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Who Will Be Affected by a Congestion Pricing Scheme in Beijing?

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Abstract

Equity concerns have been an important obstacle to adopting congestion pricing, in both developed and developing countries. However, the existing evidence on the equity effects of congestion pricing has come only from developed countries. In this paper, we shed light on the distributional consequences of a congestion pricing scheme currently under consideration in Beijing. We find that under this scheme, which covers the areas within the city's third ring road, a very small proportion of motorized trips would be subject to the full congestion charge. The directly affected individuals typically have higher household incomes and are wealthier than individuals who are not directly affected by the congestion pricing scheme. This finding reflects the fact that individuals who drive to work in Beijing are relatively wealthy. More important, we find that the Suits index for the congestion charge is 0.027, indicating that the congestion charge is slightly progressive.

Keywords: congestion pricing, distributional concerns, equity

JEL Classification: H23 (Externalities and Redistributive Effects)

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Introduction

Transportation experts strongly recommend congestion pricing for reducing traffic congestion, and experiences in London, Singapore, and Stockholm have demonstrated its efficacy (e.g., Leape 2006; Olszewski and Xie 2005; Börjesson et al. 2012). By reducing automobile use, congestion pricing can also generate environmental benefits (e.g., Anas and Lindsey 2011). Despite these benefits, however, only a few cities in developed countries, and no cities in developing countries, have adopted this policy. In contrast, a considerable number of cities in developing countries have implemented driving restrictions, under which certain vehicles cannot be used at certain times (Wang et al. 2014). Cities adopt driving restrictions instead of congestion pricing largely because rationing is considered more equitable and thus more politically acceptable (Rouwendal and Verhoef 2006; de Grange and Troncoso 2011). Indeed, Karlström and Franklin (2009, 283) write that equity effects have long been recognized as the Achilles heel of congestion pricing "because the rich or otherwise privileged are likely to be more able to cope with the toll than the poor or those who are otherwise disadvantaged, either by paying the toll or by adjusting behavior." Studies of the equity effects of congestion pricing have focused on cities in developed countries. See Eliasson and Mattsson (2006, section 2) for a summary of the literature.

Largely because of equity concerns, the Beijing municipal government has also been using rationing policies, including driving restrictions (Viard and Fu 2015; Wang et al. 2014) and vehicle purchase restrictions (Yang et al. 2014) instead of congestion pricing. However, a congestion pricing scheme in Beijing may not be regressive in practice. In fact, private car owners in China are relatively wealthy, and Cao (2011) finds that taxing motor fuels in China is quite progressive. In this paper, we analyze the potential equity effects of congestion pricing by characterizing the Beijing residents who will be directly affected by a possible congestion pricing scheme and by using the Suits index to measure the progressivity of the congestion charge.

The extraordinarily high air pollution levels that often occur in Beijing have recently prompted the Beijing municipal government to explore the possibility of using congestion pricing to reduce driving (Beijing Municipal Government 2013). In particular, the Beijing government is considering the following scheme. Beijing has a set of concentric ring roads around the city center and the charging zone would be within the third ring road. Vehicles driving into this zone at any time are charged 8 Renminbi (RMB; roughly $1.25) each time they enter. Private and government- or company-owned automobiles, shuttles, and taxis will all be charged, but buses will be exempt. Residents living within the third ring are eligible for a 90 percent discount.

To investigate the distributional effects of this congestion charge scheme, we characterize the economic and social characteristics of the individuals who would be directly affected by the congestion pricing scheme. We also study the percentage of motorized travel that would be directly affected by the congestion pricing scheme. Our analysis covers commuting trips, school trips, and discretionary trips. Consistent with our focus on the characteristics of the directly affected individuals, Eliasson and Mattsson (2006) conclude that, in the case of Stockholm, the two most important factors for determining the equity effects of congestion pricing are who is directly affected by the charge (i.e., the first-order vertical equity) and how revenues are used. In this paper, we focus on the first-order vertical equity impacts of the congestion charge, and we leave the second-order or horizontal equity impacts for future research.[1]

Using household survey data from 2010, we find that only about 5 percent of motorized trips in Beijing will be directly affected by the congestion pricing scheme. More important, the directly affected individuals tend to be wealthier than those who are not directly affected. The directly affected individuals tend to live in households that have higher annual income and more living space per household member, and they tend to be better educated and more likely to be male. We find similar results for school trips: individuals who use cars or taxis to go to school inside the third ring road tend to come from wealthier households. We also find that regardless of where they live in Beijing, individuals who drive to work have higher household income, live in larger residences, are better educated, and are more likely to be male than individuals who are employed but do not drive to work. Thus, our evidence suggests that congestion pricing in Beijing will affect the rich or the privileged more than others. In addition, we find that the Suits index of the congestion charge scheme is 0.027, indicating that it is slightly progressive.

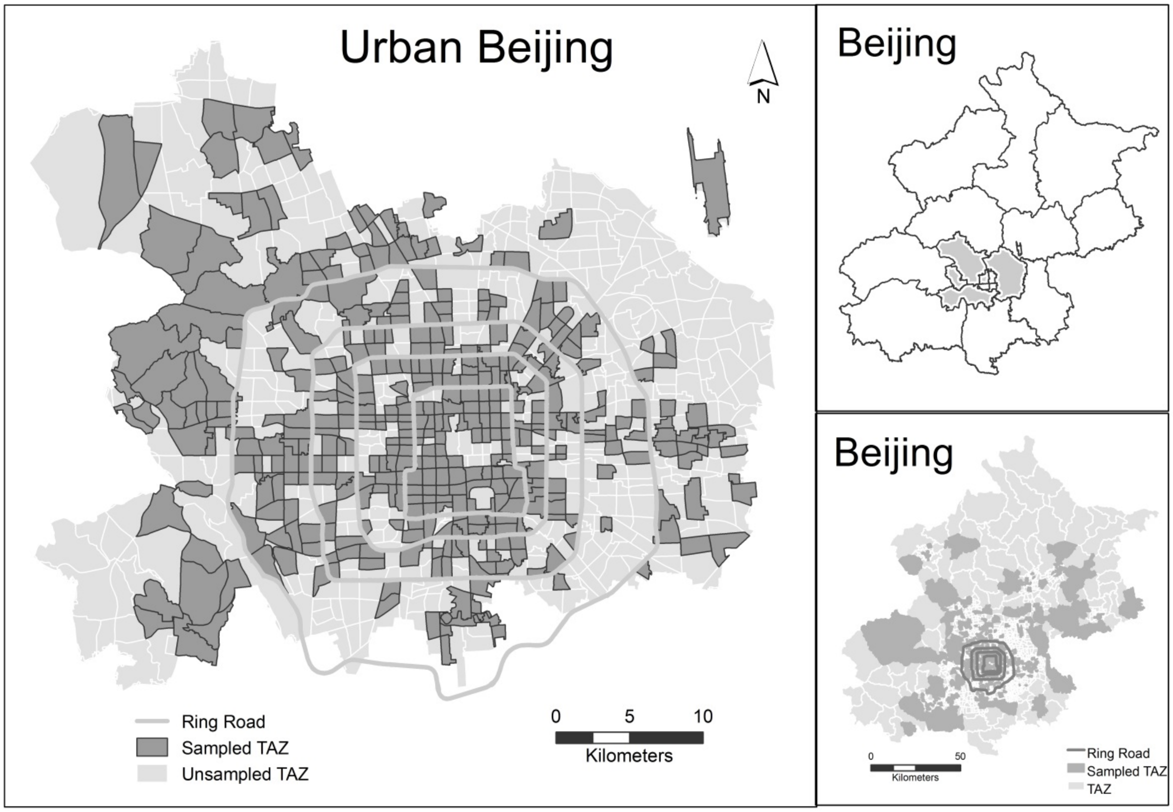
Data

Our analysis is based on the 2010 Beijing Household Travel Survey conducted by the Beijing Transportation Research Center (BTRC), an agency of the Beijing municipal government. The BTRC has conducted annual household travel surveys for many years, and the Beijing municipal government uses these surveys to understand Beijing residents' travel behavior and to inform transportation policies. Academic researchers have also used the survey data to analyze transportation in Beijing (e.g., Wang et al. 2014).

We focus on the 2010 survey because of its large sample size. The 2010 survey adopts a multistage sampling strategy with the target of a 1 percent sampling rate. The BTRC randomly selects 642 traffic analysis zones (TAZs) of the 1,911 in the entire city. TAZs are geocoded areas defined by the BTRC for traffic analysis. Each of the administrative districts in Beijing has 16 to 238 TAZs, based on the size of the area and the population of the district. TAZs are smaller in districts with higher population densities. The average TAZ is about 1.5 square kilometers. In the inner eight districts, on which the sampling focuses, TAZs range from 0.21 to 16 square kilometers. On average, about 75 households in each TAZ are randomly selected for in-person interviews to collect data on trips taken during a designated 24-hour period (the household's travel day). Figure 1 shows the sampled and unsampled TAZs in Beijing; the surveyed TAZs are distributed evenly within each ring road.

[1] Second-order impacts refer to changed traffic flow and individuals' adjustment of their travel behavior. Horizontal equity refers to the extent to which individuals within a class (e.g., income, gender, ability, and race) are treated similarly (Levinson 2010).

Figure 1. Traffic analysis zones in Beijing



The survey gathers (1) information about each segment of a trip taken by each member of a household during the household's travel day, including travel purpose (e.g., going to work), travel mode (e.g., automobile), time when the travel began and ended, and the TAZ codes of the origin and the destination; (2) household information, including the TAZ code of the residence, vehicle ownership, household income, whether renting or owning the housing, and if owning, the size and building type of the housing; and (3) household member information, including gender, age, occupation, whether possessing a driver's license, whether employed, and if employed, the TAZ code of the workplace.

Findings

We focus on the directly affected individuals because they must either pay the congestion charge or switch to other transport modes, at least in the short run. We consider whether the directly affected individuals tend to have low income or wealth. To provide context for this analysis, we first estimate the fraction of trips that will be directly affected by the congestion charge.

A Small Share of Beijing Commuters Would Be Directly Affected

The full sample includes 140,395 trips[2] made by 88,304 individuals from 43,772 households.[3] Of the full sample of trips, 43 percent are motorized trips. Of these, only 5 percent involve driving (or taking a taxi) into the third ring road and thus will be directly affected by the congestion charge. Of these directly affected trips, 48 percent are work trips,[4] 5 percent are business trips, 5 percent are school trips, and the other 42 percent are discretionary, including trips to stores, restaurants, gyms, parks, banks, or hospitals, and trips to visit friends or relatives.

To provide further context for commuters, we estimate the percentage of employed individuals who will be directly affected by the congestion charge. Of the 41,078 employed individuals in our sample,[5] only 3.1 percent live outside but drive to work within the third ring. Since 6.4 percent of these 1,276 individuals have access to government- or company-owned cars, and many of them can avoid the congestion charge, just 2.9 percent of employed individuals will be directly affected by the congestion pricing scheme. In our sample, 11 percent of the employed population live outside and work inside the third ring but do not drive to work. That is, 14 percent of the employed live outside but work inside the third ring, and 23 percent of these individuals drive (or take a taxi) to work. For comparison, 20 percent of our sample live and work within the third ring, 57 percent both live and work outside the third ring, and 10 percent live inside but work outside the third ring. This last group needs to pay 10 percent of the congestion charge when they drive home from work.

Directly Affected Commuters Tend to Be Wealthy

We compare the characteristics of the directly affected commuters with those of two comparison groups of individuals: (1) those who live outside and work within the third ring but do not drive to work; and (2) the full sample of employed individuals minus the directly affected group. The congestion charge does not directly affect, but could indirectly affect, the behavior of individuals in these comparison groups. For example, if the congestion charge reduces congestion, the lower time cost of driving could induce some individuals in the comparison groups to drive. Analyzing such responses, however, is outside the scope of the paper.

Compared with either of the two comparison groups of individuals, as shown in Table 1, the directly affected individuals, on average, have higher household income and larger living space, are more likely to own their residence, are better educated, and are more likely to be male. The directly affected individuals, on average, are about one year older than those who live outside and work within the third ring but do not drive to work, and they are about one year younger than the full sample of employed individuals (excluding the directly affected individuals).

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[2] These trips do not include the return leg of a round trip. The purpose of the return leg is often missing in the survey.

[3] The survey covered 116,142 individuals from 46,900 households. Some individuals did not make any trips in the designated 24 hours.

[4] Our classification of trips is based on the answers to the following question: What is the purpose of your trip? “Working” and “business trips” are two options listed in the survey answers. It is possible that some survey subjects may have chosen the answer of “working” for both commuting and business trips.

[5] The survey covers 49,634 employed individuals. Some individuals did not make work trips on the survey day.

Table 1. Comparing directly affected commuters with two other groups

	1	2	3	4	5
	Directly affected group (group 1)	Individuals who enter 3rd ring to work other than directly affected group (group 2)	p-value of comparing group 1 and group 2 means	Full sample of employed other than directly affected group (group 3)	p-value of comparing group 1 and group 3 means
Observations	1,276	4,361		39,802	
Year of birth	1973	1975	0.000	1972	0.000
Male	0.63	0.50	0.000	0.54	0.000
Head	0.43	0.40	0.075	0.43	0.979
Education (0–8 levels)	6.19	5.89	0.000	5.45	0.000
Number of autos per household	1.07	0.29	0.000	0.40	0.000
Proportion having access to government or company car	0.06	0.01	0.000	0.02	0.000
Household income (1–7 levels)	2.16	1.70	0.000	1.62	0.000
Housing size (square meters)	91.29	74.98	0.000	78.23	0.000
Housing size per household member (square meters)	37.00	30.29	0.000	31.00	0.000
Proportion who are homeowners	0.79	0.66	0.000	0.66	0.000
Commute distance (kilometers)	12.15	12.54	0.139	7.04	0.000
Bus station density at home TAZ	44.06	47.88	0.001	48.45	0.000
Bus station density at work TAZ	68.46	67.98	0.707	49.47	0.000

Notes: Number of observations is the number of observed individuals, not trips. Some individuals make more than one work trip on the survey day. Therefore, the number of observed trips is larger than the number of observed individuals. The three groups make 1,283, 4,402, and 44,529 trips, respectively. The household income groups are explained in Section 3.6, below.

The directly affected individuals, on average, have the same commuting distance as those who live outside and work inside the third ring but do not drive to work. However, the directly affected individuals live in TAZs with a lower density of bus stops, where the density of bus stops in a TAZ is defined as the number of bus stops in the TAZ divided by the size of the TAZ in square kilometers. A possible explanation for this result is that the directly affected individuals, who have higher incomes and are better educated, choose to live in larger residences that are located farther from public transportation.

Figure 2. Household income distribution of employed

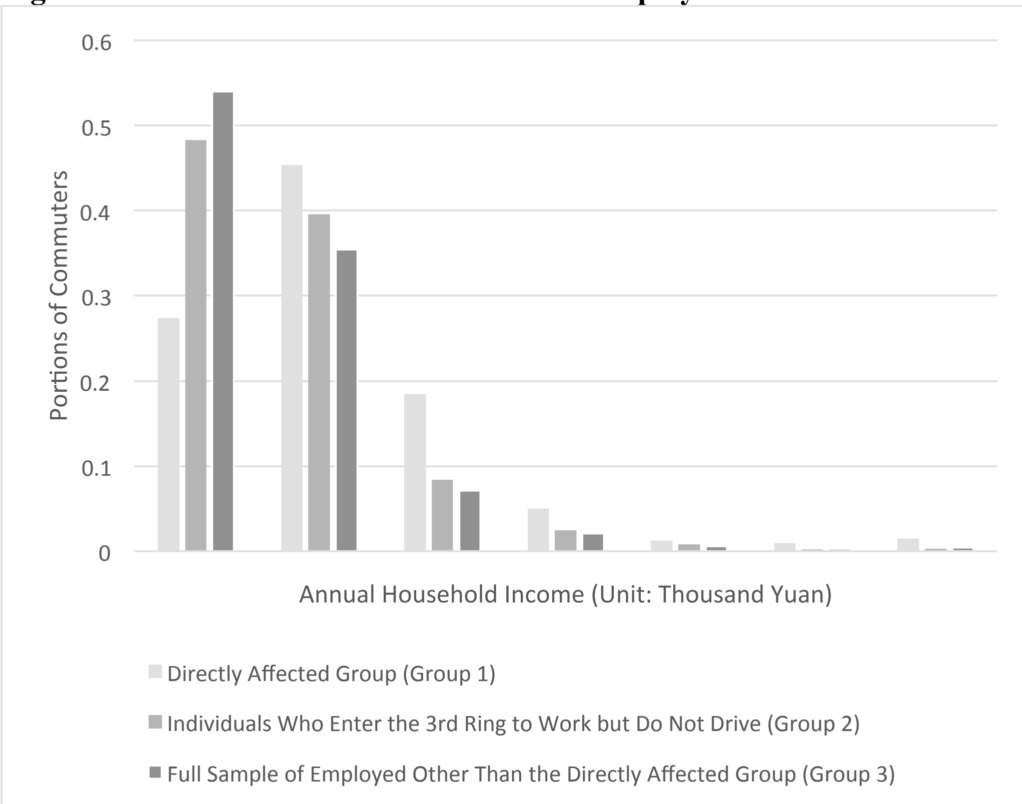


Figure 2 compares the income distribution of the households in which the directly affected individuals and the two comparison groups of individuals live. It illustrates that 54 percent of the full sample, other than the directly affected individuals, and 48 percent of those who live outside and work inside the third ring but do not drive to work have annual household incomes of less than 50,000 RMB. In contrast, only 27 percent of directly affected individuals have incomes of less than 50,000 RMB. Furthermore, the share of directly affected individuals who have annual household incomes of more than 100,000 RMB is more than twice the share of such individuals in the two comparison groups. These observations are further evidence that the directly affected individuals have much higher incomes than the two comparison groups of individuals.

Figure 3. Residence size distributions of three groups of individuals

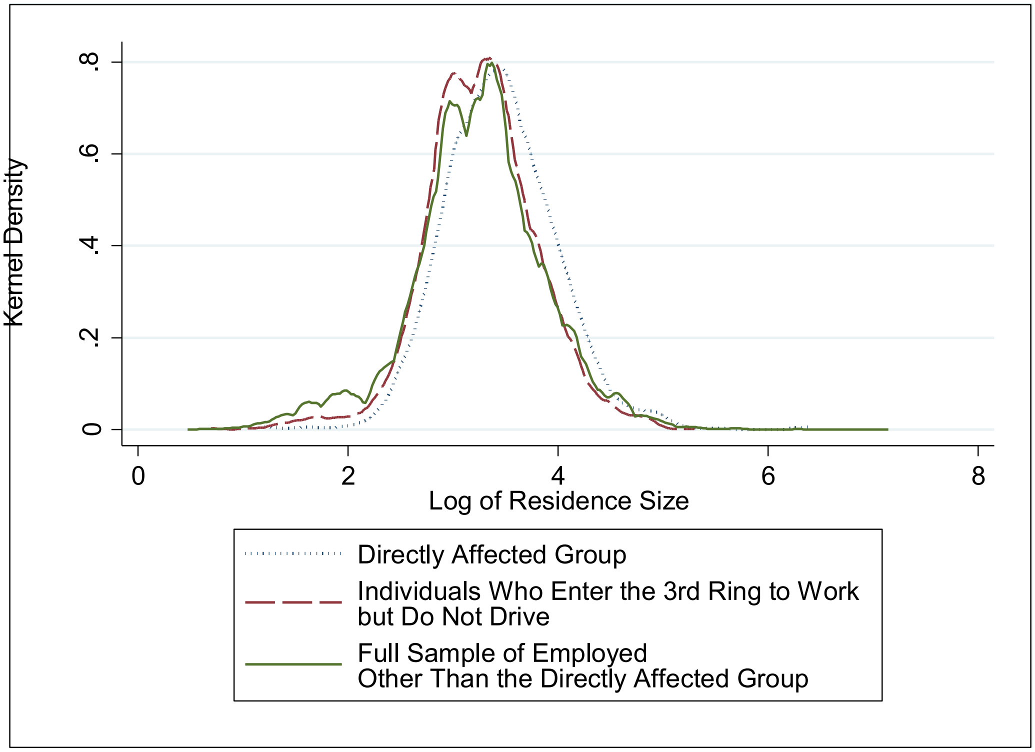
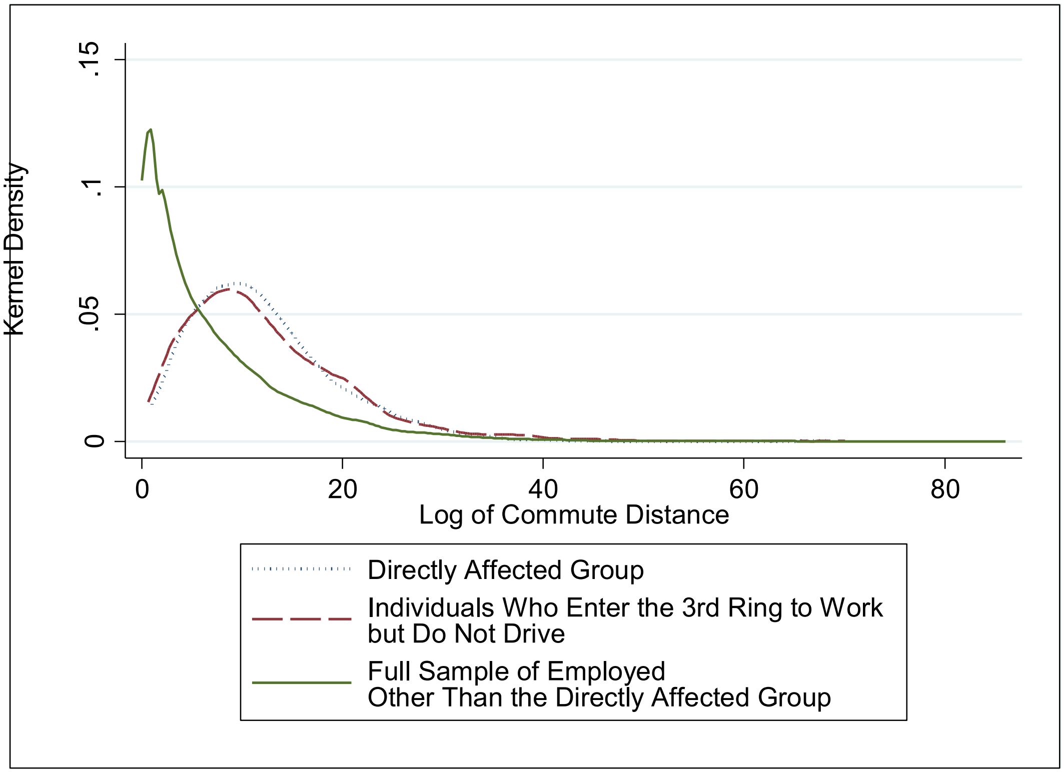


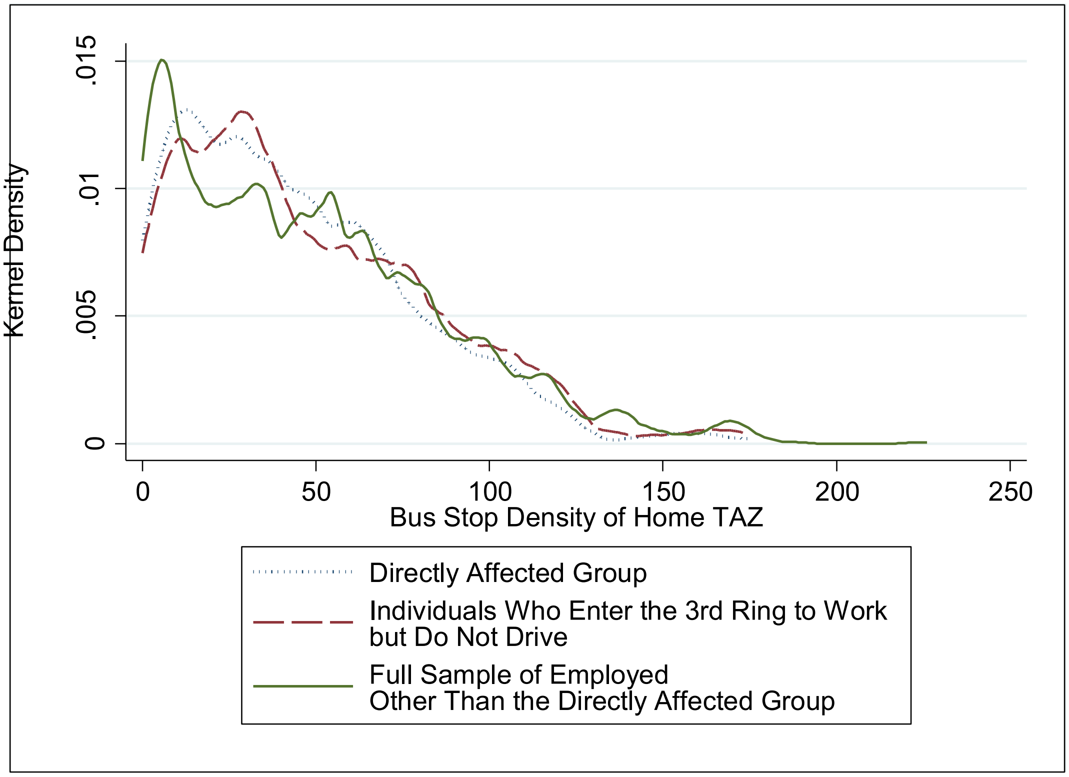
Figure 3 shows the estimated kernel density functions of log residence size. The distribution of the directly affected individuals generally lies to the right of the distributions of the two comparison groups of individuals. The figure indicates that the cross-group differences in mean residence size, which Table 1 reports, are not driven by outliers. Figure 4 shows that the full distribution of commute distance, not only the average, of the directly affected individuals is very similar to that of those who live outside and work inside the third ring but do not drive to work. Even though the directly affected individuals, on average, live in TAZs with a lower density of bus stops, Figure 5 shows that the distribution of bus stop density for the home TAZs of the directly affected individuals is not dramatically different from that for the home TAZs of those who live outside and work inside the third ring but do not drive to work.

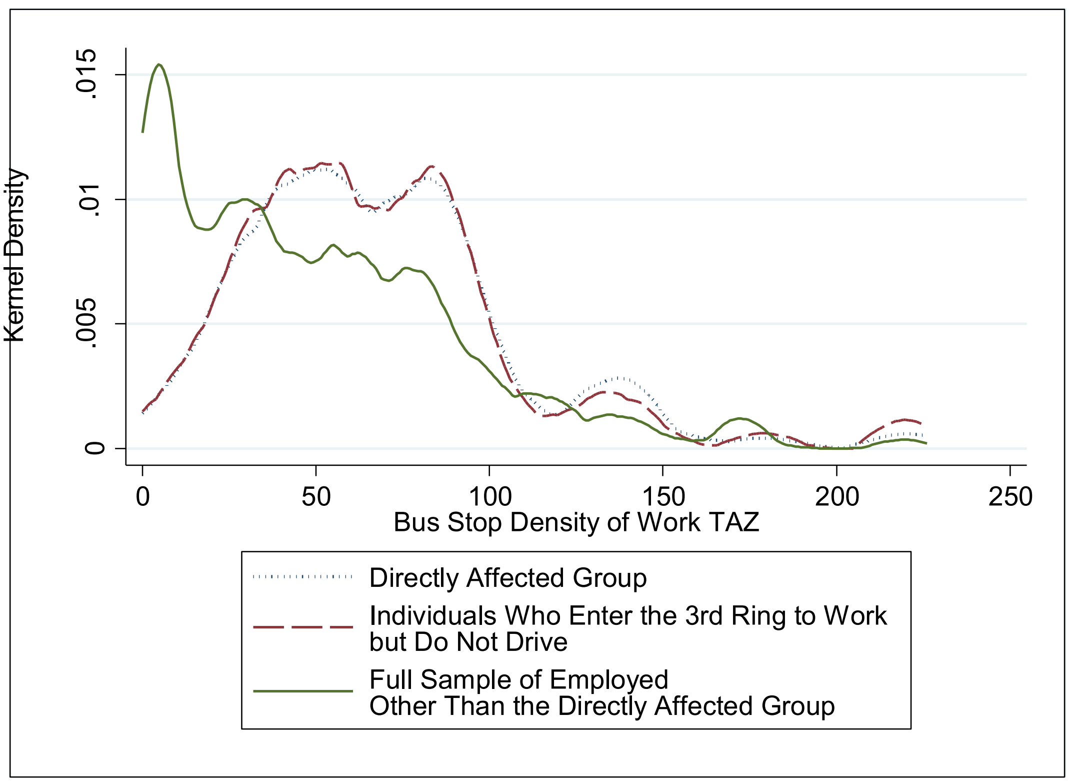
Figure 4. Commute distance distribution of employed



Notes: Of the employed population, 16 percent, accounting for 6,463 trips, have zero commute distance because they live and work in the same TAZ.

Figure 5. Bus stop density distribution of the employed





Directly Affected Individuals Making Discretionary Trips Tend to Be Wealthy

A total of 46,552 individuals in our sample make 76,443 discretionary trips. Of these individuals, only 2 percent drive into the third ring to make discretionary trips and therefore will be directly affected by the congestion charge. About 5 percent of these directly affected individuals have access to a government or company car. Table 2 compares these directly affected individuals with two comparison groups: those who make discretionary trips that enter the area within the third ring but not by car or taxi, and the full sample of individuals who make discretionary trips other than those directly affected.

As with the directly affected commuters, the individuals making discretionary trips have higher incomes and larger homes, own more automobiles, and are more educated than the individuals who make discretionary trips but are not directly affected. One difference between the individuals making discretionary trips and the commuters is that the former are not more likely to own homes than the comparison groups. Otherwise, we reach a similar conclusion as for the commuters, that the congestion pricing scheme will directly affect individuals who are relatively wealthy.

Table 2. Comparing individuals who make discretionary trips

	1	2	3	4	5
	Directly affected group (group 1)	Individuals who make discretionary trips that cross 3rd ring but do not drive (group 2)	p-value of comparing group 1 and group 2 means	Full sample of individuals who make discretionary trips other than directly affected group (group 3)	p-value of comparing group 1 and group 3 means
Observations	772	2,155		45,780	
Year of birth	1968	1959	0.000	1959	0.000
Male	0.60	0.42	0.000	0.44	0.000
Head	0.50	0.53	0.142	0.52	0.160
Education (0–8 levels)	5.50	4.72	0.000	4.40	0.000
Number of autos per household	0.91	0.24	0.000	0.32	0.000
Proportion having access to government/company car	0.05	0.01	0.000	0.01	0.000
Household income (1–7 levels)	1.98	1.45	0.000	1.46	0.000
Housing size (square meters)	92.23	74.21	0.000	77.13	0.000
Housing size per household member (square meters)	35.33	32.07	0.010	31.92	0.001

Proportion who are homeowners	0.72	0.72	0.705	0.72	0.955
Trip distance (kilometers)	12.87	10.02	0.000	3.33	0.000
Bus station density at origin TAZ	44.63	51.22	0.000	51.81	0.000
Bus station density at destination TAZ	90.38	84.95	0.268	53.37	0.000

Notes: Number of observations is the number of observed individuals, not trips. Some individuals make more than one discretionary trip on the survey day. Therefore, the number of observed trips is larger than the number of observed individuals. The three groups make 1,346, 3,035, and 75,097 discretionary trips respectively. The household income groups are explained in Section 3.6, below.

Few School Trips Will Be Affected

A total of 6,702 individuals in our sample are of school age, defined as 7 to 20 years old. Of these individuals, only 2 percent live outside the third ring but take a car or taxi to go to a school inside the third ring. About 6 percent of these individuals live in households having access to a government or company car. Table 3 compares these directly affected students with two comparison groups: those students who live outside and go to a school inside the third ring but do not take a car or taxi to school, and the full sample of students other than those directly affected. Compared with either group, the directly affected students live in households that have higher incomes and larger living space per household member and are more likely to be homeowners. The directly affected students do have longer school trips and live in areas with lower density of bus stops.

Table 3. Comparing individuals who make school trips

	1	2	3	4	5
	Directly affected group (group 1)	Individuals who enter 3rd ring to school but do not drive (group 2)	p-value of comparing group 1 and group 2 means	Full sample of school age other than directly affected group (group 3)	p-value of comparing group 1 and group 3 means
Observations	135	347		6,565	
Year of birth	1998	1996	0.000	1998	0.132
Number of autos	1.13	0.36	0.000	0.45	0.000
Proportion having access to government or company car	0.06	0.02	0.014	0.02	0.001
Household income (1–7 levels)	2.09	1.44	0.000	1.52	0.000
Housing size (square meters)	89.12	76.34	0.001	78.87	0.012
Housing size per household member (square meters)	27.80	24.32	0.004	25.06	0.033
Proportion who are homeowners	0.80	0.69	0.017	0.71	0.024

School trip distance	8.52	6.95	0.004	2.69	0.000
Bus station density at home TAZ	43.54	52.16	0.010	49.73	0.071
Bus station density at school TAZ	59.41	62.97	0.295	53.10	0.071

Notes: Number of observations refers to the number of observed individuals, not trips. Some individuals make more than one school trip on the survey day. Therefore, the number of observed trips is larger than the number of observed individuals. The three groups make 135, 347, and 7,788 trips, respectively. The household income groups are explained in Section 3.6, below.

Other Congestion Pricing Schemes Would Likely Affect the Relatively Wealthy

We have assumed that the congestion pricing scheme covers the area within Beijing's third ring road, and we have consequently defined the directly affected individuals as those who live outside the third ring road but drive inside. Our primary findings are not sensitive to potential variations of the congestion pricing scheme. Table 4 compares the individuals who drive to work with those who are employed but do not drive to work, regardless of where they live in Beijing. Individuals who drive to work have higher household incomes, live in larger residences, are better educated, and are more likely to be male.

Table 4. Comparing individuals who drive to work with those who do not drive to work

	1	2	3
	Individuals who drive to work	Individuals who do not drive to work	p-value
Observations	8,115	32,963	
Male	0.67	0.51	0.0000
Education (0–8 levels)	5.91	5.37	0.0000
Household income (1–7)	2.01	1.55	0.0000
Housing size	89.84	75.87	0.0000
Housing size per household member	34.76	30.31	0.0000
Proportion who are homeowners	0.77	0.64	0.0000

Notes: The household income groups are explained in Section 3.6, below.

The Congestion Charge Is Slightly Progressive

In this section, we present evidence that the congestion charge is progressive. We first compare, by income bracket, households' share of the congestion charge with their share of income, and we then compute the Suits index, a measure of progressivity (Suits 1977).

The household travel survey asks each household to choose one of seven annual income groups, and we do not observe the exact income of any individual household. To compute the income share of each income group, however, we need to know the average income of the households in each income group. Because the BTRC data do not have sufficient information, we supplement the data with household income data from the Chinese General Social Survey in 2010 (CGSS2010), conducted by the sociology department at Renmin University of China. This survey includes 520 households in Beijing and records their exact annual incomes in 2009. We divide the households in the CGSS2010 survey into the same seven income groups as those in the travel survey. We use the average income for each of the seven income groups as an estimate of the average income for a corresponding group in the travel survey.[6]

For each income group, Table 5 presents the average income, the number of households in the travel survey, and the share of total income.

Table 5. Comparing income share with congestion charge share

Income group	Average income	Households in travel survey	Share of total income	Share of total congestion charge
<5	3.34	27,936	0.414	0.346
[5,10)	6.93	12,440	0.365	0.423
[10,15)	11.42	2,280	0.108	0.154
[15,20)	17.93	655	0.049	0.037
[20,25)	20.78	203	0.018	0.012
[25,30)	27.5	102	0.012	0.01
>=30	56.25	145	0.034	0.018

Note: The unit of household income is 10,000 Chinese yuan. The average income for each income group comes from the 2010 Chinese General Social Survey.

To calculate the share of congestion charge for each income group, we first calculate the congestion charge for each household. The congestion charge is zero for households that are not directly affected. For households that are affected, we compute the total charge the household pays across all of its trips. Note that only a single congestion fee is charged to an affected trip in which multiple household members share the same vehicle.

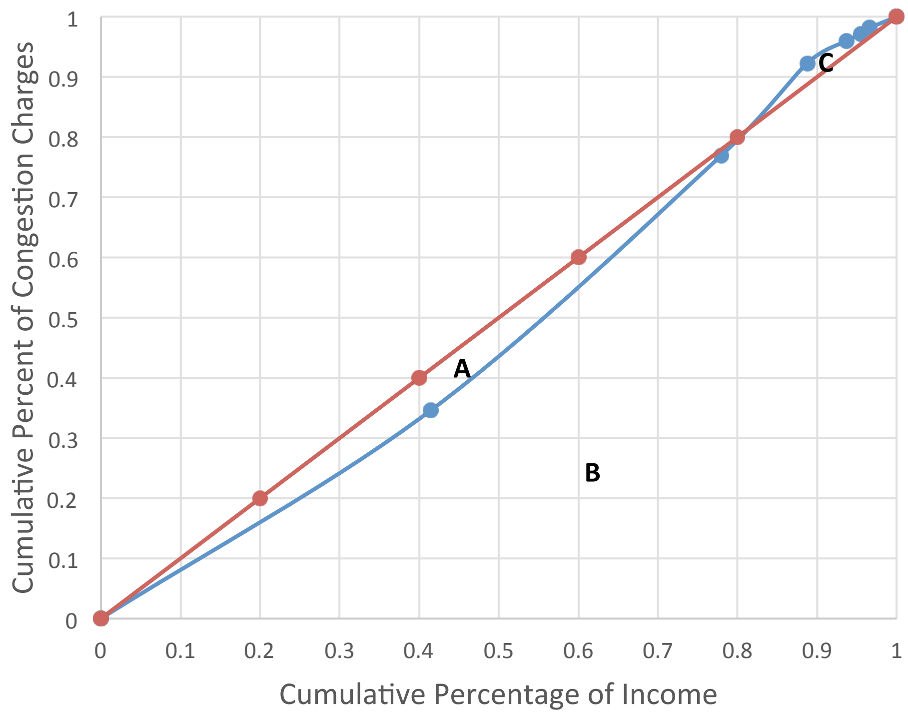
The last column in Table 5 presents the share of the total congestion charge paid by each income group. Households in the lowest and the four highest income groups pay smaller shares of total congestion charge than their shares of total income. Only two middle-income groups, those with incomes between 50 thousand and 150 thousand Yuan, pay higher shares of the congestion charge than their shares of income.

These findings are intuitive. Because households in the lowest income group seldom drive, their share of the congestion charge is relatively small. Households in the highest income groups are more likely to drive and pay congestion charge, but the congestion charge is small relative to their incomes.

[6] No household with an annual household income of 25–30 ten thousand yuan is sampled in CGSS2010. Therefore, we assume the average income for this group is 27.5 ten thousand yuan.

We next use the Suits index to measure the progressivity of the congestion charge. The Suits index ranges from –1 to 1. A negative Suits index indicates that the charge is regressive, and a positive one indicates that the charge is progressive. For a proportional charge, the Suits index would be 0. The Suits index is calculated from the progressivity curve, which plots the cumulative share of income against the cumulative share of congestion charge paid. If the curve follows the 45-degree line the Suits index is zero. As shown in Figure 6, the curve is first below the 45-degree line and then above the 45-degree line after cumulative income is more than 80 percent. The Suits index is calculated as (A–C) / (A+B) = 0.027, where A, B, and C are areas as shown in Figure 6. According to this Suits index, the congestion charge we consider in this paper is slightly progressive.

Figure 6. Congestion charge progressivity curve



Conclusion

Our findings suggest that under the congestion pricing scheme that covers the areas within the third ring road of Beijing, a very small proportion of motorized trips in Beijing will trigger the full congestion charge. More important, compared with individuals in the two control groups, the directly affected individuals typically are wealthier, have higher household incomes, live in larger residences, are better educated, and are more likely to be male, although income and wealth vary across individuals within the group of directly affected commuters. Overall, the Suits index of the congestion charge is 0.027, indicating that the congestion charge is slightly progressive.

Other than the distributional concern, another often-mentioned concern with congestion pricing in Beijing is that a large proportion of motorized travel in Beijing may use government or company vehicles, and drivers of government or company vehicles are not responsive to congestion charges (Creutzig and He 2009). In the survey data set, only about 6 percent of the directly affected commuters have access to a government or company car, though it is possible that the survey underestimates the proportion of commuters who have access to a government or company car.

This paper has focused on the distributional effects of a Beijing congestion charge, but policymakers are also interested in the efficacy of the charge at reducing congestion. The congestion charge is more likely to affect the travel behavior of individuals making discretionary trips than those who are commuting. We observe that many motorized trips across the third ring road are discretionary. The large share of discretionary trips implies that a congestion charge could be effective at reducing congestion, but testing this hypothesis would require economic modeling of individuals' travel behavior, which is left for future research.

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