Travel Cost and Cross-city Consumption: Evidence from China's High Speed Railway

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Abstract

How does the improvement in passenger transportation infrastructure benefit consumers? This paper draws on the universe of credit and debit card transactions in China to estimate the impacts of reduced travel cost on consumer welfare. For a plausibly exogenous variation in intercity travel cost, we exploit the expansion of China's high speed railway (HSR) network. We find that direct HSR connection between two cities leads residents from one city to spend an additional 9.5% in the other city. The alternative specification using travel time as the key regressor suggests that 10 percent drop in travel time translates into 2% growth in bilateral transaction value. The effects are largest for city pairs that are less economically integrated initially and pairs where the destination city is significantly larger than the origin city. We also observe larger impacts on cross-city consumption in information service, car dealership and electronics/appliances retailing industries.

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1 Introduction

The function of cities evolves over time. During industrial eras, cities were centers of production where firms and workers cluster for production agglomeration benefits. In recent decades, cities are reshaping themselves as consumption hubs that collect a large variety of consumption goods and services (Glaeser, Kolko, and Saiz, 2001) [17]. Consumers' access to goods and services vary greatly across cities and neighborhoods. While dense metropolitan centers attract a growing number of restaurants, coffee shops, and retail outlets, smaller towns offer only a limited coverage of goods and services.

Travel cost is critical to our evaluation of consumption-based agglomeration forces. If travel is relatively costless, consumers can easily travel to other cities for experiences not available in their own cities. On the contrary, if travel is rather costly, retailers would like to locate closest to their targeted consumers, which creates strong agglomeration effects. Understanding how consumption patterns respond to changes in cross-city travel cost provides important insights into the welfare implication of city sizes. The gains in consumption variety will be much larger residents in large cities if there exists prohibitive cost for cross-city shopping.

While there is an abundance literature on trade cost and consumer welfare, relatively little attention has been paid to the role of consumer travel cost. This paper seeks to fill that gap by combining a uniquely rich dataset on the universe of credit card transactions in China with plausibly exogenous variation in cross-city passenger travel cost thanks to the expansion of High Speed Railway (HSR) system of China. The rapid expansion of China's high-speed railway network provides an ideal setting to explore the implications of lower cross-city travel cost. While highways, traditional railways and air travel make business trips across cities possible, the advent of high-speed railway makes large-scale cross-city travel faster and much more convenient, allowing an unprecedented amount of people move back and forth across cities, sometimes even within a day. As of 2014, China has the world's longest and most heavily used HSR network with 15,399 km of track in service, connecting over 81 cities, with an annual ridership reaching 857 million (Lin, 2017). This offers us a unique opportunity to study how cross-city shopping behaviour responds to changes in travel cost, and the overall consumer welfare implication of large passenger transportation projects.

At the center of the analysis lies the construction of an extremely rich collection of microdata. We obtain records on the universe of credit/debit card transaction in China settled through UnionPay, the only interbank payment network in China, over the period 2011-2016. The record contains information on card identifier, transaction time, location and merchant information, which allows us to construct a monthly series on bilateral consumption

flows between all the Chinese city pairs for each merchant type (eg. car dealership, jewelers). We combine this data with the information on all the new HSR connections during this period.

Our baseline analysis employs a simple difference-in-differences approach. We look at how debit/credit card transactions made by residents from city A in city B change when these two cities are connected by HSR. We control for city pair fixed effects, as well as origin/destination city-specific monthly fixed effects to take care of the overall impacts of HSR connection at city level. In another word, our main effects are identified through changes HSR connection that varies at origin-destination pair level over time, conditional on monthly changes in the overall spending patterns and economic prospects of both the origin and destination cities. We find a significant 10% growth in bilateral card transaction value, accompanying a 24% growth in bilateral card transaction count, following HSR connection.

One empirical challenge is the non-random placement of HSR lines. Although our baseline specification controls for origin/destination times month fixed effects, there is still the possibility that HSR connections target at city pairs that are expected to experience closer economic relationship. To ensure that we are identifying the causal effect of HSR connection on bilateral consumption patterns, we propose an event study design to test the identifying assumption of parallel trends.

We also adopt another empirical approach that links responses in bilateral consumption to changes in travel cost. One important empirical advantage of this approach is that we can focus on city pairs not directly connected, but still experience drops in bilateral travel cost because of the possibility of transferring at nearby cities with HSR connections. Our findings suggest that a one percent drop in travel time translates into 0.2% growth in bilateral card transactions. As HSR usually shorten the travel time between a connected city pair by a half, the estimated effects line up well with the results using connection dummy as the key independent variable.

To explore deeper at the mechanisms at work, we examine the heterogeneous treatment effects of HSR on different types of city pairs and sectors. We find that the HSR effects are most pronounced when the destination city (the city where transactions take place) is much larger than the origin city (the city where the consumers reside). It suggests that HSR encourages residents from smaller cities to access a richer variety of goods and services in larger cities, but not the other way around. As for sectoral heterogeneity, we find that the four consumption categories that experience the largest treatment effects of HSR connection are transportation, information services, car dealership and electronic/appliance retailers. These are either high-value consumption goods or service sectors, where large information asymmetries exist between buyers and sellers, and the provision of goods is often facilitated

by face-to-face interactions between them.

There is a small literature looking at the spatial dimension of consumption. Couture (2016)[11] studies consumers' gains from density in restaurant consumption. Davis, Dingel, Monras and Morales [12] evaluates the relative importance of spatial and social frictions shaping consumers' restaurant choice in New York City. Handbury, Rahkovsky and Schnell (2016)[18] studies if differences in access to health food explain the inequality in healthy food intake across income groups. Agarwal, Jensen and Monte (2017) [1] looks at the spatial pattern of consumption using credit card transaction records in the US, and find that consumers' mobility is quite limited. Our contribution to this literature is to direct estimate the responses of cross-city consumption to travel cost by exploiting exogenous variations in travel cost. Our research design separates out the role of travel cost in shaping spatial consumption patterns, from distance in general, which could also capture cultural similarity and endogenous sorting.

Our paper contributes to a growing literature on estimating the economic impacts of transportation infrastructure projects. Recent papers have studied the skill premia in local labour markets (Michaels, 2008) [19], income volatility (Burgess et al., 2012) [10], gains from trade (Donaldson, 2013) [13], and asymmetric effects on core and peripheral markets (Faber, 2014) [16]. Also, papers in urban economics have explored the effects of urban transportation improvements on urban growth (Duranton and Turner, 2012) [15] and urban form (Baum-Snow et al., 2015) [6], Baum-Snow 2012) [15]. A few recent papers also start to look at the economic impacts of HSR. Bernard et al. (2014) [7] further examines the response of Japanese firms to a particular Shinkansen line with a focus on supplier relationships. Berhens and Pels (2011) [8] documents a significant change in passenger travel behavior along the Paris-London corridor after the high speed Eurostar was in operation. Ahlfeldt et al. (2010) [2] present evidence that the HSR line connecting Cologne and Frankfurt in Germany substantially increases the GDP of the regions that enjoy an increase in accessibility. Zheng and Kahn (2013) [20] and Lin (2017) studies the HSR in China, documenting significant impacts of HSR on housing price and employment.

2 Data

To examine the effect of travel cost on cross-city consumption patterns, we combine data on debit/credit card transactions with information on high speed railway connections.

2.1 Cross City Consumption Data

The foundation of our outcome data is the universe of credit and debit card transactions settled through the UnionPay network, the only interbank payment network in China. The transactions come from 2.7 billion cards from 2011 to 2016 across 264 merchant categories. Currently, we work with the 1% sample but will extend our analysis to the full sample soon. We aggregate the raw transaction data by month, consumption category and resident-transaction city pair.

The upper panel of Table1 shows the summary statistics of monthly transaction value and count for all city pairs with positive transaction amount. If we exclude consumption in one's own city, the transaction count is 35 in a month for an average city pair, amounting to 82,000 RMB in value.

It is noted from our data that Chinese consumers spend a significant proportion of their money out of their own city. Figure 1 plots the trend in the average share of card transaction value made outside of one's own city across cities of different sizes from 2011 to 2015. It is clear to see that residents in smaller cities are more likely to consume in other cities, which could come from the fact they are limited with a smaller variety of goods in their own city. Another message from this figure to be noted is that the share of consumption in other cities grows gradually from 2011 to 2015, a sign of growing economic integration across Chinese cities.

2.2 High-Speed-Railway Data

Our paper relies on the expansion of China's HSR network for time variations in cross-city travel time. China has the largest and fast-expanding HSR network in the world. Till 2016, 16 long-distance lines and 25 intercity lines are operating. (Intercity lines are generally connecting cities in the same province.) Most of the long-distance lines have several segments, each of which has a different open date. In our dataset, we have 79 separate segments/lines opened in total.

We have collected HSR connection data by following official news of the opening of HSR lines and stops along each line. Based on this information, we construct a city-by-city matrix that specifies bilateral HSR connection status on all the city pairs for each month from 2011 to 2016.

2.3 Effects of HSR on travel time

To obtain a complete picture of the impact of HSR on city connectivity, we construct a new dataset on monthly city-to-city travel time from 2011 to 2016. Consumers are making choices across three types of transportation: traditional railway, highway, and HSR. The rapid expansion of HSR not only shortens passenger travel time between connected cities, but also between indirectly-connected ones where passengers transfer at a midway HSR hub.

Our measurement of travel time relies on three components: (i) travel time needed to cover a given distance by railway, highway and HSR; (ii) a transportation network database that maps the evolution of each mode of transportation; and (iii) the computation of route along the network with lowest travel time. We describe the construction of these components in the appendix.

The lower panel of Table1 shows changes in our calculated bilateral travel time from 2011 to 2015 as a result of HSR expansion. It is clear that the average travel time between Chinese city pairs drops from 11.87 hours in 2011 to 10.49 hours in 2015. If we focus our attention on directly-connected city pairs only, their average travel time decreases from 3.2 to 1.93 hours during the same time span.

3 Empirical Strategy

3.1 Baseline Difference-in-differences

The introduction of HSR routes that reduce the travel time between cities makes it easier for consumers from one city to access the amenities in another. To examine the effects of HSR connection on cross-city consumption, we start with a simple difference-in-differences approach. Our main specification is:

$$y_{ijt} = \beta connect_{ijt} + \alpha_{ij} + \eta_{it} + \gamma_{jt} + \epsilon_{ijt} \tag{1}$$

where y_{ijt} stands for log bilateral credit/debit transaction value or count generated by residents from city i at city j within month t. $connect_{ijt}$ is a dummy that switches to one when city i and city j are connected by HSR. To account for changes in transaction value at the extensive margins, we also use $log(Y + (Y^2 + 1)^{1/2})$ as the outcomes where Y is bilateral transaction value or count, and as a result include all the zeros in these two outcomes. We control for pair fixed effects ($alpha_{ij}$) and year fixed effects throughout our analysis, and also additionally control for origin/destination city by month fixed effect (β_{it} and γ_{jt}) in different specifications. We also include the interaction term of pair distance and different year trends,

as well as the interaction of an ever-connected dummy and year trends, for fear that closer city pairs and city pairs that eventually get connected might experience higher growth in bilateral transaction value even without HSR connection. Standard errors are clustered at pair level.

3.2 Event Study

A major empirical challenge in evaluating the impacts of transportation is that highway, railway and HSR lines are not randomly allocated. In particular, a obvious identification concern is that HSR connections are correlated with a pre-existing trend in city growth and development. Our gravity-style estimation in Equation 1 controls for the interaction terms between monthly fixed effects and origin/destination city fixed effects, so pre-trends at both origin and destination cities separately will not bias our results. A faster-growing city might have higher chances in receiving HSR treatment, but as long as their residents will spend equally more money across all destinations had it not been connected to HSR, the growth trend will be absorbed by origin-specific year fixed effects and not affect our estimation. However, we cannot rule out the possibility that HSR linkage targets at city pairs that are more economically integrated and are expected to experience higher growth in bilateral consumption. If is appears to be true, our estimates will be biased upwards. To address this, We test the parallel trend assumption by estimating the following event study specification:

$$y_{ijt} = \sum_{k=-5}^{24} \beta_k (MonthSinceConnect_{ijt} = k) + \alpha_{ij} + \eta_{it} + \gamma_{jt} + \epsilon_{ijt} \tag{2}$$

where y_{ijt} stands for log bilateral credit/debit transaction value or count generated by residents from city i at city j within month t. $MonthsSinceConnect_{ijt}$ counts the month since a particular city pair ij was connected, with negative values indicating periods before connection and positive values indicate post-connection periods. $alpha_{ij}$ is pair-fixed effect. η_{it} and γ_{jt} are origin/destination specific monthly fixed effects.

By estimating the treatment effect in the five months leading up to the HSR connection event, this specification allows us to test for the presence and slope of trends prior to HSR connection without imposing parametric structure.

To estimate the event study on a fully balanced sample of city pairs both before and after each HSR connection event, we exclude city pairs that were connected in the first five months of our dataset (Jan 2011 to April 2016), and pairs that were connected in the last 24 months of our sample. Inevitably, we face the tradeoff between a longer event study and a

smaller sample of connected cities. We choose five months prior to HSR connection because a major HSR line in our sample, the Beijing-Shanghai HSR line, was opened in June, 2011. A longer pre-period means that we need to exclude city pairs connected through this line from our estimation sample.

3.3 Indirect connection

As has been briefly discussed in Section 2.3, we construct a time-varying matrix of bilateral travel time for all Chinese city pairs. It provides us with two major empirical advantages. First, it allows us to directly estimate the elasticity of consumption patterns to changes in travel time. Second, because passengers travelling between two cities not directly connected by HSR can still benefit from HSR connection by transferring at a midway HSR hub and making part of their journey on HSR, we can focus on the treatment effects of travel time on a sample of non-directly connected city pairs. It helps us deal with the identification issue that HSR might target at city pairs with growing economic linkages. For instance, with the opening of Shanghai-Beijing line, the travel time between Shanghai and Baoding, a smaller city near Beijing, drops significantly as Baoding residents can start with a short trip to Beijing and continue their trip to Shanghai through HSR. The drop in bilateral travel time between Shanghai and Baoding is less likely to be planned by the railway authority, and not likely to be correlated with any pair-specific shocks The specification takes the form of:

$$y_{ijt} = \beta log(traveltime_{ijt)} + \alpha_{ij} + \eta_{it} + \gamma_{jt} + \epsilon_{ijt} \tag{3}$$

where $log(traveltime_{ijt)}$ denotes the travel time by the fastest mode of transportation from city i to city j in month t. The rollout of HSR network not only reduces travel time between directly connected cities, but also changes travel time across non-directly connected ones through transferring. We run the regression in equation (2) at both the full sample, and a subsample of city pairs that have not been connected by HSR lines directly.

4 Results

4.1 Direct HSR connection

Table 2 reports our baseline result from estimating equation 1. HSR connection is estimated to have a large and statistically significant impact on cross-city expenditure: direct HSR connection between two cities leads to 9.5% growth in total consumption amount made by residents from one city on the other, controlling for city pair fixed effects and origin/destination

fixed effects. The effects on the number of transactions are even stronger: as shown in Column (2), HSR connection leads to 24% growth in the number of transactions made by card. The effects growth by about 30% when we additionally account for impacts at the extensive margin.

Figure 3 presents the event study graphs. Bilateral transaction values are flat and not significantly different from zero in the five leads up to the HSR connection, it grows a bit following HSR connection but the effects jump a bit potentially because of the strong seasonality in spending. Although the trend goes upward following HSR spending, most of the post-treatment monthly dummies are not very precisely estimated. The pattern is much clearer with the number of transactions as the outcome: the bilateral amount of transactions are flat leading up to HSR connection event, start to pick up a few months later, and remain statistically significant from zero since the ninth month after connection. Taken together, these estimates indicate that HSR connection encourages consumers to spend money in another city connected by HSR. The finding that the coefficients grow gradually years after HSR rather than immediately suggests that local consumers adjust their travelling and shopping behavior gradually.

4.2 Indirect travel time changes

We report estimation results from Equation 3 in Table 3 and 4. It is clear that a reduction in travel time leads to significant growth in bilateral transaction value and count with the elasticity of 0.19 and 0.24. The estimated elasticities usually double in specifications with $log(Y + (Y^2 + 1)^{1/2})$ as the outcomes, which suggests large effects at the extensive margins.

In Table 4, we rerun Equation 3 in a sample of city pairs without direct HSR connections. Reductions in travel time among these pairs come from the possibility that residents from one city could travel to another city via an HSR hub, having one leg of the trip on HSR. This specification deals with the identification concern that HSR placement might target at city pairs with improving economic integration. The estimated coefficients are similar to those in Table 3: a one percent drop in travel time leads to 0.19 and 0.14 percent growth in bilateral transaction value and count, respectively. It indicates that the main effects of HSR connection on cross-city consumption operate through reductions in travel cost across cities.

5 Heterogeneity

5.1 Heterogeneity across city pairs

In this section, we explore the heterogeneity of treatment effects of HSR-induced travel time reductions across different types of city pairs. The questions we ask are:

1. Are cities pairs less economically integrated prior to HSR connection gaining more or less from HSR connection?

2. Will HSR impacts be larger for city pairs where the transaction cities are significantly larger than the residence cities? (i.e. If Beijing is connected to Baoding, a smaller city, will the consumption by Baoding residents in Beijing grow more than consumption in the opposite direction?)

To explore these questions we start from Equation 3 by interacting our travel time measure with two sets of variables: (1) Initial transaction value by city pairs (2) Relative sizes of transaction/resident cities: defined as the ratio of the size of transaction city on that of residence city.

Table 5 reports the results on heterogeneity across city pairs with different initial levels of bilateral consumption. I divide the full sample of city pairs into three groups: cities with zero transaction value in 2011, pairs with positive but below median transaction value among all pairs in 2011, and those with positive and above-median transaction value. I then repeat the specification in Equation 3 across these three groups. It is clear that the growth is highest among pairs in the second group: those with positive but below-median initial transaction value. It suggests HSR will be most beneficial for city pairs with existing economic linkages but less than fully integrated at the beginning. One explanation is that the HSR benefits in reducing travel cost are stronger for these pairs because alternative forms of transportation are less developed.

Our next step is to examine whether or not the relative size differences between transaction and residence cities matter. Conceptually, if we are connecting a small city to a much larger city, we might expect residents from the smaller city travel more to the larger one than the other way around. To implement this idea empirically, we introduce a ratio of sizes between destination (the city where transactions take place) city and origin city (the city where consumers live in), Table 6 reports results on interaction terms between HSR-induced reduction in travel time and the size ratio of destination and origin city. The interaction term is negative and significant. In another word, the response to travel time reductions are larger when the destination city is much larger than the city where consumers come from. It suggests that the effects of HSR connection are not symmetric: upon connection, residents

from smaller cities are more likely to increase their consumption in the connected large cities than the other way around. This result has important implications when we estimate the distribution of welfare gains from HSR network across space.

5.2 Heterogeneity across consumption categories

In this section, we consider the heterogeneity of treatment effects across different consumption categories. There are 264 merchant types in total in our data.

We aggregate merchant types into 20 different consumption categories, and conduct our analysis at the pair*month*category level. We repeat the estimation in Equation 1 for these 20 categories on $log(Y_m+(Y_m^2+1)^{1/2})$, where Y_m is bilateral transaction value within category m. We pick this measure because there is a larger share of zeros at the pair*month*category level, and to make our results comparable across categories we try to keep the sample size to be the same for each regression.

Table 7 shows the results. The sectors that experience largest impacts are transportation, car/ship dealership, information services and electronics/appliances. It appears that consumers take the opportunity to visit other cities for services and high-value consumption goods, such as cars and electronics/appliances. Arguably these are sectors featuring relatively large information asymmetries between sellers and buyers, which make the provision of goods benefits from interactions between these two sides of the market.

On the other hand, we find no effect of HSR connection on cross-city electronic shopping and mail orders, which serves as a good placebo test, as travel cost plays no role in electronic shopping and mail ordering where no physical trips are required.

6 Concluding remarks

In this paper, we look at how cross-city consumption behavior responds to improvements in intercity transportation infrastructure by leveraging detailed transaction data on 2.7 billion credit and debit cards. The identification relies on plausibly exogenous variations in travel time across cities over year due to the rapid expansion of the high-speed railway (HSR) network in China. We find that HSR connection leads to significantly higher level of consumption made by consumers from one city in the other. Even for cities pairs that are not directly-connected by HSR, reductions in travel time via transferring through HSR routes still lead to growth in cross-city consumption.

A natural next step of this paper is to quantify the welfare gains from increased consumption variety through the lens of a structural model. The welfare gain could constitute

a key benefit of the HSR system in China. In addition to the aggregate welfare impact, it is important to examine the distributional impact across regions and income from this massive national transportation project .

Table 1: Summary Statistics

Bilateral Card transaction

	Obs	Mean	Variance	Min	Max
Full sample					
Transaction Value (Y)	1,956,691	438969.3	8915559	1.01	1.19E+09
Transaction count (N)	1,958,032	196.111	4909.729	1	679574
Exclude Own city transactions					
	Obs	Mean	Variance	Min	Max
Transaction Value (Y)	1,935,262	82453.49	663243.6	1.01	8.32E+07
Transaction count (N)	1,936,603	35.54825	284.3884	1	31580

Bilateral travel time (hours)

Non-directly-connected City Pairs					
Year	Obs	Mean	Variance	Min	Max
2011	945,168	11.87198	6.794826	0	38.86555
2012	945,168	11.23069	6.360186	0	38.86555
2013	945,168	11.16783	6.375538	0	38.86555
2014	945,168	11.07896	6.366019	0	38.86555
2015	945,168	10.49217	6.040043	0	38.86555

Directly-connected City Pairs					
Year	Obs	Mean	Variance	Min	Max
2011	15,588	3.200037	3.37146	0.0555975	30.40011
2012	15,588	2.692872	2.808059	0.0555975	26.05581
2013	15,588	2.519781	2.781843	0.0555975	26.05581
2014	15,588	2.329033	2.649976	0.0479998	26.05581
2015	15,588	1.93742	1.675605	0.0252716	13.81823

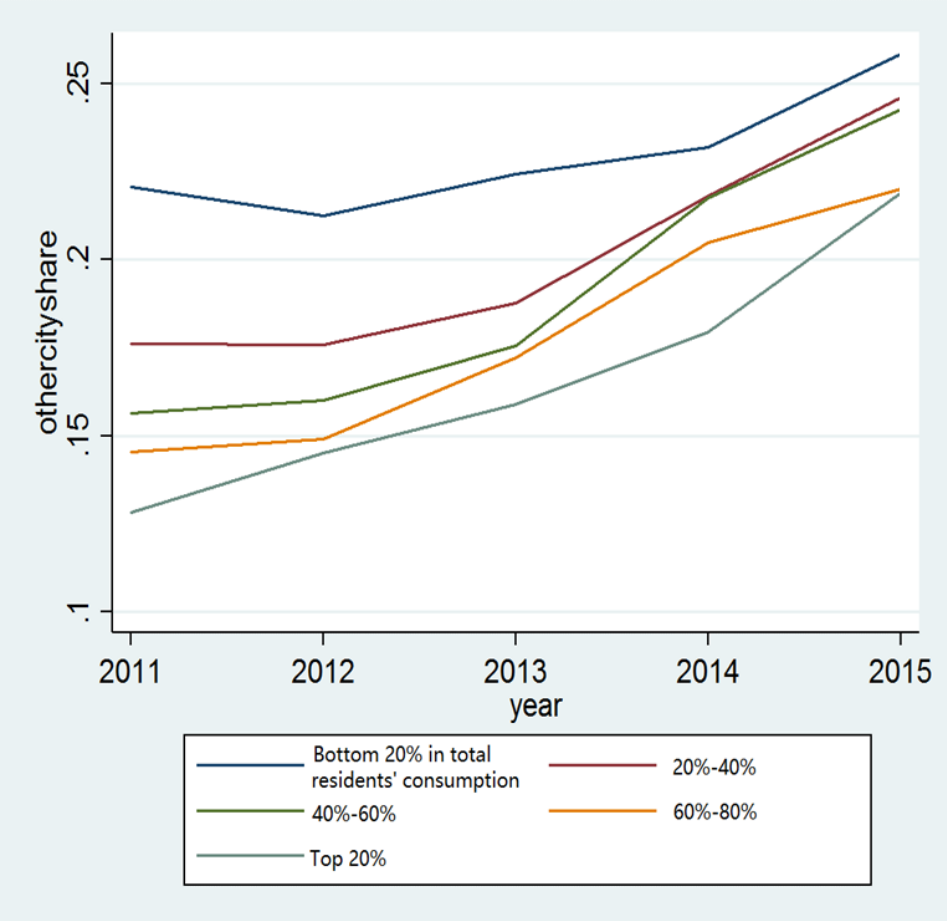


Figure 1: Share of card transaction value in non-resident city: by sizes of resident city

Notes:

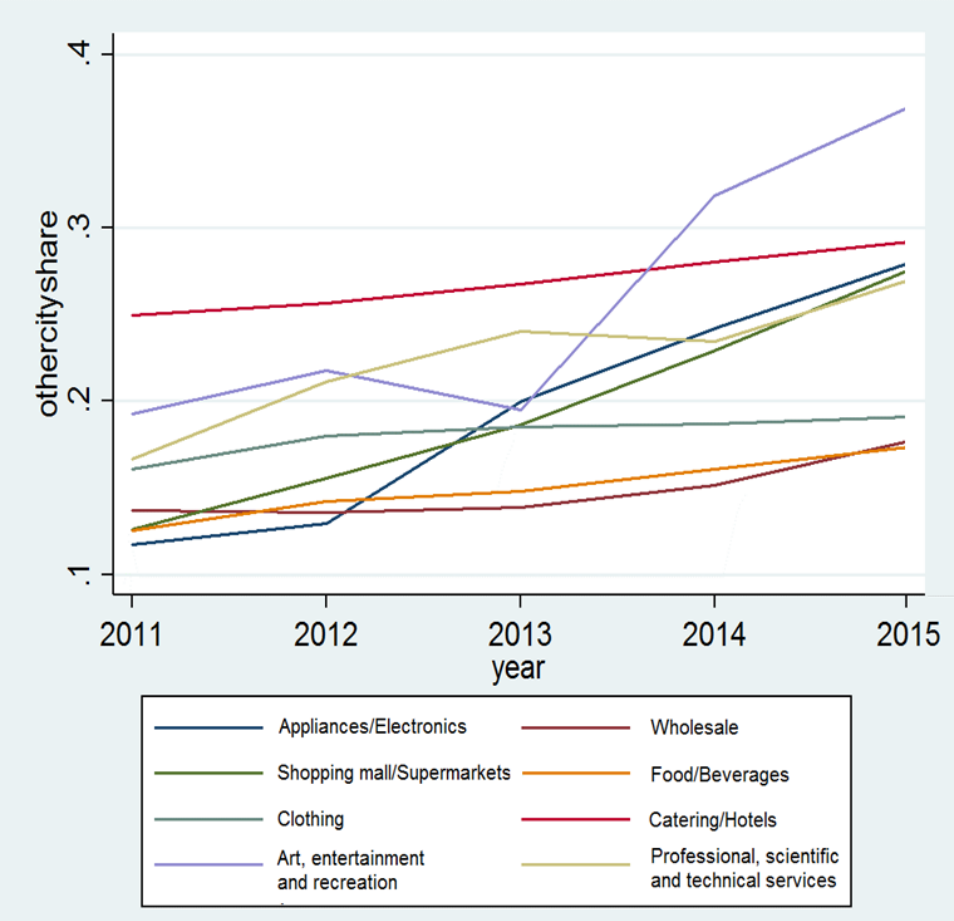


Figure 2: Share of card transaction value in non-resident city: by sectors

Notes:

Table 2: HSR connection and bilateral consumption

Sample	All City Pairs			
VARIABLES Y: Bilateral Transaction Value N: Bilateral Transaction Count	log(Y)	log(N)	$log(Y + (Y^2 + 1)^{1/2})$	$log(N + (N^2 + 1)^{1/2})$
connect	0.0953*	0.240***	0.130	0.318***
	(0.0529)	(0.0396)	(0.141)	(0.0523)
Bilateral pair FE	Y	Y	Y	Y
Origin city*Monthly FE	Y	Y	Y	Y
Destination city*Monthly FE	Y	Y	Y	Y
Observations	1,946,559	1,947,906	6,323,149	6,323,149
R-squared	0.676	0.878	0.661	0.864

Notes:Bilateral transaction value (Y) is the aggregate value of credit/debit card transactions incurred by consumers from origin city at destination city. Bilateral transaction count (N) is the total number of card transactions. Connect is a dummy that switches to one if the origin and destination city is connected by HSR.

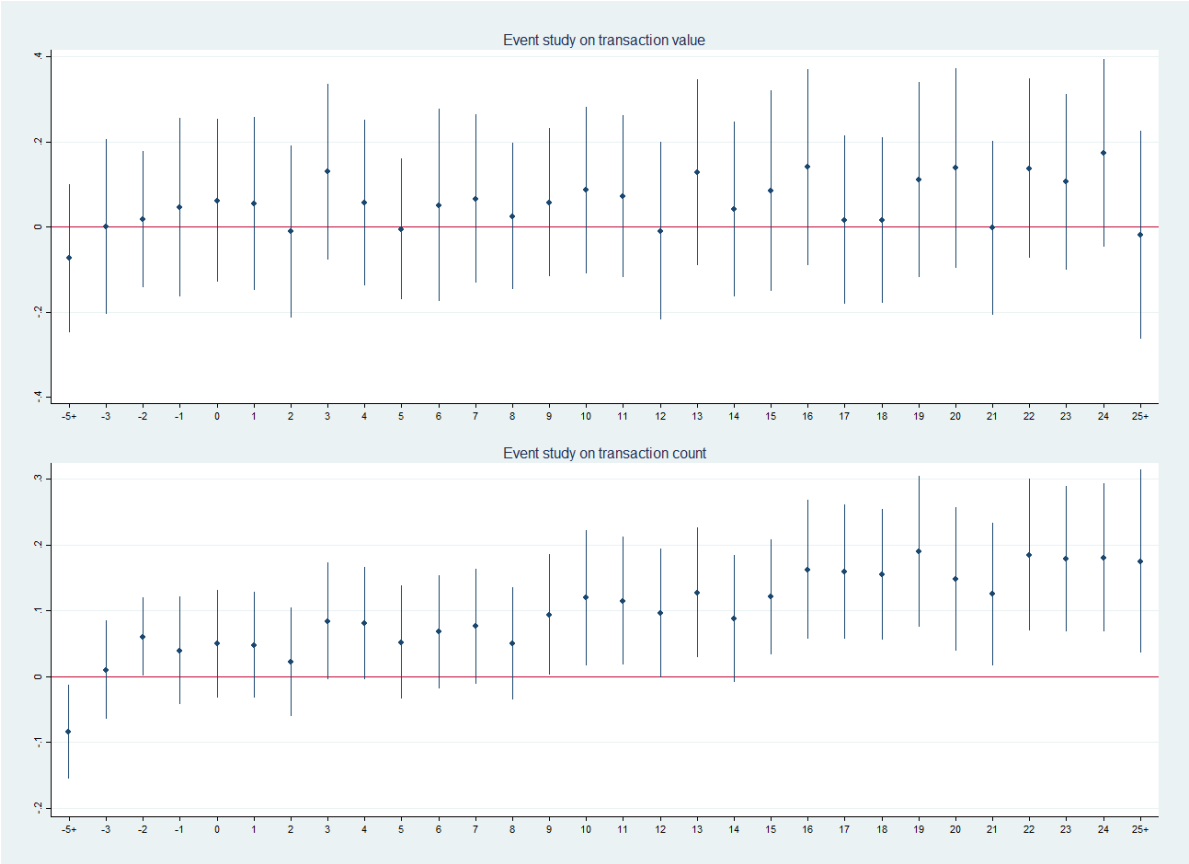


Figure 3: Bilateral transaction value: Monthly Event Study

Notes:T

Table 3: Travel time and bilateral consumption: All city pairs

Sample	All City Pairs			
VARIABLES Y: Bilateral Transaction Value N: Bilateral Transaction Count	log(Y)	log(N)	$log(Y + (Y^2 + 1)^{1/2})$	$log(N + (N^2 + 1)^{1/2})$
log(travel time)	-0.186***	-0.235***	-0.362***	-0.277***
	(0.0512)	(0.0374)	(0.118)	(0.0441)
Bilateral pair FE	Y	Y	Y	Y
Origin city*Monthly FE	Y	Y	Y	Y
Destination city*Monthly FE	Y	Y	Y	Y
Observations	1,666,361	1,667,492	5,107,584	5,107,584
R-squared	0.649	0.859	0.686	0.858

Notes:The sample includes monthly observations of all 285*285 city pairs. Bilateral transaction value (Y) is the aggregate value of credit/debit card transactions incurred by consumers from origin city at destination city. Bilateral transaction count (N) is the total number of card transactions. Travel time is defined by the shortest time to travel between the origin and destination city, which changes following direct or indirect HSR connections.

Table 4: Travel time and bilateral consumption: Non-directly connected pairs

Sample	Non-directly connected pairs			
VARIABLES Y: Bilateral Transaction Value N: Bilateral Transaction Count	log(Y)	log(N)	$log(Y + (Y^2 + 1)^{1/2})$	$log(N + (N^2 + 1)^{1/2})$
log(travel time)	-0.193***	-0.147***	-0.503***	-0.194***
	(0.0554)	(0.0355)	(0.126)	(0.0412)
Bilateral pair FE	Y	Y	Y	Y
Origin city*Monthly FE	Y	Y	Y	Y
Destination city*Monthly FE	Y	Y	Y	Y
Observations 1,598,887	1,600,005	5,030,208	5,030,208	
R-squared	0.621	0.839	0.672	0.842

Notes:The sample includes monthly observations of city pairs that have not been connected by HSR by the end of 2015. Bilateral transaction value (Y) is the aggregate value of credit/debit card transactions incurred by consumers from origin city at destination city. Bilateral transaction count (N) is the total number of card transactions. Travel time is defined by the shortest time to travel between the origin and destination city, which changes following direct or indirect HSR connections.

Table 5: Heterogeneity across initial transaction levels

Column	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Pairs with zero initial transactions		Positive below-median initial transactions		Positive above-median initial transactions	
VARIABLES	log(Y)	$log(Y+(Y^2+1)^{1/2})$	log(Y)	$log(Y+(Y^2+1)^{1/2})$	log(Y)	$log(Y+(Y^2+1)^{1/2})$
log(traveltime)	0.0238	-0.488***	-0.443***	-0.951***	-0.0308	0.201***
	(0.130)	(0.109)	(0.104)	(0.170)	(0.0452)	(0.0742)
Bilateral pair FE	Y	Y	Y	Y	Y	Y
Origin city*Monthly FE	Y	Y	Y	Y	Y	Y
Destination city*Monthly FE	Y	Y	Y	Y	Y	Y
Observations	213,946	2,489,856	414,035	1,255,232	1,037,719	1,362,304
R-squared	0.399	0.277	0.378	0.394	0.687	0.657

Notes:Bilateral transaction value (Y) is the aggregate value of credit/debit card transactions incurred by consumers from origin city at destination city. Bilateral transaction count (N) is the total number of card transactions. Travel time is defined by the shortest time to travel between the origin and destination city, which changes following direct or indirect HSR connections. Columns (1) and (2) include city pairs with no card transactions in 2011. Columns (3) and (4) include city pairs with below-median positive transaction value, and columns (5) and (6) include pairs with above-median positive value.

Table 6: Heterogeneity: Different Origin/Destination size ratio

Sample	All city pairs		Non-directly connected pairs	
VARIABLES	log(Y)	$log(Y + (Y^2 + 1)^{1/2})$	log(Y)	$log(Y + (Y^2 + 1)^{1/2})$
log(traveltime)	-0.0888*	-0.0226	-0.129**	-0.253*
	(0.0524)	(0.124)	(0.0617)	(0.130)
log(traveltime)#Dest/Ori size ratio	-0.00381*	-0.0271***	-0.00517**	-0.0300***
	(0.00229)	(0.00545)	(0.00218)	(0.00558)
	(1.05e-06)	(1.13e-06)	(9.86e-07)	(1.06e-06)
Bilateral pair FE	Y	Y	Y	Y
Origin city*Monthly FE	Y	Y	Y	Y
Destination city*Monthly FE	Y	Y	Y	Y
R-squared	0.650	0.688	0.622	0.673

Notes:Bilateral transaction value (Y) is the aggregate value of credit/debit card transactions incurred by consumers from origin city at destination city. Bilateral transaction count (N) is the total number of card transactions. Travel time is defined by the shortest time to travel between the origin and destination city, which changes following direct or indirect HSR connections. Dest/Ori size ratio is the ratio of total transaction value incurred in destination(transaction) city and that incurred in origin(resident) city.

Table 7: Heterogeneity across merchant types

Outcome: $log(Y + (Y^2) + 1)^{1/2})$ Y: Bilateral Transaction Value					
Categories	Transportation	Agriculture services	Electronics/ appliances	Wholesale	Shopping mall/ supermarkets
connect	0.774***	0.204***	0.512***	0.279***	0.143***
	(0.0826)	(0.0383)	(0.0662)	(0.0901)	(0.0425)
Bilateral pair FE	Y	Y	Y	Y	Y
Origin*month FE	Y	Y	Y	Y	Y
Destination*month FE	Y	Y	Y	Y	Y
Observations	6,323,149	6,323,149	6,323,149	6,323,149	6,323,149
R-squared	0.596	0.387	0.597	0.596	0.625
Categories	food/beverages	car/ship dealers	fashion retailer	catering and hotels	sporting goods, book and music
connect	-0.0336	0.538***	0.139***	0.125**	0.164***
	(0.0707)	(0.0939)	(0.0508)	(0.0498)	(0.0307)
Bilateral pair FE	Y	Y	Y	Y	Y
Origin*month FE	Y	Y	Y	Y	Y
Destination*month FE	Y	Y	Y	Y	Y
Observations	6,323,149	6,323,149	6,323,149	6,323,149	6,323,149
R-squared	0.648	0.647	0.628	0.644	0.579
Categories	art/entertainment and recreation	medical service	personal/household services	Car repair maintenance	Other retailers
connect	0.0992**	0.167***	0.106***	0.188***	0.242***
	(0.0470)	(0.0347)	(0.0293)	(0.0503)	(0.0373)
Bilateral pair FE	Y	Y	Y	Y	Y
Origin*month FE	Y	Y	Y	Y	Y
Destination*month FE	Y	Y	Y	Y	Y
Observations	6,323,149	6,323,149	6,323,149	6,323,149	6,323,149
R-squared	0.577	0.576	0.605	0.555	0.583
Categories	Finance and insurance	Information	Professional and technical services	Educational services	electronic shopping and mail orders
connect	0.451***	0.521***	0.239***	0.0630***	-0.0249
	(0.0648)	(0.0498)	(0.0545)	(0.0235)	(0.0208)
Bilateral pair FE	Y	Y	Y	Y	Y
Origin*month FE	Y	Y	Y	Y	Y
Destination*month FE	Y	Y	Y	Y	Y
Observations	6,323,149	6,323,149	6,323,149	6,323,149	6,323,149
R-squared	0.682	0.638	0.548	0.540	0.419

Notes:

References

[1] Agarwal, Sumit and Jensen, J. Bradford and Monte, Ferdinando, The Geography of Consumption, Working Paper 2017

[2] Ahlfeldt, Gabriel M., and Arne Feddersen. *From periphery to core: economic adjustments to high speed rail.* (2010).

[3] Agrawal, Ajay, Alberto Galasso, and Alexander Oettl. "Roads and Innovation." Rotman School of Management Working Paper 2478752 (2014).

[4] Baum-Snow, Nathaniel. *Did highways cause suburbanization?.* Quarterly Journal of Economics 122.2 (2007): 775-805.

[5] Baum-Snow, Nathaniel. "Urban Transport Expansions, Employment Decentralization, and the Spatial Scope of Agglomeration Economies." (2014).

[6] Baum-Snow, N., Brandt, L., Henderson, J. V., Turner, M. A., Zhang, Q. (2015). Roads, Railroads and Decentralization of Chinese Cities.

[7] Bernard, A B, A Moxnes, and Y U Saito (2014a) "Geography and Firm Performance in the Japanese Production Network", RIETI Discussion Paper 14-E-034.

[8] Christiaan Behrens and Eric Pels, "Intermodal competition in the London-Paris passenger market: High-speed rail and air transport," Journal of Urban Economics, online 29 December 2011

[9] Bullock, Richard Harvey, Andrew Salzberg, and Ying Jin. *High-speed Rail–the First Three Years: Taking the Pulse of China's Emerging* Program. No. China Transport Topics No. 04. World Bank., 2012.

[10] Burgess, Robin, and Dave Donaldson. *Can Openness Mitigate the Effects of Weather Fluctuations? Evidence from India's Famine Era.* (2010).

[11] Couture, V. (2016). Valuing the Consumption Benets of Urban Density, Working paper.

[12] Davis, D., J. Dingel, J. Monras, and E. Morales (2016). How Segregated is Urban Consumption?, Working paper.

[13] Donaldson, Dave. *Railroads of the Raj: Estimating the impact of transportation infrastructure.* forthcoming, American Economic Review, 2014.

[14] Donaldson, Dave, and Richard Hornbeck. *Railroads and American economic growth: A "market access" approach*. No. w19213. National Bureau of Economic Research, 2013.

[15] Duranton, Gilles, and Matthew A. Turner. *Urban growth and transportation.* Review of Economic Studies 79.4 (2012): 1407-1440.

[16] Faber, Benjamin. *Trade Integration, Market Size and Industrialization: Evidence from China's National Trunk Highway System.* forthcoming, Review of Economic Studies, 2014.

[17] Glaeser, E., J. Kolko, and A. Saiz (2001). Consumer City, Journal of Economic Geography, Vol. 1, pp. 27-50.

[18] Handbury, J., I. Rahkovsky, and M. Schnell (2016). Is the Focus on Food Deserts Fruitless? Retail Access and Food Purchases Across the Socioeconomic Spectrum, Working paper.

[19] Michaels, Guy. *The effect of trade on the demand for skill: evidence from the Interstate Highway System.* Review of Economics and Statistics 90.4 (2008): 683-701.

[20] Zheng, Siqi, and Matthew E. Kahn. *China's bullet trains facilitate market integration and mitigate the cost of megacity growth.* Proceedings of the National Academy of Sciences 110.14 (2013): E1248-E1253.