 2006).

Table 1
Overview of international comparative studies of travel behavior in Western European Countries, Canada and the USA. Sources: Axhausen et al. (2003); Banister (2005); Banister et al. (2007); Bratzel (1999); Button (1998); CEMT (2003, 2004); Cervero (1998); Clark and Kuijpers-Linde (1994); Dargay and Gately (1999); Donaghy and Poppelreuter (2005); Downs (1999); Dunn (1981); Giuliano (1999); Giuliano and Dargay (2005); Giuliano and Narayan (2003, 2004, 2006); Gleesen and Low (2001); Hass-Klau (1993); Ingram and Liu (1999); Kenworthy (2002); Newman (1996); Newman and Kenworthy (1999); Newman et al. (1999); Nivola (1995, 1999); Pucher (1988, 1994, 1995a,b, 1998); Pucher and Banister (2003); Pucher and Buehler (2006); Pucher and Kurth (1995); Pucher and Lefevre (1996); Schafer (1999); Schafer and Victor (1997, 2000); Schwanen (2002); Simma and Axhausen (2001, 2003); Stead and Marshall (2001); Stern and Richardson (2005); Timmermanns et al. (2003); TRB (2001); Vuchic (1999); Yago (1984).

Author	Year	Level of analysis			Type of study		Countries analyzed	Role of G vs. USA comparison in analysis		Role of land-use and urban form in analysis			Role of transport policies in analysis		
		Aggregate		Individual Level data	Multivariate statistical	Descriptive		Central	Part	Central	Part	Mentioned	Central	Part	Mentioned
		Nations	City												
Banister et al.	2007	X				X	EU and USA		X			X	X		
Giuliano/Narayan	2006	X		X	Regression		USA and UK			X					X
Pucher/Buehler	2006	X	X		Regression	X	USA and Canada					X			
Banister	2005	X	X			X	EU		X			X	X		
Donaghy/Poppelreuter	2005	X				X	EU and USA					X		X	
Giuliano/Dargay	2005	X		X	Probit regression		USA and UK				X				X
Stern/Richardson	2005	Regions				X	EU Regions					X			
Downs	2004	X				X	Worldwide				X			X	
OECD (CEMT)	2004	X	X			X	Western Europe and USA		X		X		X		
Giuliano/Narayan	2003	X		X	Regression		USA and UK			X					X
OECD (CEMT)	2003	X	X				W. Europe USA & Russia		X		X		X		
Pucher/Banister	2003	X				X	North America, W. Europe		X			X	X		
Pucher/Dijkstra	2003	X				X	USA, NL, Germany	X			X		X		
Simma/Axhausen	2003	X		X	SEM*		Germany and Holland								X
Timmermanns et al.	2003			X	Regression		USA,J,CAN,UK,NL			X					
Axhausen/Akiva	2003	X		X	SEM*		USA, Austria, CH, UK								X
Kenworthy	2002		X		Regression	X	Worldwide		X		X			X	
Schwanen	2002		X		Regression		Western Europe			X					
Gleeson/Low	2001	X	X			X	USA, UK and Australia							X	
Simma/Axhausen	2001	X		X	SEM*		Germany, UK, Switzerland								X
Stead Marshall	2001									X					X
TRB	2001	X				X	W. Europe and USA		X		X		X		
Schafer/Victor	2000	World regions			Linear model		Worldwide					X			
Bratzel	1999		X			X	Europe				X		X		
Dargay/Gately	1999	X			Regression		Worldwide								
Giuliano	1999	X				X	W. Europe and USA			X				X	
Ingram and Liu	1999	X	X		Regression		Worldwide								X
Newman/Kenworthy	1999		X		Regression	X	Worldwide		X		X			X	
Newman et al.	1999		X		Regression	X	Worldwide		X		X			X	
Nivola	1999	X				X	OECD		X	X				X	
Vuchic	1999	X	X			X	W. Europe, USA and CAN		X		X			X	
Button	1998	X				X	Europe and USA								
Cervero	1998		X			X	W. Europe and Canada		X		X		X		
Pucher	1998	X	X				Germany and USA	X			X		X		
Schafer/Victor	1997	X				X	Worldwide					X			X
Newman et al.	1996	X	X			X	Worldwide				X			X	
Pucher/Lefevre	1996	X				X	W. Europe USA and CAN	X			X		X	X	
Nivola	1995	X				X	W. Europe, USA and CAN		X		X			X	
Pucher	1995a	X	X			X	Europe and USA	X			X		X		
Pucher	1995b	X	X				Europe and USA	X			X		X		

Pucher/Kurth	1995	X	X			Europe					X	X	
Clark/Kjippers	1994		X		X	USA and Netherlands							
Hass-Klau	1993	X	X		X	Western Europe				X		X	
Orfeuil	1993	X			X	Western Europe		X		X			X
Pucher	1994	X	X		X	Canada and USA				X		X	
Newman/Kenworthy	1989		X	Regression		Worldwide		X	X				X
Pucher	1988	X			X	Germany and USA	X				X		X
Yago	1984	X			X	Germany and USA	X				X		X
Dunn	1981	X			X	W. Europe and USA		X		X		X	

Note: Studies without a comparative analysis were excluded.
* SEM = Structural Equation Modeling.

Second, all levels of government in the USA subsidize roadways more heavily than in Germany. German road users pay 2.6 times as much in gasoline taxes and registration fees per year as all levels of government spend on construction and maintenance of roads (BMVBS, 1991–2010; Buehler et al., 2009). In the USA all levels of government spent between 10% and 30% more on roads per year than they collect in fees and taxes from road users (Puentes, 2003; USDOT, 1990–2008).

Third, in almost all German metropolitan areas public transport service, timetables, and tickets are integrated across operators and offer seamless travel to passengers through regional public transport associations. Pioneered in the late 1960s in the Hamburg region, Verkehrsverbunds have spread to nearly all metropolitan areas by 2010 (Baron, 1995; VDV, 2008). With one ticket passengers can use all modes of all public transport operators region-wide at steeply reduced fares: up to 75% discounts compared to tickets for single trips. In contrast monthly tickets in the USA are often limited to single operators and only offer more limited discounts of 10–20% (APTA, 2008; VDV, 2008). Public transport service in Germany is also more abundant: 57 vs. 24 vehicle km of public transport service per-capita annually (APTA, 2006; VDV, 2008).

Fourth, German cities place many restrictions on drivers, such as reduced speeds and limited parking (Boltze and Schaefer, 2005; Topp, 1993). Most German cities have traffic-calmed all of their neighborhood streets to 30 km/h (19 mph)—often 70% or 80% of all urban streets. Moreover, home zones limit car travel speeds to 7 km/h (4 mph) and give bicyclists, pedestrians and children at play priority over the car. Most German cities have pedestrianized their downtowns and thus make it impossible to pass through the city center by automobile (GTZ, 2004; Hajdu, 1989; Hass-Klau, 1993; Topp, 1993). Pedestrian zones are rare in the USA and traffic calming is limited to single streets and often at higher speeds than in Germany (Pucher and Buehler, 2008).

Fifth, land-use planning in Germany keeps settlements compact and trip distances short—thus supporting public transport, walking, and cycling (Hirt, 2007; Kunzmann, 2001; Schmidt and Buehler, 2007). In contrast to the USA, land-use planning in Germany involves all levels of government in a top-down bottom-up planning process that is designed around collaboration and mediation. In contrast to the USA, land-use-plans are coordinated with transport plans at all levels of government, assuring that planners consider the transport impacts of new developments. Moreover, differences in property right laws limit greenfield development in Germany.

2.4. Culture and attitudes

Culture and attitudes are often mentioned as explanatory variables for international differences in travel behavior. Gleesen and Low (2001) developed the theory of "*ecosocialization*", which is an indicator for cultural change towards more sustainability and sustainable modes of transport in society as a whole. Cultural differences might also be related to different lifestyles. Dissimilarities in travel witnessed between the USA and Europe may be attributed to greater acceptance of government intervention, differences in corporate power over the transport sector, and more concern about externalities of car use in Europe (Deakin, 2001; Nivola, 1995, 1999; Yago, 1984).

Germany and the USA share many similarities in system of government and culture that shape transport policies and travel behavior. Both countries are democracies with federal systems of government and a history of local self-government (Doering, 2000; Leipold, 2000; Wentzel and Wentzel, 2000). Both are market economies with significant government involvement in the transport sector (Hansjuergens, 2000; Wentzel and Wentzel, 2000). Both countries have among the highest rates of motorization in the world: 560 cars per 1000 population in Germany compared to 780 cars per 1000 inhabitants in the USA (BMVBS, 1991–2010; USDOT, 1990–2008). In fact after WWII, motorization in Germany increased at a faster rate than in the USA: from 12 cars per 1000 population in 1950 to 390 cars per 1000 population in 1980—compared to an increase from roughly 200–580 cars per 1000 population in the USA (KBA, 2006; USDOT, 1990–2008). The rapid increase in Germany is possibly related to a depressed level of car ownership in the aftermath of WWII. Since 1990, motorization rates in Germany are increasing at a slower rate than the USA.

Both countries have extensive limited access highway networks—many stretches of the German Autobahn still do not have any speed limits (IRF, 2007). Car manufacturing and related sectors are important to both national economies—accounting for 20% (Germany) and 10% (USA) of GDP (USDOT, 1990–2008, VDA, 2007). In both countries the automobile is an important symbol of freedom and mobility (Schmucki, 2001; Wachs et al., 1992; Wolf, 1986). Similar to the USA, the trend toward decentralization of German cities is strong (Karsten and Usbek, 2005; Schmidt and Buehler, 2007; Schulz and Dosch, 2005).

3. Analysis

The explanatory factors identified above might have a different influence on travel behavior in each country—thus contributing to a unique transport system. First, the influence of these factors on travel behavior in each country is investigated through a bi-variate analysis. Second, regressions are estimated to control for the joint influence of all explanatory factors on mode choice. Both analyses are based on a pooled sample of trips made by individuals in the USA and Germany in the years 2001 and 2002.

3.1. Data sources and variables in the analysis

Data for this analysis originate from two comparable national travel surveys: the National Household Travel Survey (NHTS 2001) for the USA and the Mobility in Germany Survey (MiD, 2002). Travel surveys can vary widely, by survey period, sample size, survey method, target population, inclusion criteria, sampling technique, and response rates (Kunert et al., 2002). However, NHTS and MiD rely on similar methods and contain similar variables—and thus provide a unique opportunity for an international comparison of travel behavior.[1] Both, NHTS and MiD are representative for the countries as a whole and different metropolitan area size categories. The two surveys are mostly carried out by phone (CATI), randomly assign travel days to individuals, rely on 1 day travel diaries as memory joggers, include adults and children as target population, and have a 41% overall response rate. For both surveys, data are available for households, persons, and trips. The data presented here are based on 25,848 German households with 61,729 individuals and 26,082 American households with 60,882 individuals.

Even though the datasets are similar, some differences in methodology and variable measurement remain. For example, a small percentage of German respondents (<5%) answered the initial household survey using a mail-in paper survey, while all individuals in the USA were interviewed by telephone. Moreover, the German survey relied on the German citizen registry to draw a stratified random sample, while the US survey was carried out by (stratified) random digit dialing (RDD). Both survey teams conducted non-response analysis and both surveys provide weights to control for non-response bias and are representative for each country.

Most variables had to be transformed to be made fully comparable for the analysis. Other variables had to be merged to the datasets. For example, household distance to public transport and population and workplace density were merged to the datasets. The US Federal Highway Administration (FHWA) provided those data for the USA directly to the researcher. The German Clearinghouse for Transport Data helped merging data to the MiD survey, since exact geographic identifiers for households are not publicly accessible for the German dataset.

The selection of variables for this analysis is guided by the literature review above and availability of data in the two travel surveys. Details about variables, their measurement and data sources are discussed below and displayed in Table 2. Household income, automobile availability, gender, and household lifecycle stage measure socio-economic and demographic factors. Some of these variables can be easily calculated using the two datasets. For example, household life cycle is approximated by a series of dummy variables based on employment status of household members and the presence of children. Automobile availability is measured as vehicle ownership per household member at driving age.

Household income is more difficult to compare across countries. In the surveys income is measured as an ordinal variable using dissimilar income categories for each country. To increase comparability, the ordinal income variables are transformed into interval variables based on income interval mid-points (Healey, 2005). After transformation of the variables, NHTS and MiD based estimates of average and median income for each country are comparable with other external international data sources (OECD, 2003–2007). Education level is not available as control variable, since the variable in the US survey focuses on post-high school education and the German survey only reports the type of high school attended.

Spatial development patterns are approximated through population density at place of residence and a variable capturing the mix of residences and jobs at place of residence. FHWA provided a special version of the NHTS dataset identifying the census tract of each respondent's household. Obtaining the census tract identifier made it possible to add data about workplace and population density per census tract to the survey data. The German government "Local Statistics" database provided information on settlement area and transport infrastructure land area per municipality (DESTATIS, 2003b, 2005).

Land-use data are available at the level of the municipality in Germany and the census tract in the USA. Moreover, population density is measured as population per settled land area in Germany and population per land area in the USA. The measure for the USA is geographically more precise than the German data, but includes unsettled land within census tracts, which is excluded for the German measure. Even though both measures could ideally be more comparable (e.g. more geographic detail for Germany and excluding non-settled land area for the USA), they are the best available data. In this dataset, average population density in Germany is 2.3 times higher than in the USA—a ratio which is in line with other aggregate data sources on population density over settled land area (NRI, 2006; Schulz and Dosch, 2005).

Mix of land-uses is measured at the same geographic scale as the population density variable described above and is approximated by an index ranging from zero to one. A value of one indicates a balanced mix of residents and jobs in a given area, while a zero stands for almost no mix of jobs and residents.

Data availability limits the bi-variate and regression analysis of transport policy variables at the level of the individual. As discussed above, there are many differences in transport policies between Germany and the USA, which might help explain more car

[1] In fact, prior to implementing the MiD, one of the German head researchers had studied the predecessor to the American NHTS during a 1 year stay at Oak Ridge National Laboratories in the USA.

Table 2
Variables included in analysis, level of measurement, and data sources. Sources: BAA (2006); BMVBS (2004); DESTATIS (2003b, 2005, 2007); ORNL (2005); USDOC (2006a,b)).

Variable	Measurement	Explanation	Source
Policy proxies			
Household distance to a public transport stop	Two nominal variables indicating if a household is located (1) within 400 m or (2) between 400 and 1000 m from public transport	USA: distance of a household from a rail station or bus corridor	ORNL
		Germany: distance of a household from a bus stop or a rail station	MiD
Spatial development patterns			
Population density	Population per square mile	USA: population per land area per census tract	NHTS
		Germany: population per settled land area per municipality	DESTATIS
Mix of population and workplaces	Index ranging from 0 (no mix) to 1 (great mix)	USA: index based on ratio of workplaces and residents	CTPP, Gazetteer
		Germany: index based on ratio of workplaces and residents	DESTATIS, BAA
Socio-economic and demographic variables			
Household income	US dollars	USA: annual income before taxes	NHTS
		Germany: annual income before taxes	MiD
Car access	Ratio	USA: ratio of vehicles per household to household members with a driver's license	NHTS
		Germany: ratio of vehicles per household to household members with a driver's license	MiD
Teenager/child	Nominal variable	USA: value of 1 for individuals younger than driving age	NHTS
		Germany: value of 1 for individuals younger than driving age	MiD
Gender	Nominal variable	USA: value of 1 for males	NHTS
		Germany: value of 1 for males	MiD
Household lifecycle and employment	Series of nominal variables indicating household life cycle and respondent's employment status including: employed in single HH; unemployed in single HH; employed in adult only HH; unemployed in adult only HH; employed in HH with small children; unemployed in HH with small children; employed in HH with older children; unemployed in HH with older children; retired in HH of retired individuals	USA: employed individual in HH with older children as reference category	NHTS
		Germany: employed individual in HH with older children as reference category	MiD
Trip purpose	Series of nominal variables indicating if a trip was (1) a work or (2) a shopping trip	USA: series of nominal variables indicating if a trip was (1) a work or (2) a shopping trip	NHTS
		Germany: series of nominal variables indicating if a trip was (1) a work or (2) a shopping trip	MiD
Germany–USA dummy	Nominal variable	Value of 1 if respondent is from German sample	NHTS MiD

HH = household.

use in America. Household distance to public transport can serve as rough proxy for overall transport policies and is merged to the datasets. Ideally many other variables capturing differences in transport policies may be included in the analysis, such as differences in parking fees and supply, taxes on vehicle ownership and operation, provision and supply of bike paths and sidewalks, or the level of service for public transport. Unfortunately, these variables are not available for inclusion in this analysis.

FHWA provided a special file indicating the distance of any given household to rail stations and bus corridors based on GIS analysis for the USA. A similar variable existed in the German dataset already—which was based on self-reported distance to a bus or train stop. The two variables for distance to bus public transport are not fully comparable, but the best data available. The data show that 90% of Germans live within 1 km of public transport, compared to only 43% of Americans.

Additionally, the regression analysis includes a dummy variable that captures differences between Germany and the USA, not controlled for by other variables—partially accounting for transport policies and differences in culture, as well as other variables not measured directly.

3.2. Bi-variate analysis of differences in mode choice

In both countries, higher household incomes are related to more car travel and fewer trips by public transport, walking, and bicycle (see Fig. 1). In the USA car use is more common among all income groups: the share of car trips for the lowest income quartile is only 6% lower than the share of trips for the highest income quartile (82% vs. 88%). In Germany this difference is twice as large (54% vs. 68% respectively). In each income quartile the share of trips by foot, bike, and public transport in Germany is three times higher than in the USA. This difference holds even across income groups. The mode share of public transport, walk, and bike for wealthy Germans is two to eight times higher than for poorer Americans.

In Germany and the USA, individuals in households with more cars per household member at driving age choose the automobile for a higher share of trips than individuals in other households. However, the automobile accounts for slightly over 50% of trips by individuals in households with 0–0.5 cars per household member in the USA. In contrast Germans in households with more cars than drivers still make close to 30% of trips by bike, public transport, and foot.

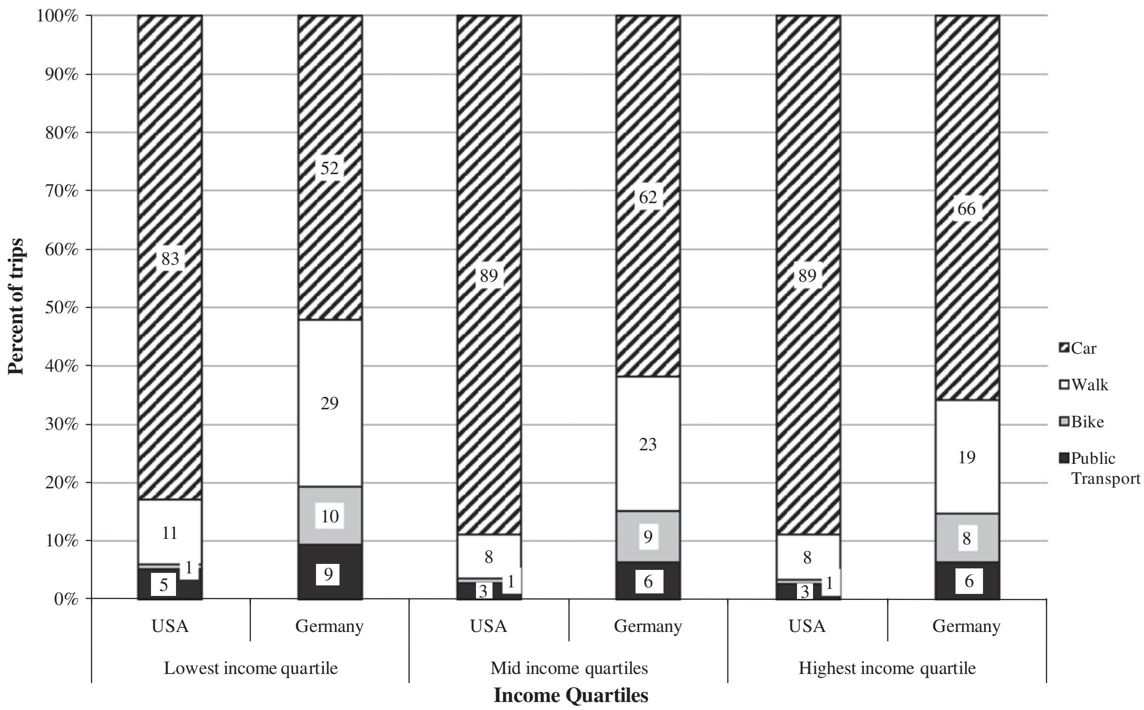

Fig. 1. Percentage share of trips by car, public transport, bicycle, and foot by household income quartiles in Germany and the USA, 2001/2002.

In the USA the share of trips by car is similar for men and women (87%), while Germany displays a larger gender gap with 65% of trips by car for males compared to only 57% for women. Men and women cycle for the same share of trips in Germany (9%). However, in the USA, men are twice as likely to cycle as women (1.2% vs. 0.6%). In both countries, employed adults in households with children are most likely to drive. American retirees make 90% of their trips by car. In contrast, retired Germans make 42% of trips by alternative modes: bike (8%), walk (28%), and public transport (7%). At the other end of the age spectrum, American children and teenagers under driving age make 77% of their trips by car compared to only 42% in Germany. Similarly, the percentage shares of trips by foot and public transport are three and seven times higher for children in Germany than in the USA.

In Germany and the USA, walking and cycling are mainly used for recreational and leisure purposes (see Fig. 2). However, bicycling in the USA has a marginal status for other trips purposes—accounting for less than 0.5% of shopping and work trips. In Germany, the bicycle accounts for at least 9% of these utilitarian trips. In both countries, public transport is mainly used for work trips. Similar to the pattern observed for cycling, however, Germans are five times more likely to ride public transport for shopping or recreational activities as Americans.

One might assume that the higher percentage of trips by automobile in the USA is related to longer average trip distances in America compared to Germany. Indeed, short trips constitute a higher share of all trips in Germany compared to the USA. In 2001, in Germany 34% of all trips were shorter than 1.6 km and 61% of trips were shorter than 4.8 km compared to only 27% (<1.6 km) and 48% (<4.8 km) in the USA (BMVBS, 2004; ORNL, 2005). However, Fig. 3 shows that in the USA even the majority of short trips are made by car: 67% of trips shorter than 1.6 km compared to 27% in Germany.

Higher population densities are associated with less car use and more walking and public transport use in both countries (see Fig. 4). The share of trips by bike declines slightly for the highest density categories in Germany; which might be related to increased public transport use in cities (Schwanen, 2002). In Germany, the share of trips by car in the lowest density category is smaller than the share of car trips in the second highest density category in the USA. Similarly, the share of public transport and walking in the second highest density category in the USA is similar to the lowest density category in Germany. Moreover, in Germany a greater mix of land-uses is associated with less car travel and more walking, cycling, and public transport use. In the USA, mode choice only varies minimally with changing levels of land-use mix.

Fig. 5 shows that in both countries trips in households closer to public transport are less likely made by car and more by public transport and foot. In both countries, the share of trips by public transport for households within 400 m of public transport is twice as high as for households located more than 1000 m from public transport. However, trips in households who lived more than 1000 m from public transport in Germany are still more likely made by bike, foot, and public transport than trips in households living within 400 m of public transport in the USA.

For all bi-variate relationships presented here, Americans rely on the car for a larger share of trips than Germans. For some variables the most car-dependent group in Germany uses the car less than the least car-oriented group in the USA. The multiple regression analysis in the next section sheds more light on the role of individual determinants of mode choice—while controlling for other explanatory variables.

3.3. Multiple regression analysis of mode choice

The mode choice model employed here builds on the literature review above and identifies socio-economic and demographic factors, spatial development patterns, and proxies for transport policies as groups of explanatory variables for international differences in mode choice. The model follows the assumption held in the literature that individuals choose the mode of transport that maximizes utility and minimizes the disutility of travel. For example an individual would choose the car if the utility derived from an automobile trip is larger than the utility of a walk, bike, or public transport trip.

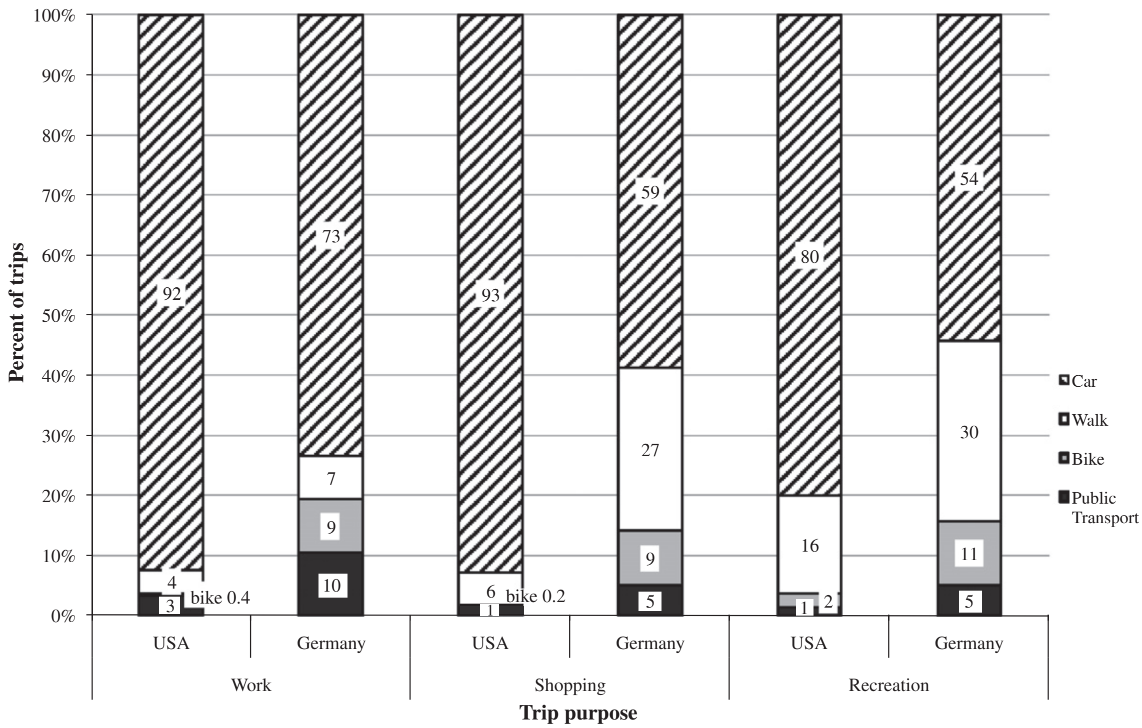

Fig. 2. Percentage share of trips by car, public transport, bicycle, and foot by trip purpose in Germany and the USA, 2001/2002.

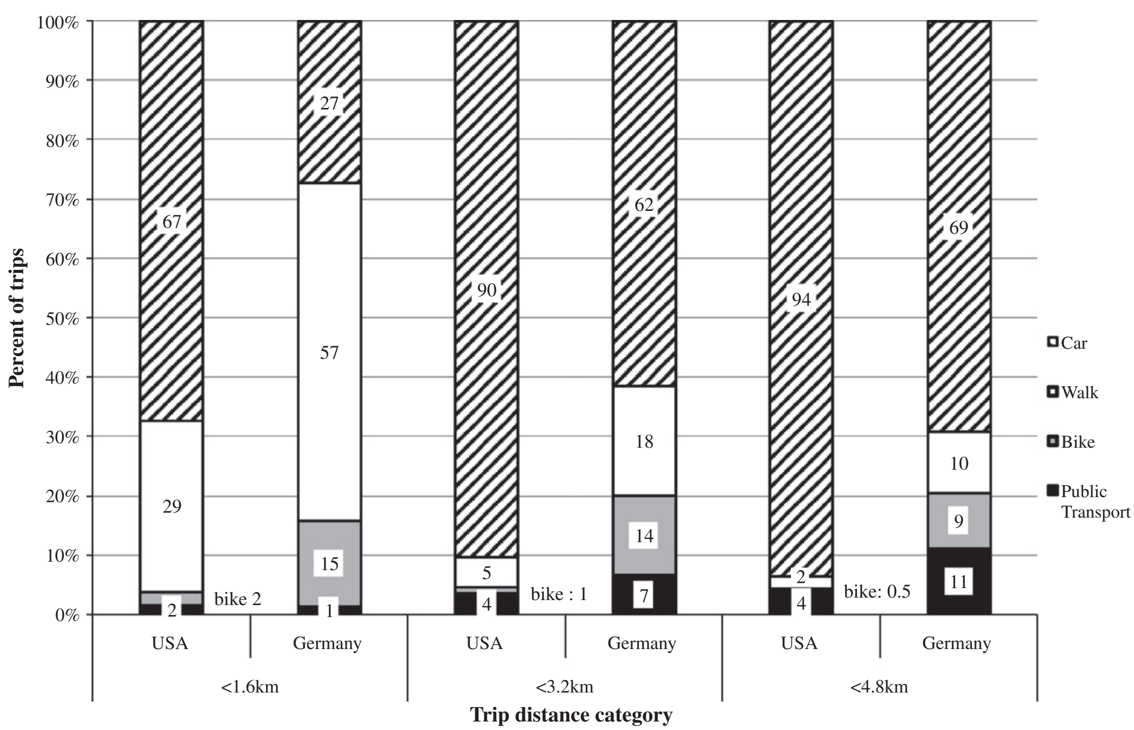

Fig. 3. Percentage share of trips by car, public transport, bicycle, and foot by trip-distance category in Germany and the USA, 2001/2002.

Individual utility is assumed to consist of a measurable deterministic and a non-measurable random error component. The deterministic component in this analysis includes characteristics of the trip decision maker, spatial development patterns, trip purpose, and proxies for policies.

This multinomial logit model (MNLM) is based on a pooled dataset with trips made by respondents from Germany and the USA. Differences in magnitude, sign, and significance of coefficients between the countries are captured through *interaction effects* for Germany. This means that for each independent variable one additional interaction variable for Germany is included in the analysis. A country dummy variable captures all factors excluded from the analysis—such as culture and policy variables (other than the distance to public transport proxy).

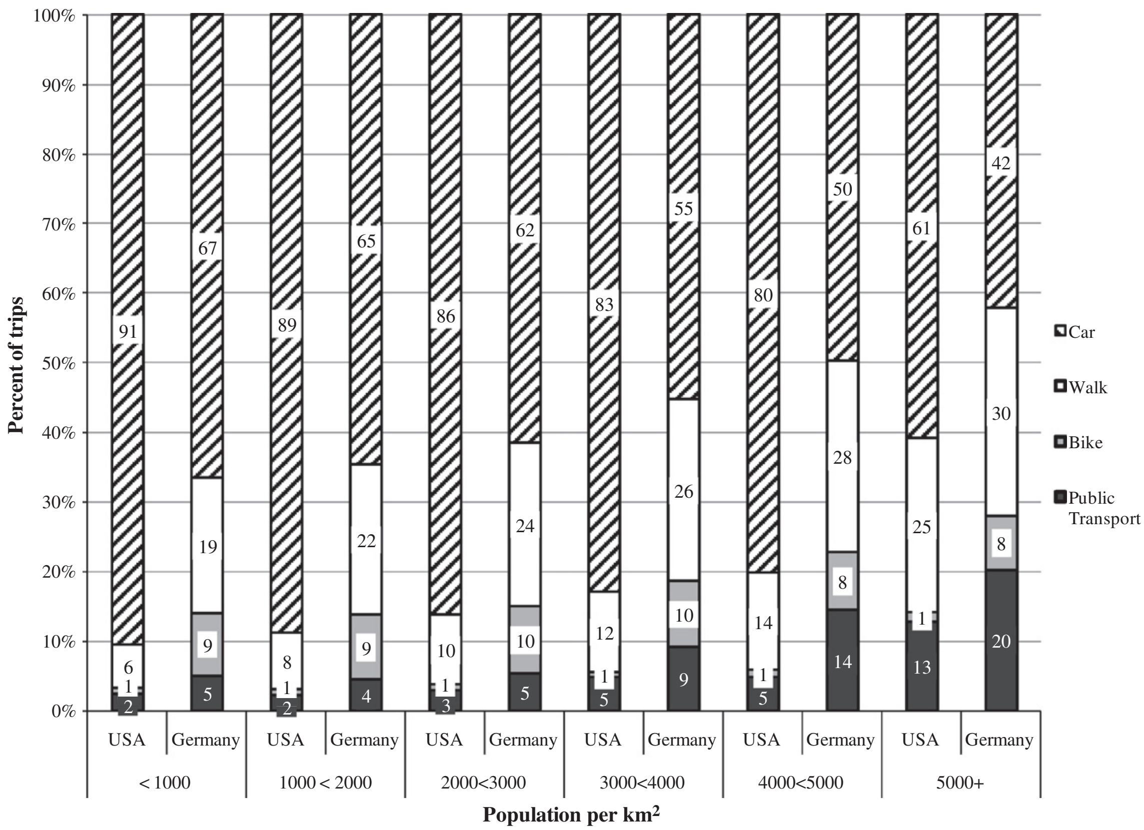

Fig. 4. Percentage share of trips by car, public transport, bicycle, and foot by population density category in Germany and the USA, 2001/2002 (population per km²).

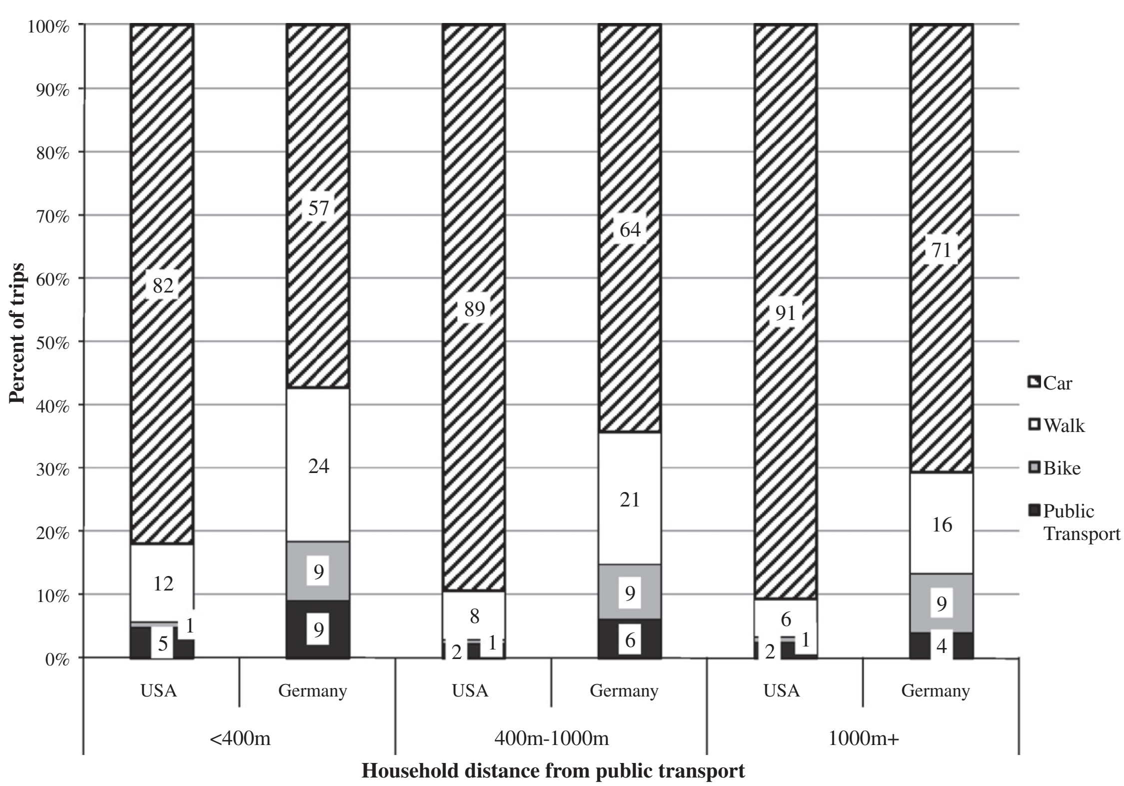

Fig. 5. Percentage share of trips by car, public transport, bicycle, and foot by household distance from public transport in Germany and the USA, 2001/2002.

Groups of variables were entered into the model sequentially, in order to identify the share of total variance explained (R^2) by individual groups of variables. This also helped identify omitted variables bias through changing signs and magnitudes of coefficients across the different models. Proxies for transport policies were included in the first model. Variables capturing spatial development patterns were added in the next model. Socio-economic and demographic factors and trip purpose were added last. Each subsequent model included the explanatory variables of the previous model(s) and added a new set of independent variables. This approach had one weakness however: the order of entering groups of variables influences changes in R^2. In order to identify the unique contribution of each group of independent variables, separate models were additionally estimated—each with just one group of independent variables. Moreover, groups of variables were entered in all possible sequences. Comparing R^2 for all models allows interpreting the range of variance explained by each group of variable independently.

4. Results and discussion

Table 3 presents results for the MNLM with interaction effects for Germany. Available indicators show that the model is appropriate and a good fit. Hausmann, Small-Hsiao, and Wald tests confirm that MNLM is appropriate and that the independence of irrelevant alternatives (IIA) assumption holds (Ben-Akiva and Lerman, 1985; Freese and Long, 2006; Koppelman and Sethi, 2000). According to the LR test the H_0 that all βs are equal to zero can be rejected for the final model. Pseudo-R^2s for the model range from 17.7% (McFadden) to 30.6% (Nagelkerke). As explained above, independent variables were entered subsequently in the modeling process. Pseudo-R^2 for individual groups of independent variables are: 7.8% (Mc Fadden) to 14.4% (Nagelkerke) for policy proxies, 9.0% (Mc Fadden) to 16.3% (Nagelkerke) for land-use variables, 13.5% (Mc Fadden) to 23.9% (Nagelkerke) for socio-economic and demographic variables only, and from 6.1% (Mc Fadden) to 11.5% (Nagelkerke) for the trip purpose variables.

Overall, the model predicts mode share well. Predictions for Germany are slightly underestimating public transport use and somewhat overestimate bicycle use: 59.9% car, 10.8% bicycling, 6.2% public transport, and 23.0% walking. Predictions for the USA overestimate car use slightly, while slightly underestimating all other modes: 90.8% car, 0.5% bike, 1.2% public transport, and 6.5% walking.

Coefficients of independent variables are evaluated according to three criteria: (1) the sign of the coefficient, (2) its magnitude, and (3) its statistical significance. First, the signs of the coefficients show if theories of travel demand hold true in both countries. If so, signs of coefficients should point to the same and expected direction in both countries. Second, the magnitude of the coefficients shows if effects vary between the countries. Third, the statistical significance of coefficients is interpreted and analyzed. This is especially important for the interaction effects for Germany. If an interaction effect is not statistically significant, it indicates that the sign and magnitude of the effect of this variable are not significantly different between the countries.

Even controlling for other variables the likelihood to use non-automobile modes of transport is higher in Germany than the USA. For example, the odds of choosing the bike over the car in Germany are 49.7 times the odds in the USA ($e^{3.907}$). The odds of using public transport are 275% higher in Germany than in the USA ($e^{1.322}$). Finally, in Germany the odds of walking instead of driving are 4.6 times the odds in the USA ($e^{1.512}$).

Interpreting the country specific interaction effects from the MNLM is not straightforward, since interaction coefficients have to be interpreted relative to the base effect (Norton et al., 2004). In the USA, living within 400 m of public transport compared to households more than 1000 m away, is associated with 4.5% larger

Table 3
Results of multinomial logit model (MNLM) of transport mode choice in the USA and Germany with interaction effects, 2001/2002.

	Mode of transport		
	Public transport	Bike	Walk
Constant	−3.763 (32.99)**	−5.022 (26.01)**	−1.968 (32.46)**
Germany(1/0)	1.322 (8.79)**	3.907 (18.40)**	1.512 (17.70)**
Public transport access			
PT access < 400 m	0.044 (0.83)	0.082 (0.82)	0.194 (5.87)**
PT access < 400 m G	0.514 (6.33)**	−0.039 −0.35	0.307 (6.22)**
PT access 400–1000 m	−0.193 (2.72)**	−0.106 (0.85)	0.003 (0.07)
PT access 400–1000 m G	0.503 (5.27)**	0.114 (0.85)	0.299 (5.23)**
Spatial development patterns			
Population density	0.149 (8.88)**	0.085 (2.52)*	0.156 (16.69)**
Population density G	0.243 (11.46)**	−0.097 (2.69)**	−0.040 (3.06)**
Mix of use	−0.133 (1.45)	0.137 (0.85)	0.282 (5.24)**
Mix of use G	0.292 (1.98)*	0.346 (1.81)	0.030 (0.33)
Trip purpose			
Work trip	0.397 (6.00)**	−1.197 (7.68)**	−1.255 (30.04)**
Work trip G	0.216 (2.84)**	1.216 (7.60)**	0.126 (2.33)*
Shopping trip	−1.915 (19.03)**	−1.514 (10.75)**	−1.225 (33.83)**
Shopping trip G	1.261 (11.64)**	1.326 (9.19)**	0.958 (22.79)**
Socio-economic and demographic variables			
Car access/availability	−0.783 (11.16)**	−0.304 (3.13)**	−0.578 (14.02)**
Car access/availability G	−1.452 (15.11)**	−1.391 (12.28)**	−0.699 (11.73)**
Household income	−0.005 (7.49)**	−0.002 (2.00)*	−0.001 (1.28)
Household income G	0.003 (2.15)*	0.003 (1.89)	−0.006 (7.90)**
Sex (Male = 1)	0.041 (1.00)	0.723 (9.06)**	−0.014 (0.53)
Sex (Male = 1)G	−0.463 (8.85)**	−0.729 (8.53)**	−0.230 (6.84)**
Single HH with job	0.569 (4.02)**	0.386 (1.52)	0.459 (6.93)**
Single HH with job G	0.057 (0.34)	0.068 (0.25)	−0.066 −0.70
Single HH without job	1.192 (4.30)**	0.797 (1.76)	0.828 (6.05)**
Single HH without job G	−0.094 (0.30)	0.198 (0.41)	−0.429 (2.43)*
Couple HH with job	0.274 (2.66)**	0.252 (1.54)	0.207 (4.83)**
Couple HH with job G	−0.363 (2.97)**	−0.366 (2.08)*	−0.134 (2.24)*
Couple HH without job	1.193 (6.60)**	0.104 (0.22)	0.305 (3.60)**

(continued on next page)

Table 3 (*continued*)

	Mode of transport		
	Public transport	Bike	Walk
Couple HH without job G	−0.762 (3.91)**	0.392 (0.81)	−0.019 (0.20)
HH, children without job	0.679 (4.32)**	−0.164 (0.58)	0.154 (2.55)*
HH, children without job G	−0.168 (0.98)	0.376 (1.30)	−0.109 (1.47)
Retired HH	−0.156 (1.14)	−0.114 (0.76)	0.117 (2.77)**
Retired HH G	0.392 (2.71)**	0.297 (1.90)	0.199 (3.88)**
Younger than 16/18	2.884 (38.49)**	1.690 (15.42)**	0.575 (15.46)**
Younger than 16/18 G	−0.666 (7.45)**	−0.154 (1.30)	0.558 (11.25)**
Model; fit			
Observations			343,974
McFadden *R*-square			17.7
Cox-Snell *R*-square			24.3
Nagelkerke *R*-square			30.7
Log Likelihood Intercept			−271541.78
Log Likelihood Full			−223580.78
Probability > Chi square			0.000

Base outcome = car.
Absolute value of *z* statistics in parentheses.
* Significant at 5%.
** Significant at 1%.

odds ($e^{0.044}$) of using public transport ($e^{0.044}$). The odds of using public transport in Germany are 1.67 times the odds in the USA ($e^{0.514}$). This indicates that household distance to public transport has a stronger effect on public transport use in Germany than in the USA.

In the USA, 1000 people more per km^2 are associated with 16% ($e^{0.149}$) greater odds of choosing public transport over the car are. Again the odds of using public transport in Germany are 1.28 times the odds in the USA ($e^{0.243}$). The stronger effects on public transport ridership in Germany might be explained by larger public transport networks with more destinations and by higher levels of public transport service compared to the USA. In the USA individuals living in dense areas or close to public transport might still have to drive to reach many destinations due to lack of accessibility by public transport.

The influence of different independent variables can also be interpreted as *marginal changes* in predicted probabilities. For example, setting all variables at their means reveals that a small change in level of mix of land-uses in Germany reduces the probability of driving by 7.9% and increases the probabilities for walking (+4.1%), cycling (+3.2%), and public transport use (+0.2%). For the USA, changes in predicted probability of a car trip are −1.6%; and +1.7% for walking. Similar to the findings for distance to public transport and population density, mix of land-uses seems to have a stronger effect on mode choice in Germany than the USA.

Coefficients of socio-economic and trip purpose variables point in the expected directions. In both countries work and shopping trips are less likely made on foot and the probability to use public transport, bike, or walk decreases with car ownership levels. Some differences remain however: Automobile access has a stronger influence on the likelihood to travel by car in Germany than the USA. This is likely related to more homogeneous automobile ownership levels in the USA, where most households have multiple cars—compared to German one car households.

In America, the odds to ride a bicycle for men are 2.06 higher ($e^{0.723}$) than those for women. However, German women are just as likely to cycle as men. Similarly, retirees are more likely to cycle in Germany and less likely to ride their bikes in the USA. This might be connected to more dangerous cycling conditions in the USA. Surveys have shown that women and the elderly prefer separate cycling facilities and highly value cycling safety (Garrard et al., 2008). Moreover, in Germany retired individuals are more likely to use public transport, while retirees in the USA are less likely to do so.

One might argue that the MNLM presented above is hiding important variations in mode choice by trip distance. Indeed, walking and cycling may be more appropriate for short distances, while public transport may more likely be used for longer trips. Two additional MNLM models are estimated to capture differences in mode choice by trip distance: one model for trips shorter than 1.6 km (1 mile) and one for trips longer than 16 km (10 miles). These models are not presented here, but results reveal expected differences and similarities in coefficients relative to the MNLM model presented above. As expected the odds of choosing the bicycle or walking over the car are greater for short trips than all trips; while the odds to choose public transport over the car are greater for longer trip distances.

For example, for short trips in Germany 1000 people more per km^2 are associated with 1.23 greater odds of walking relative to driving (compared to 1.12 for all trips). Similarly, bicycling has a stronger positive coefficient for the work trip in Germany for short trips than for all trips, indicating that the bicycle is more competitive compared to the car for short work trips. Moreover, in both countries, the odds of choosing public transport over the car for a work trip are greater for longer than average trips (odds of 2.4 vs. 1.8 in Germany and 1.9 vs. 1.5 in the USA). This is also in line with expectations. Rail public is most often geared towards commuting and rush hour traffic. Additionally, rail public transport is faster for longer trip distances due to fewer stops per kilometer traveled and thus more competitive compared to the car.

5. Conclusions

Germany and the USA have much in common, including high levels of car ownership, important automobile industries, and extensive networks of limited access highways. However, Americans walk, bike, and use public transport for only 10% of all trips compared to 40% in Germany—contributing to a less sustainable transport system in the USA. Using two comparable national travel surveys, this analysis investigated determinants of differences in mode choice.

In both countries, individuals drive for fewer trips if they live close to public transport, at higher population densities, and in areas with greater mix of residences and workplaces. Employed individuals with driver's license living in households with easy car access make a higher share of trips by automobile in Germany and the USA. However, the analysis suggests that car use is on two different levels in the two countries—with significantly higher rates of car travel for all groups of society in the USA. Even controlling for socio-economic status, household distance from public transport, population density, mix of land-use, trip distance, and trip purpose, the majority of Americans make 70% or more of their trips by automobile. In Germany, only the most car-oriented groups of society display such high levels of car use.

The analysis reveals significant differences in travel behavior even between similar individuals in Germany and the USA. For example, Germans in households with more cars than drivers make a three times higher share of trips by foot, bike, and public transport compared to Americans in similar households (29% vs.

9% of all trips). Moreover, Germans living at population densities of fewer than 1000 people per km^2 walk, bike, and ride public transport for a three times higher share of trips than Americans living at comparable population densities (33% vs. 9%). Lastly, walking, cycling, and public transport account for over 70% of trips shorter than 1.6 km (1 mile) in Germany compared to only slightly over 30% in the USA.

For some explanatory variables the most car-oriented group in Germany walks, bikes, and uses public transport more than the least car-dependent group in America. For example, the share of walk, bike, and public transport trips for the highest German income quartile is two times higher than for the lowest income quartile in the USA (33% vs. 17% of all trips). Similarly, Germans living more than 1000 m (slightly more than 1/2 mile) from public transport, walk, bike, and ride public transport for a higher share of trips than Americans living within 400 m (1/4 mile) of public transport (29% vs. 18% of all trips). Lastly, Germans living at population densities of less than 1000 people per km^2 drive for a lower share of trips than Americans living at four times higher population densities.

The regression analysis reveals significant differences in the magnitude of the impact of explanatory variables on mode choice. Distance to public transport, population density, and automobile access have a weaker influence on car travel in the USA than in Germany. Significant differences in the direction of explanatory factors remain as well. For example, German retirees are more likely to walk, bike, or ride public transport, while the share of trips by car increases with retirement age in the USA. Similarly, there is no gender difference in cycling in Germany, while women are significantly less likely to ride a bike than men in the USA.

Differences in magnitude and direction of the impact of explanatory factors on mode choice might be related to a more car-dependent built environment and more auto-oriented transport policies in the USA (Pucher and Lefevre, 1996). Even in dense areas close to public transport, many Americans may have to drive since most destinations are not accessible without a car. A lack of sidewalks, crosswalks, and bike lanes and paths make walking or cycling dangerous in many American cities. Moreover, outside of major cities, such as New York City, public transport networks in the USA are not as extensive as in Germany and public transport service is often limited to a few trains or busses per day—mainly during the peak commuting hours (TRB, 2001; Cervero, 1998).

Some aggregate level studies suggest that Germany may follow the USA in wealth, motorization, and travel behavior with a 20–30 year time lag (e.g. Schafer, 1999). However, even controlling for all variables included in the regression analysis, Germans are significantly more likely to walk, bike, and use public transport than Americans. This suggests that other contextual factors—other than socio-economic and demographic and spatial development variables—influence travel behavior as well. These contextual factors include transport and land-use policies as well as cultural preferences. This analysis provides initial evidence that given these differences between the countries, Germany may not necessarily be headed towards American levels of car use in the future.

Transport policy differences that make car use less attractive and more expensive combined with policies that promote alternative modes and make them faster and more convenient in Germany may help explain this trend. Compared to Germany, in the USA gasoline taxes and registration fees are lower; road construction and maintenance are subsidized at a higher rate; highways penetrate most cities; car parking is cheap and ubiquitous; public transport service is less frequent, rarely integrated, and less attractive; and infrastructure for walking and cycling is less common (Buehler et al., 2009; Pucher and Lefevre, 1996). Implementation of German-style policies may be a first step towards reducing car dependence in America. Policies that make alternatives to the car more attractive work best when they are supported by measures that make automobile use less attractive. Gasoline tax increases can reduce car use in the USA. In the face of steep increases in the market price of gasoline between 2005 and 2008, Americans reduced their driving and made more trips by public transport, bike, and foot (APTA, 2010; FHWA, 2009, 2010). These changes in travel behavior may not have been sustained, however, since vehicle miles traveled increased and public transport ridership fell, once gasoline prices started declining.

Results of this analysis caution American planners and policy makers to curb their expectations for quick lasting changes in individual mode choice. Compared to Germany, population density and public transport access has a smaller influence on mode choice—and Americans living close to public transport and in dense areas still drive for a significant share of their trips. Thus implementing policies that increase population density and promote public transport access may initially have a more limited impact on the share of trips made by car. Over time, as regional population densities increase and public transport networks become more extensive, this may change, however.

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