Who Pays Congestion Charges?
Debunking Old Misconceptions with Registry Data

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15 May 2025

Abstract

We analyze the equity and effects on commuting of two full-scale congestion charging systems by examining micro-registry data encompassing all Swedish citizens and their cars, including yearly paid congestion charges from 2018 to 2020. The data include a rich set of socioeconomic information, such as income, yearly paid congestion tax, family status, geographical location of employment and residence. We use descriptive analyses as well as fixed effects models (FE) to show how paid congestion charges vary with changes in various variables. The charges are weakly regressive, with a Suits index of -0.03 (Gothenburg) and -0.06 (Stockholm). Moreover, the income effect is several times larger in the OLS model than in the FE model in both cities, suggesting that the income effect results from income correlating with factors such as location of residence and time-invariant individual-specific preferences for paying the charge, and not primarily because of the income itself. We find, indeed, a vast variation in paid charges between individuals within income groups. It is so large that it raises the question of whether it is even relevant to classify the tax as regressive or progressive. We find that few people pay the charge on a regular basis, implying that it is less informative to measure the equity effects of congestion charges using self-reported behaviour in a "normal week" or observed trips for one day. Moreover, in the FE models shows that commuting across the cordon is only weakly associated with the paid annual charge, suggesting that the paid congestion charge is not primarily explained by commuting across the charging cordon.

Keywords: congestion charges, equity, commuting, registry data, spatial distribution, taxes.

JEL codes: R41, R48, Q54.

1 Introduction

Transport economists have, for decades, advocated congestion charges as a means to combat congestion in metropolitan areas. However, few cities have implemented such charges, partly due to concerns about their negative distributional effects. Still, earlier studies on these effects often rely on data that are inadequate in several respects. First, studies using national travel survey data—sometimes in combination with transport models (Craik and Balakrishnan, 2023; Eliasson and Mattsson, 2006; Santos and Rojey, 2004; West and Börjesson, 2020)—lack information on the actual charges paid. Second, other surveys that explicitly ask respondents about their congestion charge payments rely on self-reported data for a single day or a "usual day" (Eliasson, 2016). As we demonstrate in this paper, travel patterns vary significantly across days and weeks throughout the year for most individuals, making it difficult for respondents to accurately recall or define a "normal week." This can lead to substantial reporting errors (Rosenfield et al., 2020). When travel behaviour is reported for only one day, variations within individuals across days, weeks, and seasons are entirely missed. Third, the number of observations in such surveys is often too small to support a detailed geographical breakdown of the sample. Fourth, studies relying on transport models (Meyer de Freitas et al., 2017) or census data—such as average values or the percentage of the working population commuting by local authority (Santos and Caranzo, 2022)—typically overlook the variation between individuals living in the same neighbourhood.

In this paper, we contribute to the literature on the distributional effects of congestion charges by analyzing individual-level registry data, including the annually paid congestion charges in two cities where such charges have been implemented: Stockholm and Gothenburg. These systems are cordon-based, where the charge is levied upon crossing the toll cordons. The charging levels are time-dependent, with the highest rates during peak hours on weekdays. No charges are levied during evenings, nights, or weekends.

Most previous studies on the equity effects of congestion charges analyze redistributive effects between income groups. One likely reason for this focus is the limitations imposed by poor data or the common practice of averaging across income groups. However, this practice typically masks the substantial variation in the congestion charges paid within income groups (Heyndrickx et al., 2021). Still, variations within income groups are highly relevant if congestion charges partly serve as a fiscal tax, as they challenge the fundamental criterion of horizontal equity (Mankiw et al., 2009). Additionally, many equity analyses of congestion charges have concluded that the recycling of revenues is central to the distributional effects (Levinson, 2010; Mayeres and Proost, 1997). However, if the variation within income groups is significant, uniform recycling of revenues within income groups may still leave some low-income individuals much worse off. Variation in the paid charge between days within a year for an individual also impacts the distributional effects (which cannot be analyzed using surveys that report travel behavior for a single day). To illustrate, if many individuals occasionally pay the charge rather than a few paying frequently, the redistributive effects among individuals over a year are smaller.

We contribute to the existing literature on the equity effects and potential effects on commuting of two full-scale congestion charges, in Stockholm and in Gothenburg, by being the first study using micro-registry data encompassing all Swedish adult citizens and their cars, including yearly paid congestion charge. The registry data ensures a large and an unbiased sample. The data includes a rich set of socioeconomic information, including taxable income, yearly paid congestion tax, family status (including children in the household), geocoded location of residence and employment. This type of registry data is available in the Nordic countries due to their practice of mandatorily registering all individuals residing within their borders. This enables us to examine variation among individuals within each income group in addition to individual variation in travel behaviour across days within a full year, without relying on a sample of individuals to remember, conceptualize, or report charges paid during a "normal" day or week.

The locations of residence and workplaces are geocoded for all individuals, enabling us to calculate the spatial distribution of paid charges by location of residence. We also distinguish individuals residing inside the charging zone from those residing outside. Moreover, by separating workers from non-workers, and among workers between those who commute across the charging cordon versus those who do not, we provide insight into the relationship between commuting (i.e. labour market) and congestion charges.

Geocoded residential information also allows for analyses on how paid charge varies with the distance from the central station, a proxy for distance to the charging zone, in Stockholm and Gothenburg, respectively. Assuming that congestion charges have a limited effect on fundamental choices in life, we can analyze the causal effect of changes in residential location, income, family composition, and employment, on paid charges using individual fixed-effects regression models. The fixed-effect model controls for spatial sorting and time-invariant individual specific preferences, allowing a deeper understanding why the paid charge varies between groups.

The literature often assumed that a high transit supply is needed for congestion charges to effectively decrease car usage, even though this assumption is rejected by Börjesson et al. (2014). To explore this further using real data, we analyze how the congestion charge varies with transit accessibility. By comparing two cities with very different market shares of transit trips and land-use densities (affecting car use in charged origin-destination pairs), we can explore the extent to which our conclusions are transferable between different types of cities.

The paper is structured as follows. Section 2 puts this paper into the previous literature. Section 3 outlines the study areas and Section 4 describes the data. Section 5 examines the distributional effect respect to income with, while Section 6 analyses the effect with respect to residential location and explores the impact of transit accessibility on the paid charge, and Section 7 reveals the effect of other socio-economic characteristics including income, location of residence etc. Finally, Section 8 concludes.

2 Literature

Much of the equity literature has focused on whether the congestion charges are progressive or regressive, i.e. whether average net benefit of congestion charges by income groups as percentage of income increases or decreases (Suits, 1977). Levinson (2010) and Litman (1996) both review the literature on equity effects of congestion charges, focusing on average net benefits of congestion charges by income group. Meyer de Freitas (2017) evaluates the equity effects in Zurich using an agent-based travel demand model, MatSim, over a 24 h period, concluding that the distribution of the values of time variation is important. Santos and Rojey (2004) study equity effects of cities in the UK, applying transport models and census data, and conclude that the equality effects are town-specific. West (2020) evaluates the Gothenburg congestion charge's cost and benefits by residential location using the national transport model, finding that the charges are regressive. Eliasson and Mattsson (2006) do the same for Stockholm using a transport model and travel survey asking respondents to state the trips they made in a particular survey day and find that the charges are progressive. Eliasson (2016) focuses on distribution effects based on reported travel behaviour surveys in four (Stockholm, Gothenburg, Helsinki and Lyon) cites and find that the charges are regressive. Based on NTS data, however, Craik and Balakrishnan (2023) find that the London charges are progressive while Santos and Caranzo (2022), using average income in each local authority and the percentage of the working population commuting by car, find that they would be regressive in Cardiff.

The main conclusion of the literature is that the distribution of average net benefit of the charges is highly sensitive to the road network, location of the charges, price structure, use of raised revenues, and whether alternatives, such transit or routes that avoid the toll, are available (Golub, 2010; Verhoef and Small, 2004). However, since the data quality has been limited in most studies, it is unknow whether poor data quality could be one reason for the varying results (for instance, in the survey used by Eliasson (2016) — which also includes the two cities analyzed here — car ownership is reported to be much higher than in the registry data we use suggesting that the data is not representative). No study before the present one uses unbiased registry data from all actual payments of congestion charges.

Eliasson et al. (2018) argue that negative equity effects are a more serious problem if the congestion charge functions as a fiscal price instrument rather than merely as a price correction for internalizing external marginal social costs. The importance of internalizing negative externalities is also a general conclusion in the broader tax literature (Atkinson and Stiglitz, 1976; Mankiw et al., 2009). Moreover, for a fiscal tax, a common criterion is horizontal equity, ensuring that households with similar incomes pay a similar tax (Mankiw et al., 2009). This criterion is one reason why Atkinson and Stiglitz (1976) suggest a uniform tax on all final consumption goods (unless Pigouvian taxes are needed to internalize external effects), assuming the presence of an optimal income tax. The vast variation between individuals within income groups that we find may question whether it is even relevant to classify the tax as regressive or progressive: a low-income household paying a large share of its income in congestion charges is not better off because other low-income households pay only a small amount. Moreover, the vast variation of paid charge within income groups demonstrates that congestion charges for fiscal purposes do not meet the horizontal equity criterion.

Another strand of literature views congestion charges as an additional tax on labour, thereby introducing a deadweight loss (Parry and Bento, 2001; Van Dender and Tikoudis, 2021). The seminal paper by Parry and Bento (2001) showed that, unless a congestion tax on commuting is offset by a reduction in income tax by the same amount, it decreases welfare, if the income tax exceeds the marginal external cost of commuting. Even though Van Dender (2003) concluded that the welfare-optimal congestion tax is lower for commuting trips than for other trip purposes, much of the literature on congestion charges often tacitly assumes that most trips subject to a congestion charge are for commuting. Still, commuting make up only around a quarter of total car traffic in many countries (Eurostat, 2021; UK Department of Transport, 2011; US Department of Transportation, 2017). We contribute to the literature by analyzing how the annually paid charge varies between workers and non-workers, and between workers who cross the toll cordon on their commute and those who do not.

In some cities, equity in terms of income distribution has been less of an issue compared to the distribution of charges across geographical areas. This was the case in Edinburgh, for instance (Ryley and Gjersoe, 2006). Ultimately, it was decided that residents of the City of Edinburgh residing outside the outer cordon would be exempt from the charges for this reason, whereby the proposal was rejected due to political opposition (Raje et al., 2004; Ryley and Gjersoe, 2006). Similarly, in New York, the geographical distribution of charges outside the city has been a major issue for decades (Gu et al., 2018; New York State Traffic Congestion Mitigation Commission, 2008; The New York Times, 2021). In London, follow-up reports have placed special attention on residents in central London within and outside the charging zone, as well as residents in Greater London (Transport for London, 2008), and “key workers.” Also in Sweden, and particularly in Gothenburg, there have been debates about the fairness of the cordon location. For this reason, it is relevant to compare how the total charging impacts different areas, which is another key contribution of this paper.

3 Study area

As a backdrop to the following discussions, we describe the congestion charging systems and the study areas here. The county of Stockholm has a population of just below two million inhabitants, and the Gothenburg region has a population of just above 600,000 inhabitants. In 2024, Stockholm and Gothenburg had average travel times of 19:17 minutes and 16:32 minutes per 10 kilometers, respectively, ranking 130th and 186th among European cities (with rank 1 having the longest average travel time), according to TomTom (2025).

The Stockholm congestion system was introduced in January 2006 and designed as a charging cordon around the inner city (dotted line in Figure 1). Charges are time-dependent and levied 6:30-18:30 on weekdays. Vehicles are charged when crossing the cordon in both directions. Since January 2016, a charge has also been levied on the Essinge bypass (E4/E20), which is a congested motorway connecting the southern and northern parts of Stockholm. There are 18 check-points located as depicted in Figure 1, where the Essinge bypass is depicted in green. Stockholm is built on islands, and the Essinge bypass is the only bridge between south and north of Stockholm, except through the inner city. In the period 2016-2019 the charging levels were between 1.1 EUR to 3.5 EUR per passage Table 1.[1] The maximum charge for one day also was 10 EUR. The charge on the Essinge bypass (point 9 in Figure 1) were slightly lower than the charge on the cordon during peak hour (3.0 EUR). In addition, travelling from south to north (or in the opposite direction) requires passing the inner-city cordon twice, but the Essinge bypass only once.

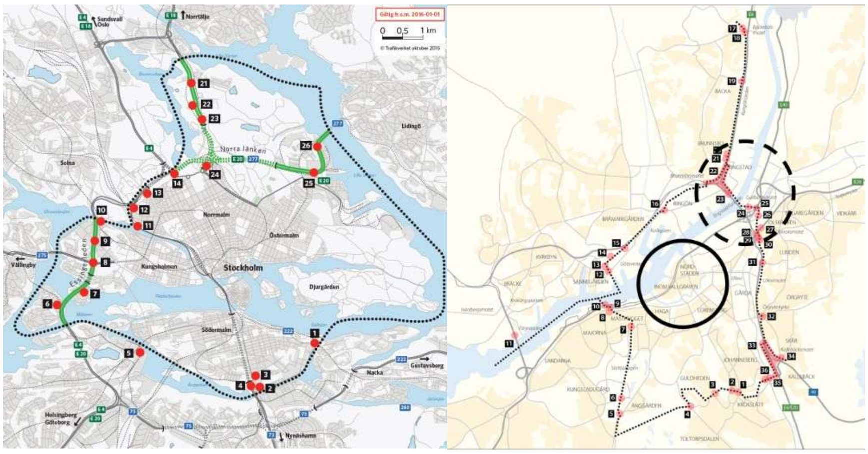

Figure 1: The Stockholm (left) and the Gothenburg (right) Congestion charging cordon (dotted line) : Gothenburg with the charging cordon. The highway hub where the main bottlenecks are located is depicted with a dashed circle and the inner city with a solid circle.

Table 1: Charged amount (EUR) in Stockholm depending on time of day before and after the charge increase.

Stockholm Time	Inner-city cordon 2016-2019	Essinge bypass (E4/E20) 2016-2019	Gothenburg 2015 on
06:00–06:29	0	0	0.9
06:30–06:59	1.5	1.5	1.6
07:00–07:29	2.5	2.2	2.2
07:30–08:29	3.5	3.0	1.6
08:30–08:59	2.5	2.2	0.9
09:00–09:29	1.5	1.5	0.9
09:30–14:59	1.1	1.1	0.9
15:00–15:29	1.5	1.5	1.6
15:30–15:59	2.5	2.2	2.2
16:00–17:29	3.5	3.0	1.6
17:30–17:59	2.5	2.2	1.6
18:00–18:29	1.5	1.5	0.9
18:30–06:29	0	0	0

[1] Throughout the paper, we use the conversion rate of 10 SEK ≈ 1 EUR.

The Gothenburg system was introduced in 2013 and consists of a circle cordon with two antlers (see Figure 1). Congestion has always been lower and more local in Gothenburg and occurs mainly around the highway hub to the north of the city centre. An important reason why the charges were introduced was to finance a new rail tunnel (the West Link), i.e. partly for fiscal reasons (Börjesson and Kristoffersson, 2015). Vehicles are charged when crossing the cordon in both directions. Since January 1st, 2015 the charge ranges from 0.9 EUR to 2.2 EUR per passage. The maximum charge has been 6 EUR since the introduction and a multi-passage rule states that if passing the cordon more than once within 60 minutes, only the highest charge must be paid.

In both cities, we denote those residing inside the dotted charging cordon as those residing inside the charging zone. We assume that those who cross the toll cordon on their commute either live inside the zone but work outside it, live outside the zone but work inside it, or live and work outside the zone but must cross the Göta älv (in blue in the map) in Gothenburg or Lake Mälaren (in blue in the map) in Stockholm.

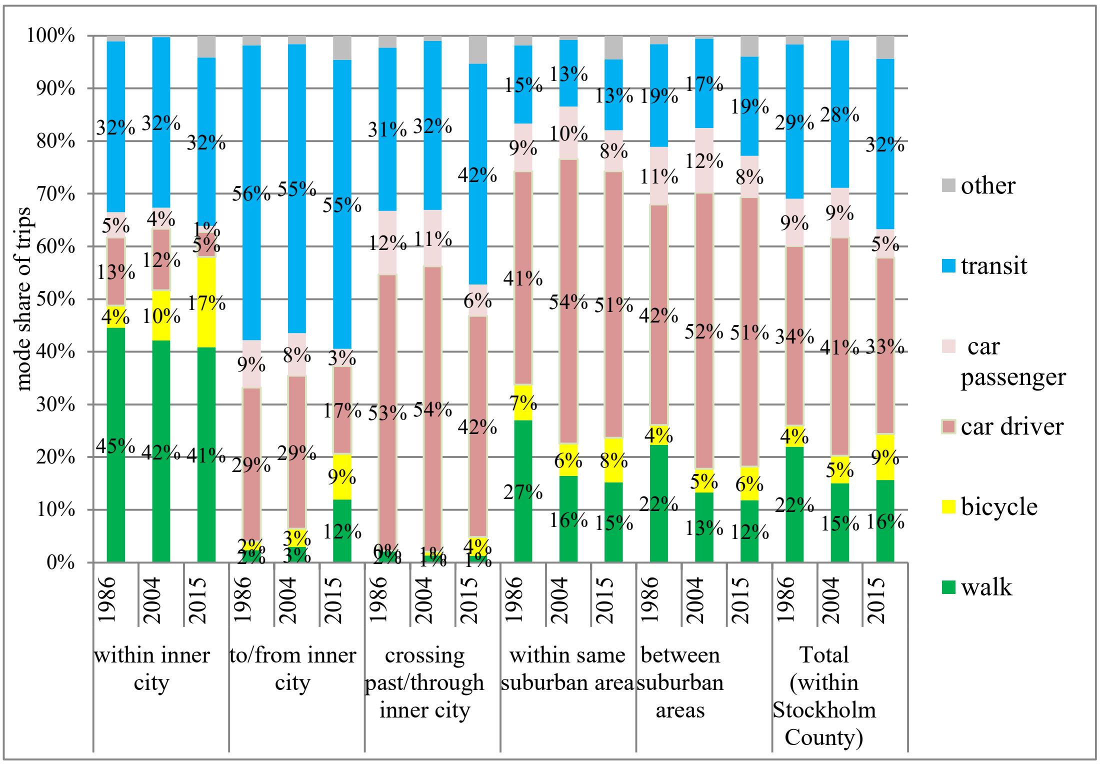

Figure 2: Modal shares by travel relation in Stockholm County. RVU Stockholm 1986, 2004, and 2015. Souces: Bastian and Börjesson (2018)

The share of car trips in the origin-destination pairs where the congestion charge in levied are different in Stockholm and Gothenburg. Figure 2 shows how the modal spits have developed in Stockholm for different origin and destination pairs based on large travel surveys. Among the trips to and from the inner city, the share of car trips decreased after 2004 (presumably at least partly due to the congestion tax) and was as low as 17% among private trips in 2015. Among trips passing through the county, the share of car trips decreased to 42% in 2015, and may have decreased further in 2016 when the charges were levied on the Essinge bypass. In Gothenburg the share of car trips in the origin-destination pairs affected by the charges where just over 60% before the charges were introduced and just below 60% thereafter (City of Gothenburg, 2013). The much lower share of car trips in Stockholm are only present when considering origin-destination pairs affected by the charges (i.e. central parts). In the regions as such, the two cities are more similar regarding car use, which is also confirmed in Table 2.

When the charges were introduced in Stockholm in 2006, the traffic across the cordon was reduced by approximately 20% (Eliasson et al., 2009). In Gothenburg, the reduction in traffic volume across the cordon was approximately 12% (Börjesson and Kristoffersson, 2015). Travel times reduced significantly in both cities. [2]In both cities, the effects of the changes on the traffic volume remained and even increased in the decades after their introduction but the effects of an increase in the charges were smaller than when they were introduced (Börjesson and Kristoffersson, 2018).

The adaptation mechanisms observed in travel surveys in Stockholm and Gothenburg are remarkably similar, in spite of the large differences in modal shares for car. In Stockholm, 24% of commuting car trips crossing the charging cordon were priced off the road, with nearly all trips switching to transit. Interestingly, 22% of discretionary car trips across the toll cordon were also priced off the road, but these trips were not replaced by trip by other modes but where never made (Eliasson, 2008). In Gothenburg, 9% of commuting trips were priced off the road, and switched to transit. Discretionary car trips crossing the charging cordon decreased by 7%, and, as in Stockholm, these trips seem to have simply vanished (Börjesson and Kristoffersson, 2015). Note also that out of all private trips crossing the cordon during charged hours, only slightly less than half of them were commuting trips in Gothenburg and slightly more than half were commuting trips in Stockholm. Professional traffic (including trucks and taxis) makes up approximately one half of all the passages across the cordon.[3]

4 Data

The microdata used for the analyses comes from the Swedish Central Bureau of Statistics (SCB) and comprises several registry databases, including records on citizens and passenger cars, that were matched using anonymized identification number. The dataset of all Swedish adult citizens spans over several decades covering a wide range of variables including incomes, household statues, geocoded residential and work location, and vehicle ownership. The information on vehicle ownership can further be connected to a passenger car database, including all passenger cars in Sweden, with information about car model, annual mileage (recorded annually during the mandatory vehicle inspection from the fourth year onwards for brand-new cars), and annual paid congestion charge from 2018 on.

For the purposes of this study, we restrict the sample to only include individuals 18 years and over, living in the greater Stockholm Conty and the municipality of Gothenburg and its adjacent commuter municipalities, Kungsbacka, Mölndal, and Härryda.[4] In the cross-sectional analyses, we restrict the data to the year 2018, to avoid any effect of the pandemic. The fixed effect analysis in Section 6 we use the years 2018-2020. Assuming that the effect of the pandemic can be captured by the year constants and does not affect the unobserved individual-specific preferences or the effects of the explanatory variables, this has no impact on the estimates of the fixed effects (FE) model.

Furthermore, individuals owning more than 4 cars, less than 0.05 % of the 2018 sample, was discarded. Finally, a small number of individuals with missing geographical data on location of residence is dropped, reducing the total number of individuals to just over 2,4 million (1,8 million in Stockholm and 0.6 million

[2] However, in Stockholm, the reduction occurred in a much larger area of the network than in Gothenburg. This is largely because the congestion was more widespread in a larger part of the network before the charges, with intersections being blocked upstream of the bottlenecks. Substantial travel time reductions were, therefore, achieved far from the cordon.

[3] Buses and taxis account for 16% of trips, trucks for 16%, private cars for 41%, and company-owned cars for 28% (assuming half of these trips are private trips with fringe benefit cars). Börjesson and Kristoffersson (2018).

[4] 18 years is also the age that a Swedish citizen can first apply for a driver license and the minimum age to vote in the general election.

in Gothenburg) and the number of households to (1.3 million in Stockholm and 0.4 million in Gothenburg).

The leftmost columns in Table 2 show some key statistics for 2018 for the Stockholm and Gothenburg samples, respectively. The variable car ownership is a dummy variable indicating whether the individual has at least one privately owned or privately leased car (both referred to as privately owned cars in this paper). While statistically different in size, the two samples are similar in terms of family status, car ownership and employment. However, the average annually paid congestion charge is almost 60% higher in Gothenburg than in Stockholm, partly due to the lower car dependence in the charged origin-destination pairs in Stockholm compared to Gothenburg. The average distance to the charging cordon is shorter in Gothenburg. Moreover, the Stockholm sample has a slightly higher average disposable income but a slightly lower share of them has access to a fringe benefit car.

A fringe benefit car is a car that can be used for private trips by an employee, even if the car is owned or leased car by the employer. Benefit cars are of special interest for the analysis of equity effects of the congestion charges since those who have a fringe benefit car often have high incomes and are less likely to pay the charge themselves since the invoice is sent to their employer. Moreover, Table 2 shows that 78% of those taxed for a fringe benefit car are male and that they have on average more than double the disposable income than others.

We are unable to identify company cars used as fringe benefits among the vehicles owned by legal entities in the registry data. However, we know for other sources that roughly half of the cars owned by legal entities 3 years or younger are fringe benefit cars.[5] Table 3 shows the average congestion charge paid per car for privately owned vehicles and cars owned by legal entities that are maximum three years old. The latter provides an indication of the congestion charges paid by the fringe benefit cars (or their owners), even if other cars owned by legal entities are also included. The average paid charge is significantly higher for cars owned by legal entities compared to privately owned cars in Stockholm, while this difference is smaller in Gothenburg. While we cannot be definite, it suggests that many individuals driving fringe benefit cars likely do not pay the congestion charge themselves (but their employer) and tend to use the cars more frequently than others, particularly in Stockholm. The difference is smaller in Gothenburg, possibly because more privately owned cars regularly pay the congestion charge there, due to a lower share of transit trips, as discussed in Section 2.

In the registry data, all individuals are linked to a household. A ‘couple household’ is defined as a married couple or an unmarried couple residing at the same address who have at least one mutual child. An individual who is not part of a couple household and is above 18 years of age is classified as a single household if not residing with their parents (who then belongs to the parents’ household). Table 3 presents further statistics for households in Stockholm and Gothenburg. Since many households have more members than cars, car ownership is more prevalent at the household level than at the individual level, and the average mileage per car-owning household is less than half of that milage for car-owning individuals. Still, car ownership remains below 50% in both cities.

[5] There are 160,000 new cars sold to legal entities (juridical persons) in Sweden every year (Mobility Sweden, 2025). A company car is typically held for three years. There are 280,000 individuals taxed for a fringe benefit car in Sweden (Börjesson and Roberts, 2023), which implies approximately 93,000 such cars are added each year. This suggests that fringe benefit cars make up just over 50% of the cars up to three years old owned by legal entities.

Table 2: Summary statistics – Individuals 2018

	Stockholm		Gothenburg		Difference		Stockholm				Gothenburg			
	All		All		All		Taxed for fringe benefit car		Others		Taxed for fringe benefit car		Others	
	Mean	sd	mean	sd	Diff	t	mean	sd	mean	sd	mean	sd	mean	sd
Birth year	1971	18	1971	19	0.60	22.0	1971	11	1971	19	1972	11	1971	19
Female	0.50	0.50	0.50	0.50	0.00	-0.9	0.22	0.41	0.52	0.50	0.22	0.42	0.52	0.50
Single	0.39	0.49	0.41	0.49	0.02	29.5	0.23	0.42	0.40	0.49	0.25	0.43	0.42	0.49
Child in household	0.30	0.46	0.29	0.45	0.00	-24.4	0.50	0.50	0.30	0.46	0.48	0.50	0.28	0.45
Employed	0.73	0.44	0.73	0.45	-0.01	-11.3	1.00	0.12	0.72	0.45	1.00	0.09	0.71	0.45
Disposable income k€/year	32.7	173.8	28.6	59.4	-4.1	-27.6	74.0	181.6	30.8	173.2	61.8	133.5	26.6	50.9
Car ownership	0.30	0.46	0.32	0.47	0.02	36.1	0.25	0.43	0.30	0.46	0.26	0.44	0.33	0.47
Milage per year (km)	1364	908	1394	917	30	12.3	1305	944	1367	906	1358	919	1396	917
Congestion charge €/year	29.3	107.3	51.2	132.1	21.8	116.2	27.7	104.8	29.4	107.4	42.6	120.2	51.7	132.8
Distance to central station	14.0	12.9	8.8	8.4	-5.2	-362.9	14.0	11.8	14.0	12.9	11.2	9.7	8.7	8.3
Taxed for fringe benefit car	0.045	0.21	0.058	0.23	0.01	38.6								
Observations	1,829,450		602,289		2,431,739		81,703		174,7747		34,725		567,564	

Table 3: Annually paid congestion charge per car 2018, €/year

		Private		Cars (3 years or younger) owned by legal entities	
		mean	sd	mean	sd
Congestion charge	Stockholm	73	*151*	141	*253*
	Gothenburg	118	*165*	139	*205*
	Rest of Sweden	6	*38*	29	*102*
	Sweden Total	23	*86*	88	*200*
# Obs	Stockholm	762,820		152,860	
	Gothenburg	268,334		29,171	
	Rest of Sweden	3,783,129		161,717	
	Sweden Total	4,814,283		343,748	

Table 4: Summary statistics – Household

	Stockholm		Gothenburg	
	mean	sd	mean	sd
Disposable income k€/year	46.3	209.4	39.9	76.3
Employed	0.72	0.43	0.71	0.43
Child in household	0.42	0.84	0.38	0.82
Car ownership	0.39	0.49	0.41	0.49
Milage (km/y)	979	827	1018	823
Congestion charge €/year	41.5	129	71.4	158
Distance to C-station km	2,960	13,618	3,317	14,269
Fringe benefit car	0.06	0.24	0.08	0.27
Observations	1,293,022		431,532	

5 Distributional effects across income groups

Much of the equity literature on congestion charges has focused on whether they are progressive or regressive, i.e., whether the average net benefit of congestion charges, as a percentage of income, increases or decreases across income groups. A common feature of this extensive literature, with the exception of Heyndrickx et al. (2021), is its emphasis on averages within each income group, with limited discussion of variation within those groups.

Figure 3 illustrates the distribution of the annually paid congestion charge across disposable income deciles in Stockholm and Gothenburg. The average amount paid increases with income. However, there is significant variation within each income decile. There are individuals in all income groups who pay substantial amounts, and many individuals in all income groups pay nothing. This holds true in both cities and thus cannot be attributed to Stockholm's lower car dependence in the origin destination pairs where the charge is levied. For example, in Stockholm, the lowest 75th percentiles within the bottom six income deciles did not pay any congestion charge. Moreover, even among the higher income deciles, the median individual did not pay any charge. The pattern is similar for Gothenburg, although individuals in the 75th percentile of the sixth decile do pay at least a small amount, around 30 € per year. Ten percent of individuals in deciles six to ten pay more than 200–400 € annually. Thus, payment of the congestion charge is primarily confined to individuals in the upper 50th percentiles of the highest four income groups, but there are individuals in all income deciles paying the charge. In Gothenburg, the percentage of individuals paying any congestion charge rises to over 25% among the income groups beyond the fourth decile, and the average paid charge is also higher (see Table 1). The main reason for this difference between the cities is probably the higher car dependence, and the higher average congestion charge paid, in the origin-destination pairs where the charge is levied. Nevertheless, the variation within income groups is so large that it may seem less relevant to evaluate whether the congestion charge is progressive or regressive.

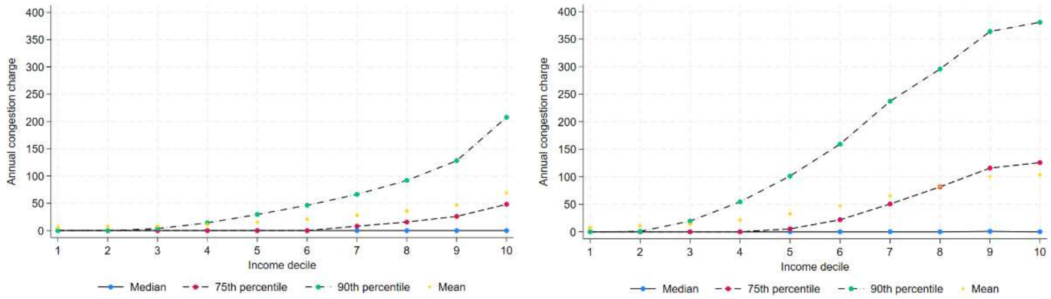

Figure 3: Distrubution of congestion charge in Sthockholm (left) and in Gothenburg (right) in 2018 per inccome decile. €/year

Much of the previous literature on equity, as referenced in the introduction, has emphasized the importance of revenue recycling when analyzing the equity effects of congestion charges. However, as previously stated, one issue with this approach is that payments are unevenly distributed within each income group. As a result, even an equal redistribution of revenues would still leave some low-income households, which pay larger amounts in congestion charges, worse off.

Another issue is that the very definition of what is considered regressive or progressive differs between taxes and subsidies. The equity of taxes is typically measured using the Suits (1977) index. The Suits index is defined as the area between the diagonal and the Lorenz curve (dotted and solid lines in Figure 4). If the person with the highest (or lowest) income paid all of the tax, the Suits Index would be S = 1 (or S = -1). If the tax were perfectly proportional to income, the Lorenz curve would coincide with the diagonal, and the index would be S = 0. A tax is considered neutral if it is proportional to income, progressive if it increases faster than income proportionally (S>0), and regressive if it increases slower than income proportionally (S>0).

The equity of subsidies is typically measured by the concentration index (Kakwani, 1977), which is also bounded between -1 and 1. However, the index is zero and the subsidy defined as neutral if all citizens receive the same amount in absolute terms (irrespective of their income). Hence the definition of what is neutral differs between the tax and the public spending components. This means that it is not even possible to define the equity of the congestion charge in combination with its recycling.

In Stockholm, the Suits index for the congestion tax is -0.06, while in Gothenburg, it is -0.03. Hence, the congestion tax is weakly regressive and slightly more so in Stockholm. However, this is only an average effect. Figure 4 shows that the congestion tax exhibits both regressive and progressive characteristics across different parts of the income distribution: it is progressive in the lower part and regressive in the upper part. Eliasson (2019) calculated the Suits index for the Stockholm charges using survey data and found it to be -0.09. Hence, the tax appears slightly less regressive in register data, possibly because the response rate among those paying the charges is lower than among those affected.

For comparison, Eliasson (2019) found the Suits index for Sweden to be -0.03 for fuel tax, -0.05 for kilometre tax, -0.08 for car ownership tax, and -0.03 for car purchase tax. Thus, the equity effects of congestion charges are comparable to those of other taxes and fees within the transport sector.

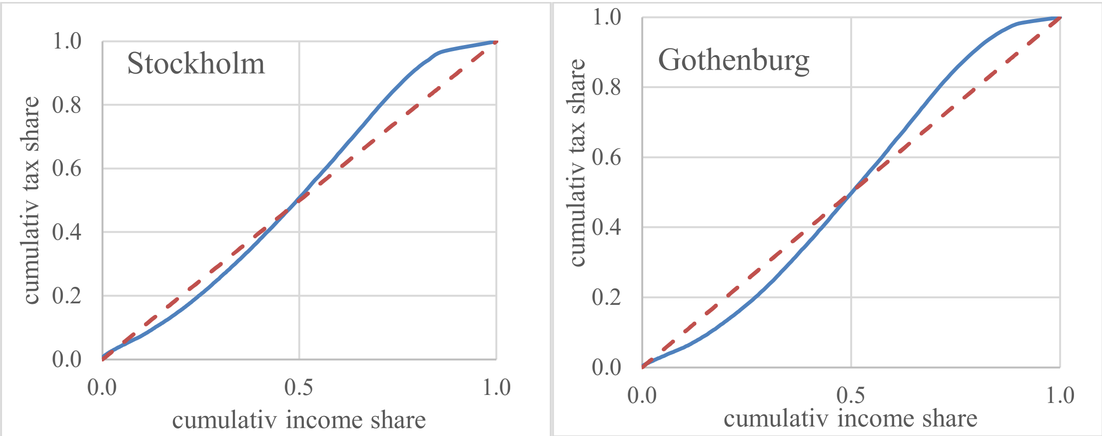

Figure 4: Lorenz curves for the congestion tax for Stockholm (left) and Gothenburg (right).

6 Distributional effects across purpose and location

6.1 Crossing the cordon on the commute

As stated in the introduction, some literature has viewed congestion charges as an additional tax on labour, thereby introducing a deadweight loss on the labour market . Our impression is that much of the literature on congestion charges has tacitly assumed that it is primarily commuting trips that pay the charge. To explore the extent to which congestion charges can be seen as an additional tax on labour, we compare the charges paid by non-workers, workers who commute across the cordon, and workers who do not. Figure 5 shows that in Stockholm, a majority of the workers do not commute across the charging cordon, whereas in Gothenburg, a majority of the workers do commute across it. In both samples, 27 percent of the population do not work (mostly students and retirees).

The average annual charge per person is indeed much higher for workers than for non-workers in both cities, but this is likely due to their less active life stages and lower car ownership rather than to the lack of commuting. In Stockholm, the workers crossing the charging cordon on their commute pay on average just below twice as much in congestion charge as other workers. However, the average charge the commuters across the cordon pay annually is just below 50 €, which corresponds to fewer than ten trips per year. The difference in average annual paid congestion charge between workers who cross the cordon during their commute and those who do not is even smaller in Gothenburg (Workers who do not commute across the cordon pay 70% of what the commuters pay annually). Moreover, the total amount paid in charges is similar among workers who do not commute across the cordon, simply because they make up a larger share of the population.

Moreover, the total amount paid in charges is similar among workers who do not commute across the cordon, simply because they make up a larger share of the population.

Now, one reason why the commuters pay crossing the cordon do not pay more could be that those who are priced off the road no longer commute regularly by car across the charging cordon but choose another travel mode, location of residence, or work location. The travel survey conducted before and after the introduction of the charges indicated that only a minority of the commuting trips by car across the cordon were priced off the road and switched to transit as discussed in Section 3 (24% and 9% of the commuting trips, in Stockholm and Gothenburg, respectively). Many commuters have a relatively high value of time, implying that the charges often reduce their generalized travel cost (Anderstig et al., 2016). This may be one reason why more commuters are not discouraged by the congestion charges.

Moreover, the evidence that so individuals pay the charge on a regular basis provides insight into why adaptation mechanisms are so varied, for those not commuting across the cordon. It suggests that adaptation to crossing the charging cordon takes the form of reducing trip frequency—for instance, instead of crossing every second week, people cross every third week.

Together, these numbers indicate that paying the charge is not primarily related to commuting, even though workers crossing the cordon on average pay more than other workers. Hence, these congestion charges cannot be considered equivalent to a tax on labour. We will explore the relationship between congestion charges and commuting in greater detail in Section 7, where we present the fixed-effects regression model.

6.2 Inside, outside, close or far from the charging cordon

In many cities, such as Edinburgh, the distribution of charges across geographical groups has been a significant issue (Ryley and Gjersoe, 2006). Therefore, in the proposal for the charges, it was suggested that residents of the City of Edinburgh Council living outside the outer cordon were to be exempt from the charges, but the congestion charges was still rejected due to political opposition (Raje et al., 2004; Ryley and Gjersoe, 2006). Similarly, in New York, the distribution of charges among geographical groups outside New York City has been a contentious issue for decades (Gu et al., 2018; New York State Traffic Congestion Mitigation Commission, 2008; The New York Times, 2021). In London, follow-up reports have paid special attention to residents in central London, both within and outside the charging zone, as well as residents in Greater London and "key workers" (Transport for London, 2008). For this reason, it is relevant to further analyze how total congestion charge payments are distributed among residents, depending on whether they live inside or outside the cordon.

Figure 6 differentiates the paid charge between those residing inside and outside the zone. In Stockholm, those residing inside the zone pay on average more, even if they have lower car ownership than those residing outside the zone. However, in Gothenburg, those residing outside the zone pay slightly more and have a higher car ownership. A probable reason is that more trips are charged in Gothenburg, also for residents living outside the zone, due to the smaller size of the city and the design of the charging system, which does not only target trips to and from the city centre. Figure 7 strengthen the argument: the mean paid charge remains stable as far out as 50 km from the central station in Gothenburg[6], whereas in Stockholm the mean paid charge

[6] The central stations in each city were chosen because they are situated near the zone centroid while also serving as key cultural and business hubs.

decreases 10 kilometres from the central station. Hence, in Gothenburg, the congestion charge is paid by residents across a much wider area, presumably reflecting the fact that the larger city of Stockholm has a larger share of car trips that do not pass through the inner city or the bypass—partly because many trips to and from the city center are made using public transit.

However, as noted above, these averages hide substantial variation within individuals.

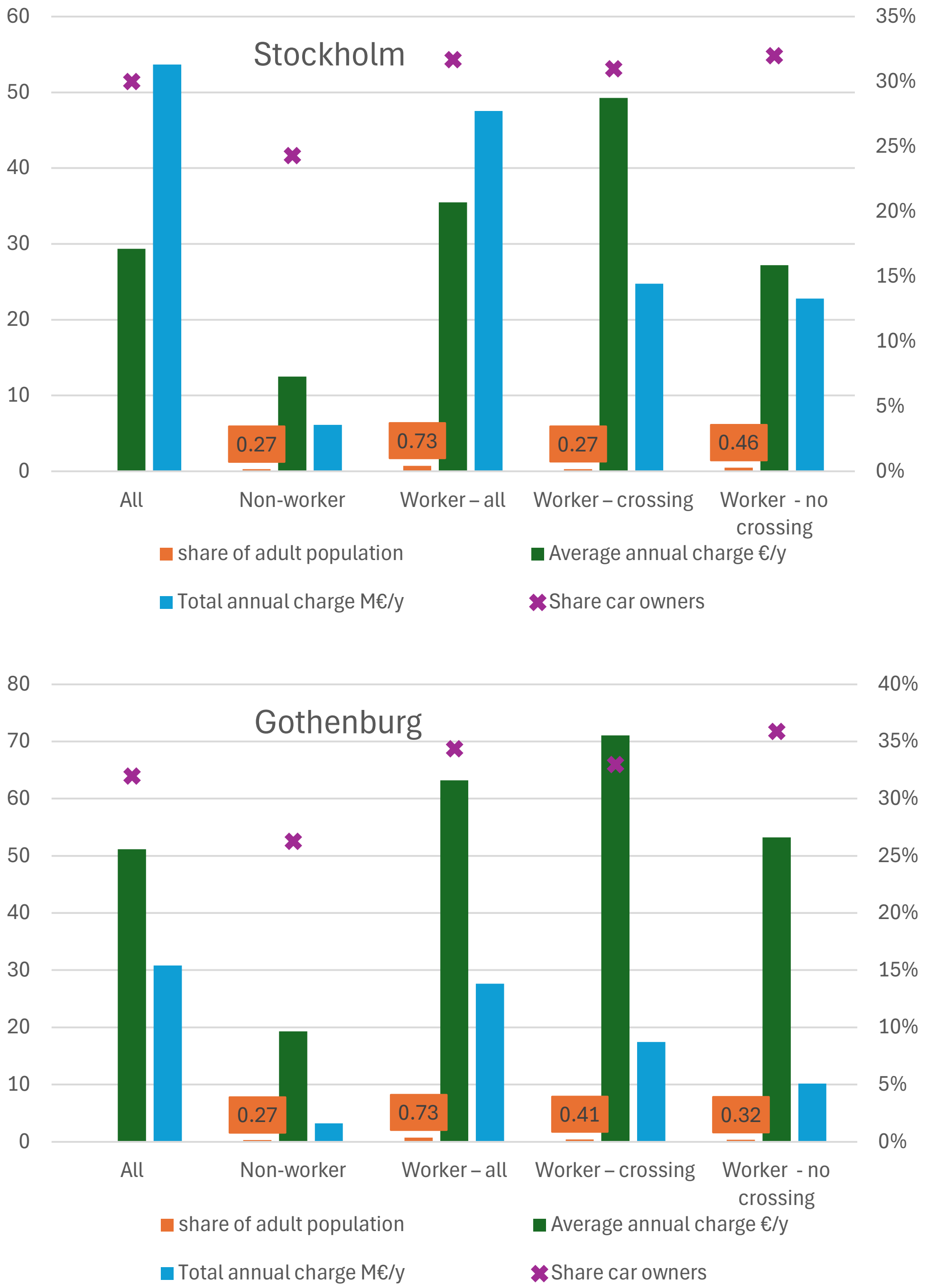

Figure 5: Distrubution of congestion charge in Stockholm (top) and in Gothenburg (bottom) in 2018 for workers, non-workers and commuters crosing and not crossing the zone.

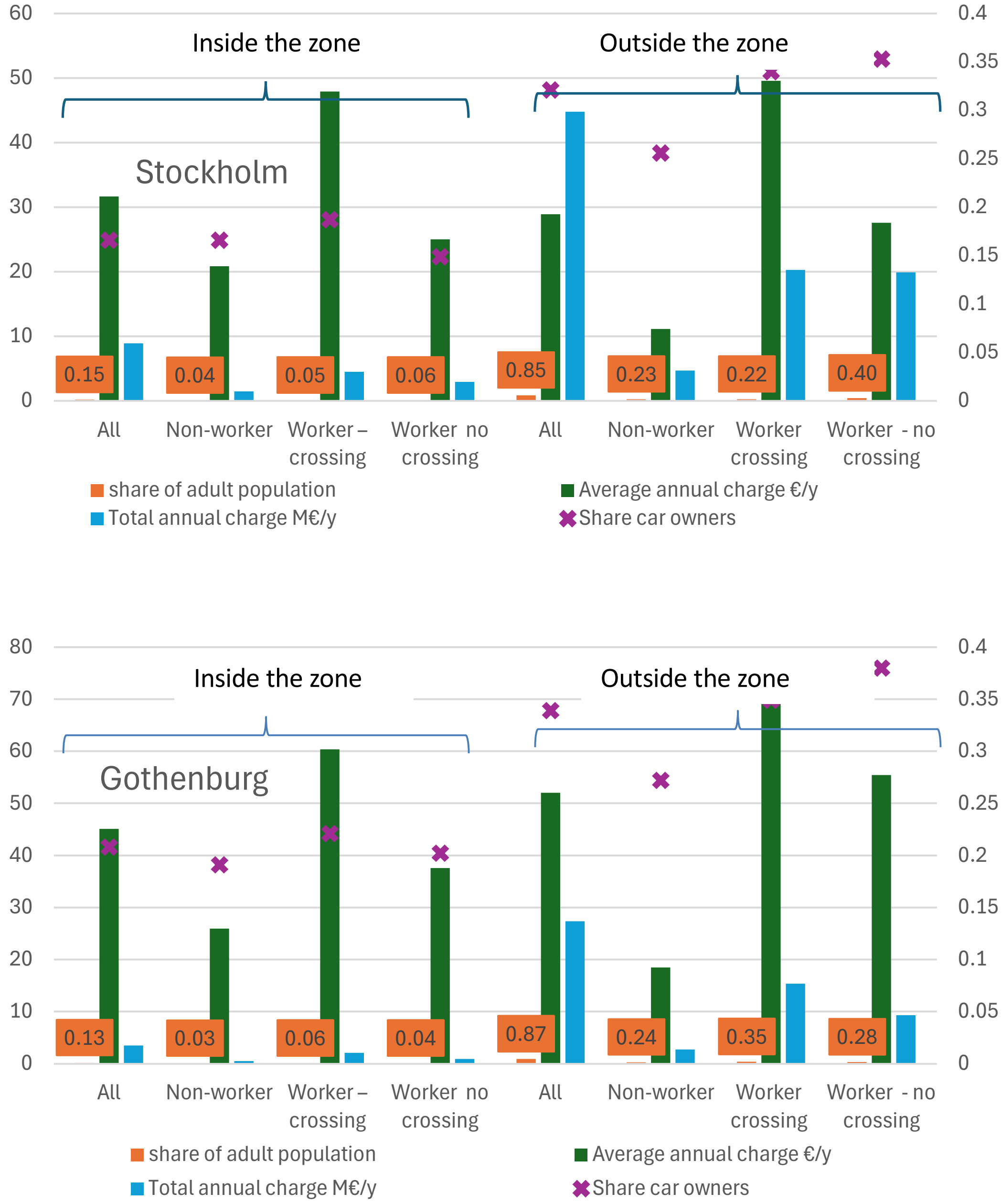

Figure 6: Distrubution of congestion charge in Sthockholm (top) and in Gothenburg (bottom) in 2018 for workers, non-workers and commuters crosing and not crossing the zone, residing inside or outside of the zone.

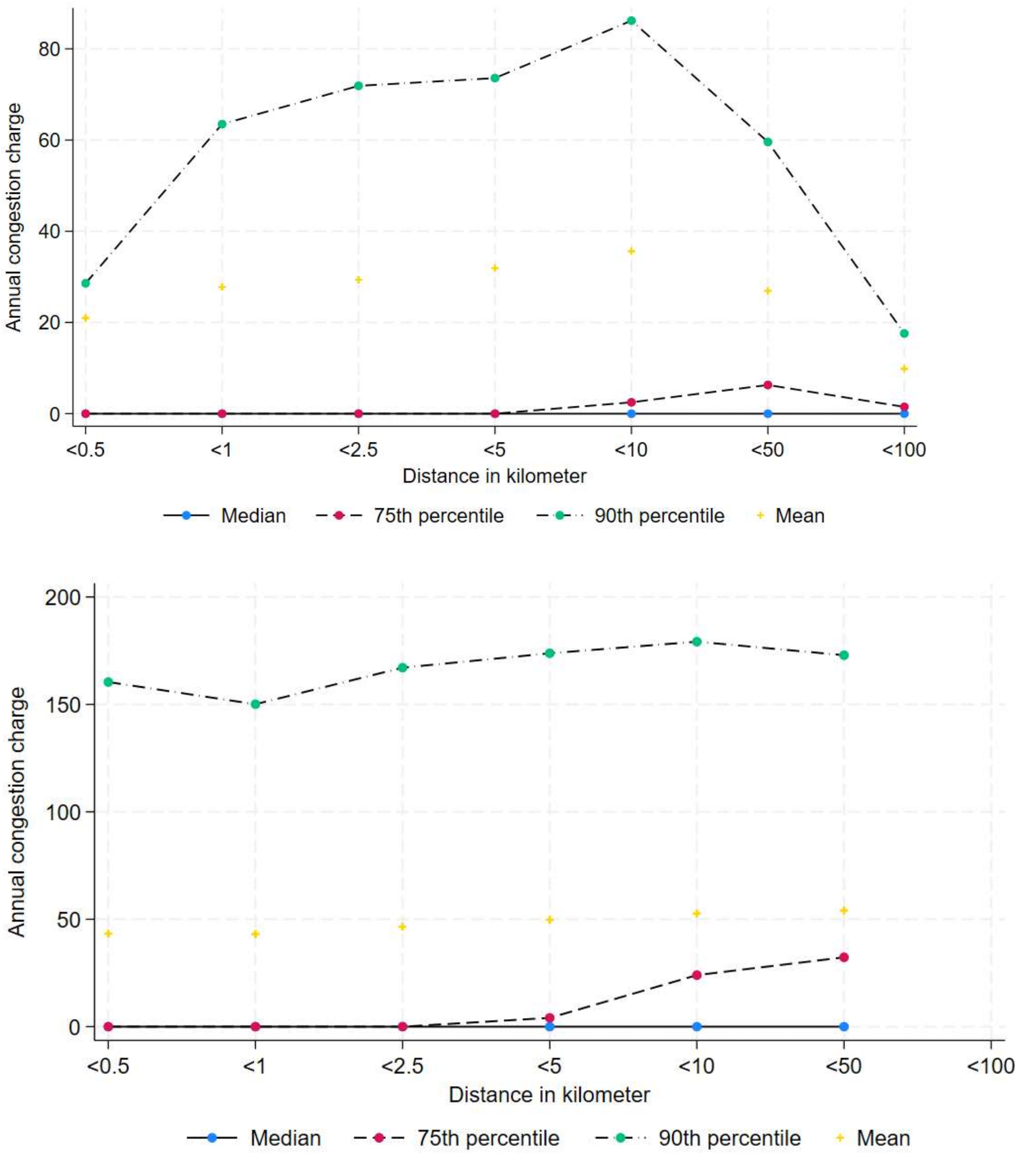

Figure 7: Distrubution of congestion charge in Sthockholm (top) and in Gothenburg (bottom), depending on the distance to the zone form the location of residence.

6.3 Transit accessibility

It is generally assumed that negative equity effects arising from congestion charges can be avoided or decreased by good transit accessibility. It is also generally assumed that good transit accessibility would increase the effect (price elasticity) of congestion charges. To explore this further, we plot the average paid charge in a residential zone as function of the decile of transit accessibility by residential or work location. We can only do this for Stockholm, since we lack measure of transit accessibility for Gothenburg. We only have of transit accessibility for the year 2017, but there's no reason to believe it would differ from 2018. Let $\tilde{R}$ be the set of zones with where jobs and residents are located. Accessibility by transit is measured by the logsums (Ben-Akiva and Lerman, 1985) calculated by (residential or work) zone *r* as

$$A_r = \ln \sum_{r' \in \tilde{R}_r} exp\,(\mu c_{rr'})\, n_{r'},$$

where $n_{r'}$ is the number of jobs in destination zone r'. $c_{rr'}$ is the generalized travel cost by transit from zone r to zone r', derived using the national transport model SAMPERS. It is a sum over the weighted travel time components (access, waiting, transfers, and in-vehicle time) and fare. The logsum parameter, μ, reflects how sensitive travellers are to differences in the generalized costs. The logsum parameter μ, is estimated within the transport model from travellers' behaviour.

Figure 8 shows that the average paid charge is not lower for residents with higher transit accessibility. In general, there is only weak a relationship between paid charges and transit accessibility. One possible interpretation is that most residents of the Stockholm County have sufficient transit accessibility. Another is that better transit accessibility often means living closer to the charging cordon, and these two factors balance each other out. The weak association between transit accessibility and charges also persists when considering the transit accessibility of the zone where the individual work, shown in Figure 9.

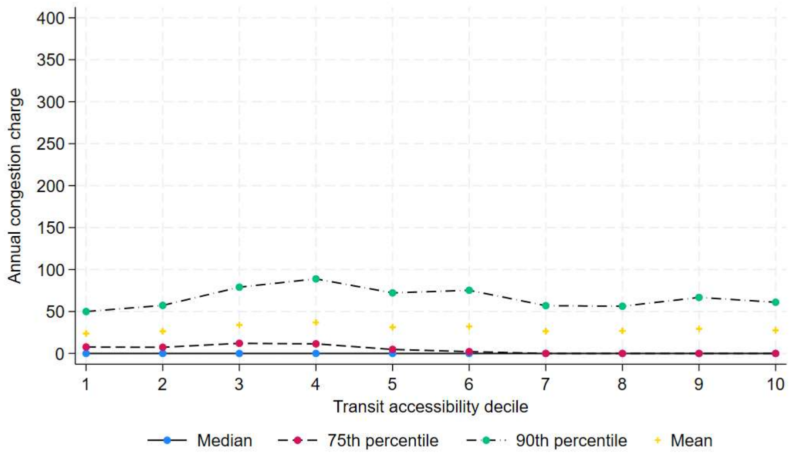

Figure 8: Average annual paid congestion charge by transit accessbiliy (A_r) decile of the zone where the indivual resides, Stockholm

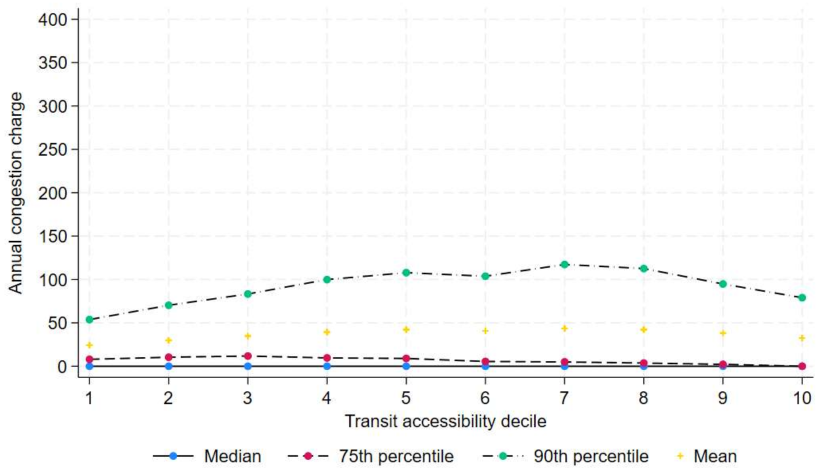

Figure 9: Average annual paid congestion charge by transit accessbiliy (A_r) decile of the zone where the indivual work, Stockholm

7 How paid charges varies with localization and socioeconomics

So far, we have analyzed how the paid charge varies with income and the localization of residence and workplace. However, since individuals are likely spatially sorted with respect to unobserved preferences for paying the congestion charge, as well as observed socio-economic characteristics such as income, family composition, and employment, this analysis obscures a deeper understanding of why the paid charge varies among groups and individuals. We are also interested in the extent to which the variation in paid charge across groups is merely a result of differences in car ownership within the population. To explore this further, we define and estimate an econometric model

$$\theta_{it} = \boldsymbol{X_{it}}'\boldsymbol{\delta} + \alpha_i + \beta_t + e_{it}, \tag{7}$$

where θ_{it} is the annual congestion charge paid by individual *i* during year t, α_i is an individual-specific constant, and β_t is a year-specific constant. Finally, X_{it} is a vector including the log of disposable income, and dummy variables that take the value one if the individual is living in a single household, have children, employment, residing inside the cordon, cross the cordon on the commute, owns a car, or have access to a fringe benefit car. The vector also includes the distance to the central station from the location of residence, which is a proxy for how close the individual is to the charging cordon.

As long as potentially confounding unobserved individual-specific preferences remain constant over time (2018-2020 in this model) and the explanatory variables $\boldsymbol{X_{it}}$ are not impacted by the congestion charge, the model reflets a causal relationship. Such assumptions seem reasonable (even for car-ownership) given that the charge remained unchanged 2018-2020 and that relatively few individuals pay a substantial amount in congestion charges. Moreover, the charges are minor compared to parking fees—where the fee for one or a few hours of parking in central Stockholm often exceeds the congestion charge—and housing costs, which vary significantly across the city.

While the policy implications of this analysis are not immediately clear—since few, if any, of the explanatory variables can be directly influenced by policymakers—the findings nonetheless enhance our understanding of how the congestion charge is distributed across the population, and help identify the underlying factors driving these payments. The insights can support policymakers in evaluating the validity of various arguments when considering the introduction or expansion of congestion charges.

Table 5 and Table 6 show the model results for Stockholm and Gothenburg. For each city, the first two columns show OLS models ($\boldsymbol{\alpha_i}$ excluded) with and without car ownership among the explanatory variables. The rest of the models include the fixed effect $\boldsymbol{\alpha_i}$. The fourth model adds car ownership among the explanatory variables. For Stockholm, a fifth model is added, including the logsum for transit accessibility among the explanatory variables.

The OLS models show that women, singles, and those residing far from the city center pay less, whereas parents, high income earners, and individuals crossing the zone on their commute pay more. The reason why women pay less is not only their lower car ownership. When controlling for car ownership, income, employment, and commuting patterns, women still pay less. This result contradicts the findings of Brownstone and Small (2005), who observed that women—presumably due to a higher valuation of reliable travel times—are more likely to choose the toll road in the American 'High Occupancy/Toll' (HOT) lanes.

In general, the effect of most of the variables decreases in the FE model, compared to the OLS model, and some even change sign. This shows that much of the difference in the paid charge across socio-economic groups arises from the correlation between time-invariant individual-specific preferences and explanatory variables, or from spatial sorting, rather than from differences in the explanatory variables themselves. That is, some individuals seem to have a higher willingness to pay the charge, independent of explanatory variables like income and location of residence and workplace. This may at first seem surprising, but is in line with research finding that the value of time varies greatly among individuals even when controlling for factors such as income (Börjesson and Eliasson, 2014).

For example, having children in the household is associated with higher paid charge according to the OLS model, but is not significant in the first FE model. This suggest that having children is correlated with individual-specific preferences for paying the congestion charge or from spatial sorting of parents. When car ownership is included, the effect becomes negative and significant in Stockholm —i.e., having a child decrease the amount paid, possibly because families travel more locally. According to OLS, single household pay much less than a couple household, but this association vanishes once we control for unobserved characteristics and spatial sorting in the FE model.

The income effect is larger in Gothenburg than in Stockholm, which seemingly contradicts the larger (in absolute terms) Suits index for Stockholm. A possible reason is the non-linear income effect—illustrated in Figure 4—which is not accounted for in the regression models. Moreover, the income effect is approximately ten times larger in the OLS model than in the FE model in both cities (when not controlling for car ownership), suggesting that the observed income effect may result from income being correlated with factors such as the spatial sorting of income groups or with individual-specific preferences for paying the charge correlating with income.

According to the OLS (1) model, a one percent increase in disposable income is associated with an annual paid congestion charge just under €20 in Stockholm and just under €30 in Gothenburg. This corresponds to an income elasticity of **0.64 in** Stockholm and 0.56 in Gothenburg, at the average congestion charge paid. According to the FE (2) model, however, a one percent increase in disposable income increases the annually paid congestion charge by less than €1 in Stockholm and €2 in Gothenburg. This corresponds to an income elasticity of 0.06 and 0.07 in the two cities. When car ownership is added to the model, the income effect is halved in Gothenburg and decreases by two-thirds in Stockholm.

When adding car ownership to the FE model, the income effect is halved in Gothenburg and decreases by two-thirds in Stockholm. Hence, a major reason why high-income individuals pay more is their higher rate of car ownership. Still, even when controlling for car ownership, a small but remaining positive effect on income charging persists in Stockholm and is even larger in Gothenburg.

Notably, the effect of employment is generally weak or statistically insignificant. Hence, the difference in the paid charge between employed and others is mostly an effect of other explanatory variables. Moreover, the positive effect of crossing the charging cordon on the commute in the OLS models decreases by more than two-thirds in the FE model and is similar in magnitude in both cities. This suggests that the higher congestion charges paid by those crossing the charging cordon during their commute are primarily due to individual-specific willingness to pay— which correlates with commuting patterns—rather than the act of crossing the cordon itself. This further strengthens our conclusion that the paid congestion charge is not primarily explained by commuting across the charging cordon. However, it is possible that those who are less concerned about paying the charge are more likely to commute across the toll cordon, whereas those who are less willing to pay may choose alternative locations for their residence or workplace. In that case, our assumption that the explanatory variable (crossing the cordon during the commute) is independent of the error term would not hold. In addition, the coefficient magnitude shows that the effect of crossing only increases annual paid charge with €5 on average, which is a relatively small amount considering over a year.

Table 5: Regression table includes all adult population in Stockholm, area 2018-2020.
Notes: Robust standard errors clustered at the municipality level in parenthesis.

	OLS (1)	OLS (2)	FE(1)	FE(2)	FE(3)
Female	-20.95*** (1.43)	-3.49*** (0.49)			
Child	5.65*** (1.06)	6.14*** (0.75)	-0.69 (0.50)	-2.20*** (0.38)	-2.20*** (0.38)
Singel	-12.15*** (1.89)	-3.87*** (0.45)	-1.30*** (0.45)	-1.56*** (0.29)	-1.51*** (0.28)
ln(Disp.Inc)	18.62*** (1.25)	3.14*** (1.04)	1.73*** (0.08)	0.65*** (0.09)	0.66*** (0.09)
Employed	0.18 (0.81)	5.40*** (1.34)	1.10*** (0.21)	0.46** (0.21)	0.46** (0.21)
Fringe car	-31.64*** (1.79)	-6.59*** (0.93)	-49.08*** (5.62)	-31.64*** (2.77)	-31.64*** (2.77)
Dist. C. Station, km	-0.33*** (0.07)	-0.73*** (0.14)	-0.04* (0.02)	-0.15*** (0.02)	-0.23*** (0.06)
Reside inside zone	-3.16 (2.97)	9.15*** (2.10)	-3.21** (1.24)	0.37 (1.14)	0.49 (1.14)
Crossing zone on commute	17.90*** (3.85)	19.05*** (4.90)	5.35*** (1.54)	4.95*** (1.65)	4.94*** (1.65)
Own a car		104.15*** (14.75)		110.01*** (15.65)	110.01*** (15.65)
Access. PT					-1.43* (0.75)
No. Obs	5,254,918	5,254,918	5,254,918	5,254,918	5,254,918
Adj. R2	0.048	0.20	0.61	0.77	0.78
Individ FE	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

The FE models also show that the annual charge paid by those residing inside the zone does not differ from that paid by those living outside it. Instead, the distance to the zone is what matters for the amount of charge paid.

Finally, in the Stockholm model, we add transit accessibility (calculated as the logsum). Interestingly, this is not significant. That is, better transit accessibility does not seem to have any major effect on the annual paid charge, as indicated in Section 6.3. Having a fringe benefit car, however, has a large negative impact on the paid charge in all models. This is not surprising, since the congestion charge bill for a fringe benefit car is sent to the employer. Now, a relatively small share of the population has a fringe benefit car, but these cars add to the regressivity of the charges, since these individuals are mostly high-income earners.

The main conclusion from this analysis is that the impact of many explanatory variables associated with the paid charge does not appear to be a direct effect, but rather a result of how individuals with different observed characteristics and unobserved preferences for paying the charge are spatially distributed and correlated. For example, many of the most relevant effects, such as the effect of income and crossing the charging cordon on the commute, weaken substantially or vanish altogether in the fixed effects (FE) model compared to the ordinary least squares (OLS) model. Still, the OLS model remains relevant because it identifies which groups actually pay the charge. However, it means that the understanding of why some groups pay more than others is greatly obscured in the former model.

Table 6: regression table includes all adult population in Gothenburg, 2018-2020.
Notes: Robust standard errors clustered at the municipality level in parenthesis.

	OLS (1)	OLS (2)	FE(1)	FE(2)
Female	-28.95*** (1.88)	-4.93* (1.93)		
Child	9.63*** (0.33)	11.70*** (0.48)	-0.21 (0.20)	-2.23* (0.84)
Singel	-18.68*** (2.56)	-7.13*** (1.05)	-0.10 (0.81)	-0.99** (0.27)
ln(Disp.Inc)	28.90*** (0.91)	4.00** (1.25)	3.71*** (0.27)	2.07** (0.47)
Employed	7.79*** (0.71)	13.83*** (0.56)	1.83 (0.92)	0.14 (0.75)
Fringe car	-52.11*** (2.69)	-10.75*** 1.68)	-53.78*** (5.20)	-30.67*** (1.65)
Dist. C. Station, km	-0.60* (0.20)	-1.63*** (0.13)	-0.12 (0.07)	-0.38*** (0.06)
Reside inside zone	-7.42** (1.64)	3.32** (0.84)	-0.64 (0.41)	1.60** (0.38)
Crossing zone on commute	19.04** (4.01)	19.61** (3.87)	4.76*** (0.74)	4.60** (0.82)
Own a car		150.67*** (19.68)		144.45*** (20.87)
No. Obs	1,777,118	1,777,118	1,777,118	1,777,118
Adj. R2	0.08	0.34	0.70	0.74
Individ FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

8 Conclusions

This study is the first to empirically examine the equity effects of full-scale congestion charging systems, and the extent to which these effects target commuters crossing the cordon, using micro-registry data covering the entire population (linked to households), including annual congestion charges paid. We analyze the cases of Stockholm and Gothenburg, where congestion charges are in place. The micro-registry data provides an unbiased and comprehensive sample, which is likely not the case for survey-based data. Given the substantial variation in paid congestion charges—even after controlling for socio-economic characteristics—biased samples may yield results that are not representative of the full population.

Moreover, while previous studies on the equity effects of congestion charges typically analyze redistributive effects between income groups based on observed trips during a single day or a stated "normal week," our study examines variation among individuals within each income group over a full year, accounting for differences in income and location of home and workplace relative to the charging cordon. This approach allows us to take into account that the individuals travel behaviour varies across days, months, and seasons and that not the same individuals that pay the charge every day. We also avoid relying on individuals' recollection or self-reporting of charges paid during a 'normal' week

We find the Suits (1977) index to be -0.03 for Gothenburg and -0.06 for Stockholm. This average effect masks the fact that charges are progressive for the lower part of the income distribution while being regressive for the upper part. Moreover, we find a vast variation in paid charge between individuals within income groups. It is so large, that it raises the question of whether it is even relevant to classify the tax as regressive or progressive: a low-income household paying a large share of its income in congestion charges is not better off simply because other low-income households pay only a small amount. Such variations are particularly important to consider in an equity analysis of congestion charges that serve as a fiscal tax, as they challenge the fundamental criterion of horizontal equity (Mankiw et al., 2009). In Gothenburg, as well as in many Norwegian cities, the congestion charge is at least partly a fiscal tax to finance new road infrastructure, thus making this a very relevant issue. However, the redistributive effects of the tax should be less relevant for a tax internalizing external cost and should be seen as a price correction rather than at tax.

Previous studies have concluded that the recycling of revenues is central to the distributional effects of congestion charges over income groups. However, the significant variation within income groups implies that a uniform revenue recycling within those groups would still leave some low-income individuals significantly worse off. Another issue related to how the recycling of revenues affects the regressivity or progressivity of the charges is that the definitions of what is considered regressive or progressive differ between taxes and subsidies. The equity of taxes is typically measured using the Suits index, which is defined as zero (i.e., neutral) when the tax is perfectly proportional to income. In contrast, the equity of subsidies or public spending is typically measured by the concentration index (Kakwani, 1977), which is defined as zero (i.e., neutral) if all citizens receive the same absolute amount, irrespective of their income. Hence, the definition of neutrality differs between the tax and public spending components. This means that it is not even possible to define the equity of the congestion charge in combination with its recycling.

We also find that few pay the charge on a regular basis, in both cities. It is rather many individuals occasionally paying the charge, making the redistributive effects among individuals over a year are smaller than when focusing on a day. The vast individual variation within a year implies that it is less informative to measure the equity effects of congestion charges using self-reported behavior in a “normal week” or observed trips for one day. Moreover, the effect of income on the paid charge is approximately ten times larger in the OLS model than in the FE model in both cities, suggesting that the substantial income effect observed in the cross-section arises from income correlating with factors such as spatial sorting and time-invariant, individual-specific willingness to pay the charge. In the OLS model, the income elasticity is 0.64 in Stockholm and 0.56 in Gothenburg at the average charge, whereas in the FE model it is only 0.06 and 0.07 (in the models not controlling for car ownership). When car ownership is added to the model, the income effect is halved in Gothenburg and decreases by two-thirds in Stockholm.

The income effect is thus similar in both cities, despite the share of transit trips in the charged origin-destination pairs being much higher in Stockholm. It underscores that there are many ways to adapt by not driving, apart from public transport. Indeed, we find that in Stockholm, the accessibility (measured as the logsum) at the location of residence (or workplace) impacts the paid charge.

Another strand of literature views congestion charges as an additional tax on labour, thereby introducing a deadweight loss (Parry and Bento, 2001; Van Dender and Tikoudis, 2021), often implicitly assuming that most of the trips subject to a commuting tax are commuting trips. We contribute to this literature by showing that the congestion charge paid by workers who do not commute across the cordon amounts to as much as 50% in Stockholm and 70% in Gothenburg of the charge paid by workers who do commute across the cordon. Moreover, the fixed effects (FE) model shows that the within-individual change in the paid congestion charge when an individual starts or stops commuting across the cordon is several times smaller than the difference between these commuters and other commuters in the cross-section. Hence, the higher charge paid by commuters crossing the charging cordon seems to be a result of spatial sorting with respect to (unobserved) willingness to pay the charges for any trip purpose, or that those less willing to pay to a larger extent choose their residence or workplace to avoid crossing the cordon on their commute. This further strengthens our conclusion that the paid congestion charge is not primarily driven by commuting across the charging cordon.

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