Debunking Congestion Charge Myths: Who Pays, Why and When?

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Abstract

We analyze the distributional effects with respect to income, home and work location, whether individuals commute across the cordon, and a range of other socio-economic variables in the two full-scale congestion charging systems in Stockholm and Gothenburg. We do this by examining unique micro-registry data covering all Swedish citizens and their cars, including yearly paid congestion charges from 2018 to 2020. The charges are weakly regressive, with a Suits index of -0.03 (Gothenburg) and -0.06 (Stockholm). However, in both cities, the income effect is several times smaller when controlling for time-invariant individual-specific preferences. Moreover, we find substantial variation in paid charges between individuals within the same income groups. This variation is so large that it raises the question of whether it is even meaningful to classify the tax as regressive or progressive. 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 based on observed trips for a single day. Furthermore, when controlling for individual-specific effects, we find that commuting across the cordon is only weakly associated with the annual paid charge, suggesting that congestion charges are not primarily explained by commuting across the charging cordon.

Keywords: Congestion charges; Road pricing; Taxation of commuting; Equity; Suits index; Registry panel data

JEL codes: H23, R41, R48, Q54

1 Introduction

For decades, transport economists have advocated congestion charges but few cities have implemented such charges, partly due to concerns about their negative distributional effects. However, studies on these effects often rely on data that are inadequate in several respects. Studies using national travel survey data (Craik and Balakrishnan, 2023) —sometimes in combination with transport models (Eliasson and Mattsson, 2006; West and Börjesson, 2020), only transport models (Meyer de Freitas et al., 2017), or census data (Santos and Caranzo, 2022; Santos and Rojey, 2004)—lack information on the actual charges paid or how these vary within individuals across days and weeks (due to variation in travel behaviour). Studies based on census data also overlook variation between individuals with similar location and socio-economic status. Moreover, in most studies, the number of survey observations is too small to support an analysis of variation across individuals within an income group, or a detailed breakdown with respect to geography. As a result, they typically analyse redistributive effects only between income groups, even though this masks substantial variation within income groups (Heyndrickx et al., 2021). Such within-group variation is highly relevant if congestion charges partly serve as a fiscal tax, since it challenges the fundamental criterion of horizontal equity (Mankiw et al., 2009).

Some 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). This can lead to substantial reporting errors (Rosenfield et al., 2020), since, as we demonstrate in this paper, travel patterns vary significantly across days and weeks. Surveys focusing on driving or congestion charges may also be subject to selection bias.

To address the various limitations in the previous literature, we use micro-registry data covering all adult citizens in the region and their cars, including yearly paid congestion charges in Stockholm and Gothenburg. The data include a rich set of socioeconomic information, including taxable income, yearly paid congestion tax, family status (including children in the household), and geocoded residence and workplace locations. Such data have not been applied in this field before. They allow us to analyse how charges vary both across individuals within the same socioeconomic groups (e.g., by income or residential area) and within individuals across days over a full year, without relying on recall or self-reported surveys. Day-to-day variation within individuals affects distributional outcomes, which single-day surveys cannot capture. To illustrate, if many individuals pay occasionally rather than a few paying frequently, the redistributive effects over a year are smaller.

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 variation within income groups is significant, uniform recycling of revenues may still leave some low-income individuals much worse off. Levinson (2010) and Litman (1996) both review the literature on the equity effects of congestion charges, concluding that results are highly sensitive to the road network, location of charges, price structure, and use of revenues. Diverging findings are also present in later studies. Craik and Balakrishnan (2023) find that the London charges are progressive, while Santos and Caranzo (2022), find that charges would be regressive in Cardiff.

There are also previous studies of the equity effects in Stockholm and Gothenburg, based on travel surveys (where respondents report their trips during a survey day) in combination with transport models. Eliasson and Mattsson find progressive effects in Stockholm, whereas West and Börjesson (2017) find regressive effects in Gothenburg. The former conclude that the key

factors for regressivity are initial travel patterns and the use of revenues, which outweigh differences in the value of time that have often been highlighted as the key parameter in modelling studies (Verhoef; Meyer de Freitas et al., 2017). However, using reported travel behaviour surveys in four cities, Eliasson (2016) finds, in contrast, that the charges are regressive in Stockholm as well as in Gothenburg, Helsinki, and Lyon. The importance of initial travel behaviour—which varies greatly over time within individuals as well as between individuals in the same income group—and the varying results for Stockholm depending on the data used, suggest that some of the variability in previous studies stems from small sample sizes or incomplete and biased data, which is addressed in the present study.

In many cities, equity in terms of income distribution has been less of an issue than the distribution of charges across geographical areas (Ryley and Gjersoe, 2006; Gu et al., 2018; The New York Times, 2021; Transport for London, 2008). We contribute to this literature since the geocoded locations of residences and workplaces enable us to calculate the spatial distribution of paid charges by residence. We also distinguish between individuals residing inside the charging zone and those residing outside. Moreover, by separating workers from non-workers, and among workers between those who commute across the charging cordon and those who do not, we provide insight into the relationship between commuting (i.e., labour market activity) and congestion charges. In this way, we can explore to what extent congestion charges can be viewed as an additional tax on labour, thereby introducing a deadweight loss (Parry and Bento, 2001; Van Dender and Tikoudis, 2021).

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

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

The paper is structured as follows. Section 2 situates this paper within the previous literature. Section 3 outlines the study areas and Section 4 describes the data. Section 5 examines the distributional effects with respect to income, while Section 6 analyses effects with respect to residential location and explores the impact of transit accessibility on paid charges. Section 7 examines the role of other socioeconomic characteristics, including income and residential location. Finally, Section 8 concludes.

2 Study area

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. 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. In the period 2016-2019 the charging levels were between 1.1 EUR and 3.5 EUR per passage.[1]

The Gothenburg system was introduced in 2013 and consists of a circle cordon with two antlers. 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 the cordon is passed more than once within 60 minutes, only the highest charge must be paid.

In both cities, 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 cordon (Göta älv in Gothenburg and Lake Mälaren in Stockholm). For maps of the two systems, see Börjesson and Kristoffersson (2018).

The share of car trips in the origin-destination pairs where the congestion charge is levied is different in Stockholm and Gothenburg. Bastian and Börjesson (2018) show how the modal splits have developed in Stockholm for different origin and destination pairs based on large travel surveys. Among the trips to and from the charging zone (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 zone, 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 were 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 is only present when considering origin-destination pairs affected by the charges (i.e. central parts). The two cities are still similar regarding car use, which is also confirmed in Table 1.

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] 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).

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

[2] However, in Stockholm, the reduction occurred in a much larger area of the network than in Gothenburg.

3 Data

The microdata employed in the analyses originate from the Swedish Central Bureau of Statistics (SCB) and encompass several registry databases, including records on citizens, their passenger cars, and the annual congestion charges paid by each vehicle owner from 2018 onwards. The dataset covers the entire adult population of Sweden and contains a broad set of variables, such as income, household composition, geocoded residential and workplace locations, vehicle ownership, and the annual mileage of cars, based on data from mandatory vehicle inspections.

We restrict the sample to only include individuals 18 years and over, living in the greater Stockholm County and the municipality of Gothenburg and its adjacent commuter municipalities, Kungsbacka, Mölndal, and Härryda. In the cross-sectional analyses, we restrict the data to the year 2018, to avoid any effect of the pandemic. In 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 four cars, less than 0.05 % of the 2018 sample, were 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 in Gothenburg) and the number of households to 1.7 million (1.3 million in Stockholm and 0.4 million in Gothenburg).

The leftmost columns in Table 1 show some key statistics for the individuals in the 2018 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 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. 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 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. Of those taxed for a fringe-benefit car, 78% are male, and they have on average more than twice the disposable income of others.

We are unable to identify fringe-benefit cars among the vehicles owned by legal entities in the registry data, or to link them to their drivers. However, we know from other sources that roughly half of the cars owned by legal entities three years or younger are fringe benefit cars.[3] The average paid charge is significantly higher for cars owned by legal entities (141€/y)

[3] There are 160,000 new cars sold to legal entities in Sweden every year (Mobility Sweden, 2025). A fringe benefit 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.

compared to privately owned cars (73€/y) in Stockholm, while this difference is smaller in Gothenburg (139 vs 118 €/y).

Table 1 also presents statistics for households in Stockholm and Gothenburg. A 'couple household' is defined in the registry data as a married couple or an unmarried couple residing at the same address that has 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). 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.

Table 1: Summary statistics – Individuals 2018

	Stockholm Individuals		Gothenburg Individuals		Stockholm Households		Gothenburg Households	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Birth year	1971	18	1971	18				
Female	0.50	0.50	0.50	0.50				
Single	0.39	0.49	0.39	0.49				
Child in household	0.30	0.46	0.30	0.46	0.42	0.84	0.38	0.82
Employed	0.73	0.44	0.73	0.44	0.72	0.43	0.71	0.43
Disp. income k€/year	32.7	174	33	174	46.3	209	39.9	76.3
Car ownership	0.30	0.46	0.30	0.46	0.39	0.49	0.41	0.49
Annual milage (km)	1364	908	1364	908	979	827	1,018	823
Charge €/year	29.3	107	29.3	107	41.5	129	71.4	158
Distance, central (km)	14.0	12.9	14.0	12.9	2,960	13,618	3,317	14,269
Fringe benefit car	0.045	0.21	0.045	0.21	0.06	0.24	0.08	0.27
Observations	1,829,450		602,289		1,293,022		431,532	

4 Distributional effects across income groups

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 a percentage of income increases or decreases (Suits, 1977). A common feature of this extensive literature, except for Heyndrickx et al. (2021), is its focus on averages within each income group, with limited discussion of variation within those groups.

Figure 1 illustrates that the average amount paid increases with disposable income in Stockholm and Gothenburg. However, there is significant variation within each income decile. There are individuals in all income deciles who pay substantial amounts, and many individuals in all income deciles 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. 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. 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 1: Distribution of annually paid congestion charges per inhabitant in Stockholm (left) and Gothenburg (right) in 2018, by income decile (€ per year)

Much of the previous literature on equity, as referenced in the introduction, emphasizes the importance of revenue recycling when analyzing the equity effects of congestion charges. However, the vast heterogeneity within income deciles means that equal redistribution of revenues based solely on income would still leave some low-income households worse off.

The Suits index (-1<S<1) is defined as the area between the diagonal and the Lorenz curve (dotted and solid lines in Figure 2). If the tax were perfectly proportional to income, the Lorenz curve would coincide with the diagonal (S=0). A tax is considered neutral if it is proportional to income (S = 0), progressive if it increases faster than income proportionally (S>0), and regressive if it increases slower than income proportionally (S>0).

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 2 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 (2016) calculates the Suits index for the Stockholm and Gothenburg charges using survey data and found it to be -0.09 and -0.13, respectively. Hence, the tax appears less regressive in registry data, particularly in Gothenburg. A possible reason is that survey response rates are lower among those without a car (often lower-income individuals, who therefore do not pay the charges). Indeed, car ownership is reported to be much higher in the surveys than in the registry data. 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.

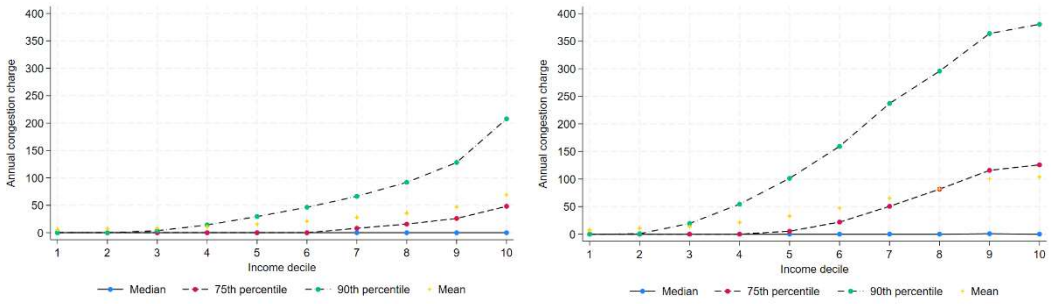

Figure 2: Distribution of annually paid congestion charges per inhabitant in Stockholm (left) and Gothenburg (right) in 2018, by income decile (€ per year)

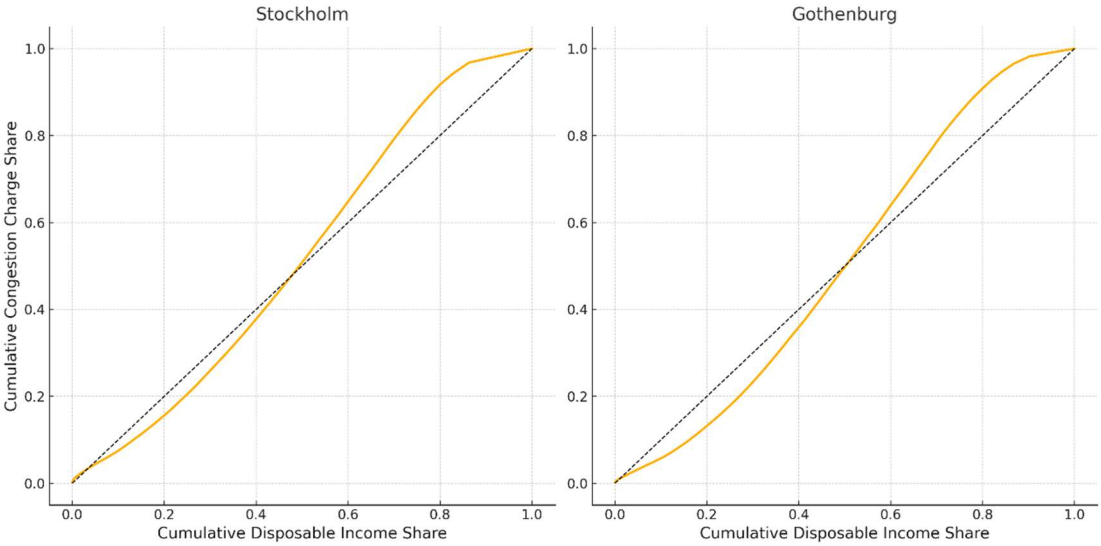

Figure 3: Lorenz curves of the congestion tax in Stockholm (left) and Gothenburg (right).

5 Distributional effects across purpose and location

5.1 Crossing the cordon on the commute

Our impression is that much of the literature on congestion charges has tacitly assumed that the charges are primarily paid for commuting trips, and thus can be regarded as an additional tax on labour. To examine the extent to which this holds true, we compare the charges paid by non-workers, workers who commute across the cordon, and workers who do not. Figure 3 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, likely due to their less active life stages and lower car ownership. 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 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.

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% as much per person as those who do, and they account for more than 40% of the total charge.

One reason why the commuters 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 (Börjesson and Kristoffersson, 2015; Eliasson, 2008). Moreover, the evidence that some

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 only 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.

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

In many cities, such as Edinburgh, the distribution of charges across geographical groups was a significant issue before the charges were rejected (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 3 shows that 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 on average 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 not only targets trips to and from the city centre. Figure 4 strengthens the argument: the mean paid charge remains stable as far out as 50 km from the central station in Gothenburg[4], whereas in Stockholm the mean paid charge 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 centre are made using public transit.

[4] 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.

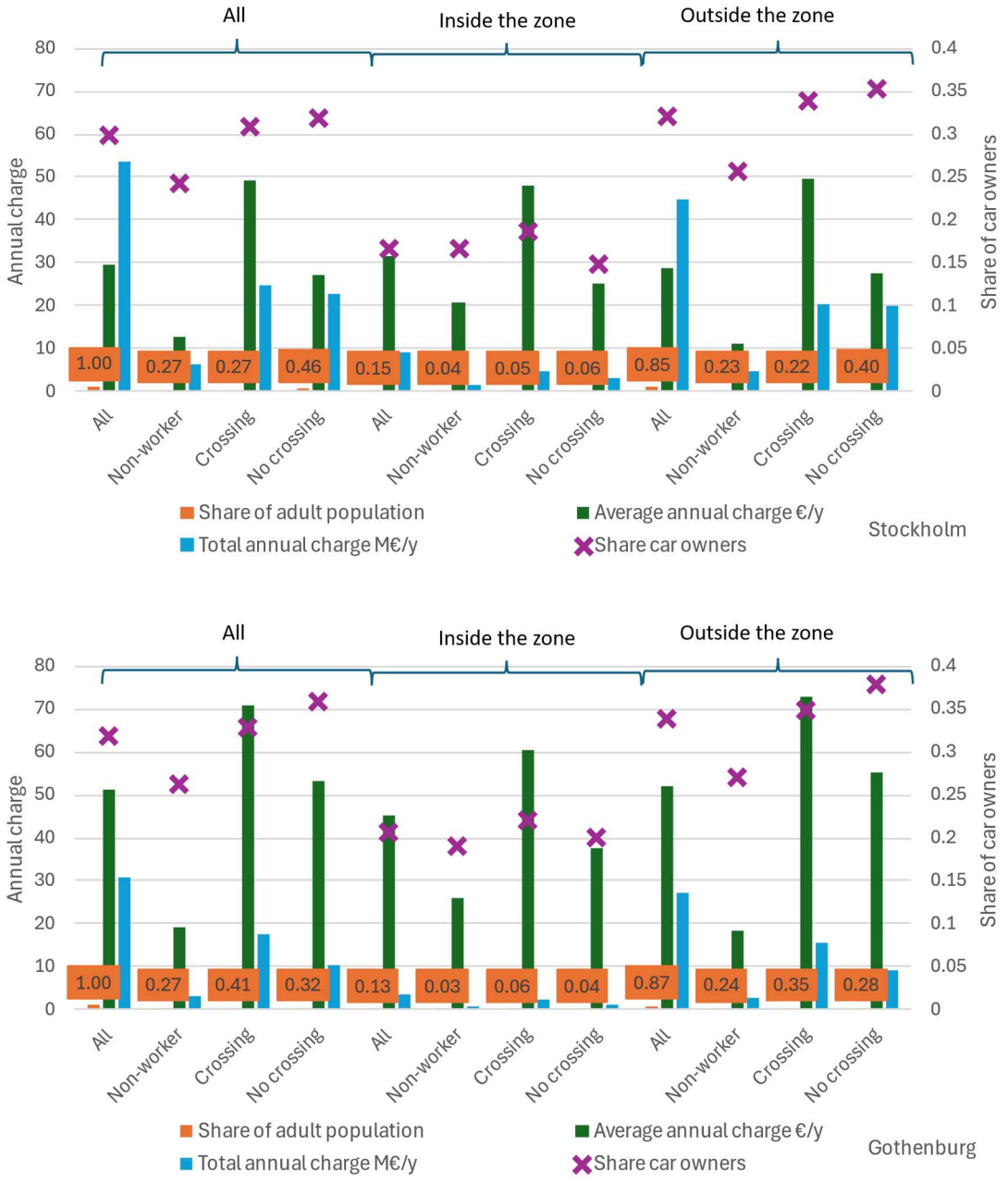

Figure 4: Distribution of the congestion charge in Stockholm (top) and Gothenburg (bottom) in 2018, for workers and non-workers, and for commuters crossing or not crossing the zone, residing inside or outside the zone.

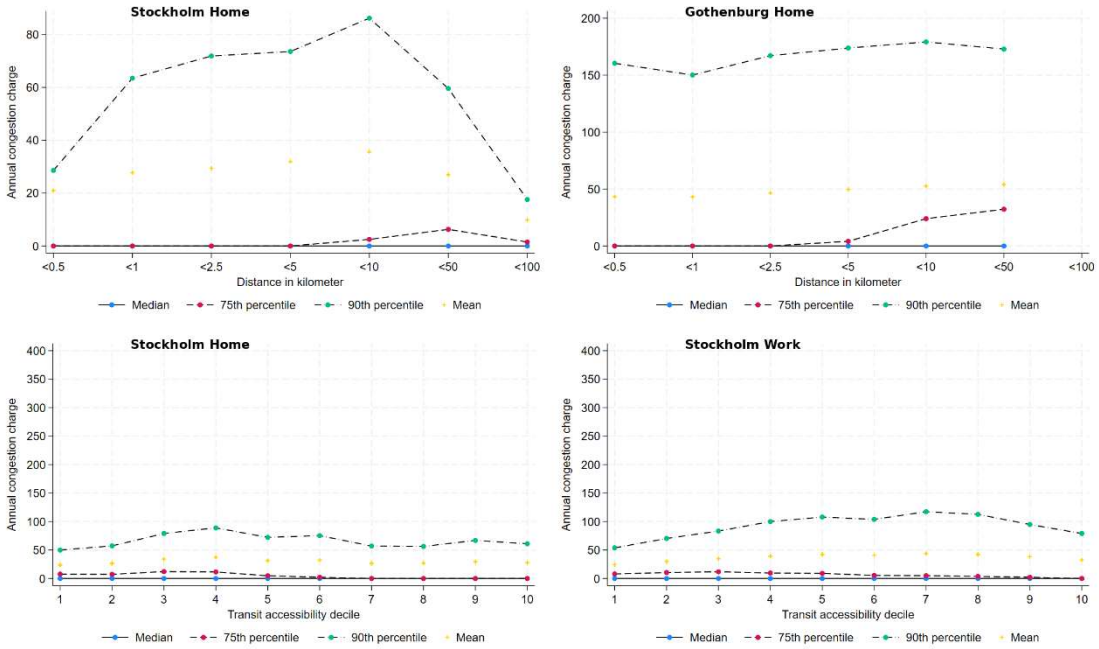

Figure 5: Annual charge per inhabitant. Top: by distance to the zone in Stockholm and Gothenburg. Bottom: by transit accessibility from home and work (in Stockholm).

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 a 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. Let $\tilde{R}$ be the set of zones 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

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

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 and is estimated within the transport model from travellers' behaviour.

Figure 4 shows that the average paid charge is not lower for residents with higher transit accessibility. In general, there is only a weak 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 works, shown in Figure 4.

6 How paid charges vary 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

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

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, has children, has employment, is residing inside the cordon, crosses the cordon on the commute, owns a car, or has 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 the unobserved individual-specific preferences remain constant over time (2018-2020) 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 2 shows 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. 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 findings 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 that parents are spatially sorted. When car ownership is included, the effect becomes negative and significant in Stockholm —i.e., having a child decreases 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 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 2—which is not accounted for in the regression models. Moreover, the income effect is eight-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. Hence, a major reason why high-income individuals pay more is their higher rate of car ownership.

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 (€5 per year) 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 or spatial sorting - which correlates with commuting patterns. 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 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.

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.

Table 2: Robust standard errors (clustered at the municipality level) in parentheses

	Stockholm					Gothenburg			
	OLS (1)	OLS (2)	FE (1)	FE (2)	FE (3)	OLS (1)	OLS (2)	FE (1)	FE (2)
Female	-20.95*** (1.43)	-3.49*** (0.49)				-28.95*** (1.88)	-4.93* (1.93)		
Child	5.65*** (1.06)	6.14*** (0.75)	-0.69 (0.50)	-2.20*** (0.38)	-2.20*** (0.38)	9.63*** (0.33)	11.70*** (0.48)	-0.21 (0.20)	-2.23* (0.84)
Singel	-12.15*** (1.89)	-3.87*** (0.45)	-1.30*** (0.45)	-1.56*** (0.29)	-1.51*** (0.28)	-18.68*** (2.56)	-7.13*** (1.05)	-0.10 (0.81)	-0.99** (0.27)
Ln (Disp. Inc)	18.62*** (1.25)	3.14*** (1.04)	1.73*** (0.08)	0.65*** (0.09)	0.66*** (0.09)	28.90*** (0.91)	4.00** (1.25)	3.71*** (0.27)	2.07** (0.47)
Employed	0.18 (0.81)	5.40*** (1.34)	1.10*** (0.21)	0.46** (0.21)	0.46** (0.21)	7.79*** (0.71)	13.83*** (0.56)	1.83 (0.92)	0.14 (0.75)
Fringe car	-31.64*** (1.79)	-6.59*** (0.93)	-49.08*** (5.62)	-31.64*** (2.77)	-31.64*** (2.77)	-52.11*** (2.69)	-10.75*** (1.68)	-53.78*** (5.20)	-30.67*** (1.65)
Dist. C. Station, km	-0.33*** (0.07)	-0.73*** (0.14)	-0.04* (0.02)	-0.15*** (0.02)	-0.23*** (0.06)	-0.60* (0.20)	-1.63*** (0.13)	-0.12 (0.07)	-0.38*** (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)	-7.42** (1.64)	3.32** (0.84)	-0.64 (0.41)	1.60** (0.38)
Crossing zone on commute	17.90*** (3.85)	19.05*** (4.90)	5.35*** (1.54)	4.95*** (1.65)	4.94*** (1.65)	19.04** (4.01)	19.61** (3.87)	4.76*** (0.74)	4.60** (0.82)
Own a car		104.15*** (14.75)		110.01*** (15.65)	110.01*** (15.65)		150.67*** (19.68)		144.45*** (20.87)
Access. PT					-1.43* (0.75)				
No. Obs.	5,254,918	5,254,918	5,254,918	5,254,918	5,254,918	1,777,118	1,777,118	1,777,118	1,777,118
Adj. R2	0.048	0.20	0.61	0.77	0.78	0.08	0.34	0.70	0.74
Individual FE	No	No	Yes	Yes	Yes	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Finally, in the Stockholm model, the transit accessibility is not significant as indicated by 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.

The main conclusion is that many explanatory variables affect the paid charge indirectly, through correlations between unobserved payment preferences and observed characteristics. Still, the OLS model remains relevant because it identifies which groups actually pay the charge.

7 Conclusions

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 partly serve as a fiscal tax (rather than a price correction), as they challenge the fundamental criterion of horizontal equity (Mankiw et al., 2009).

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 (1977) index $1>S>-1$. A tax is considered neutral if it is proportional to income ($S=0$). 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.

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 smaller than when focusing on a day. The vast individual variation within a year implies that it is less informative to use data based on self-reported behaviour in a “normal week” or observed trips for one day, which many previous studies has relied on. Moreover, the effect of income on the paid charge is eight-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.

The income effect is 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. However, 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. This further strengthens our conclusion that the paid congestion charge is not primarily driven by commuting across the charging cordon.

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