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Distributional Effects of Public Transport Subsidies

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Abstract

We analyse the distribution of transit subsidies across population groups in Stockholm. We develop a novel methodology that takes into account that the subsidy per passenger varies across transit links, since production costs and load factors vary. With this, we calculate the subsidy per trip in the transit network and analyse the distribution of subsidies across population groups. The average subsidy rate in Stockholm is 44%, but the variation across trips turns out to be large: while 34% of the trips are not subsidized at all but generates a profit, 16% of the trips have a subsidy rate higher than 2/3. We calculate the concentration index to explore the distribution of subsidies across income groups. The average subsidy per person is similar for all income groups, except for the top income quintile. This holds not only for the current flat-fare system, but also for distance-based fares and fares with a constant subsidy rate. Transit subsidies is hence not effective as a redistribution policy in Stockholm. The largest systematic variation we find is across residential areas: the average subsidy per person is five times higher in the peripheral areas of the region compared to the regional core, and the subsidy per trip is ten times higher.

Keywords: Public Transport, Subsidies, Equity, Progressive, Distribution effect, Concentration index

JEL Codes: R41, R42, R12

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1 INTRODUCTION

Governments spend vast sums on transit subsidies. There are several arguments for subsidizing transit for reasons of economic efficiency, such as scale economies and second-best pricing of road traffic externalities. But in addition to such arguments, transit subsidies are often motivated using redistribution arguments: it is argued that since transit is used more by low income groups, transit subsidies have a progressive distributional profile. However, merely noting that low-income groups make more transit trips per person does not necessarily imply that subsidies in fact accrue more to them, since subsidies per trip – the difference between the fare and the production cost per passenger – vary enormously in a transit network. Links with high occupancy rates can in fact be highly profitable, while sparsely used links are of course highly subsidized. This means that it is largely unknown to which population groups subsidies actually accrue. An analysis of the distributional effects of transit subsidies must take the variation of subsidies across links in the network into account; it is not enough to simply compare trip lengths or frequencies across different groups. This is the purpose of the present study. We develop a novel methodology to calculate the subsidy per trip, taking the variation of subsidies across links in the network into account, and analyse the distribution of subsidies across population groups for several alternative fare schemes. We use data from Stockholm in our case study, but the methodology and reasoning is general.

There is an extensive literature on socially optimal pricing and supply of transit services, considering factors such as economies of scale and density, crowding and second-best pricing of road traffic externalities (Basso and Silva, 2014; Fielbaum et al., 2016; Gschwender et al., 2016; Jansson, 1980; Jansson et al., 2015; Jara-Díaz et al., 2017b, 2017a, 2016; Mohring, 1972; Parry and Small, 2009) . A general conclusion from this literature is that fares should be differentiated in space and time to take variation in positive and negative externalities into account. However, an argument often used against such differentiated fare structures is that this would lead to a less progressive distribution of the subsidies. There are, however, few studies explore how the fare structure design impacts the distribution of the subsides across groups, which is a second purpose of this study.

There are a few studies analysing the distributional profiles of subsidies and fare structures. Some studies have found that distance-based transit fares would hurt low-income groups more than high-income groups because the former households are located in remote areas (Sanchez et al., 2007). Other studies have found the reverse (Bandegani and Akbarzadeh, 2016; Farber et al., 2014).

In order to compare subsidies and fare structures, we need a measure of their distributional profile across income groups. We will use the concentration index (Kakwani, 1977) to measure how public spending on subsidies is distributed across income groups. The index is bounded between -1 and 1. If all citizens receive the same amount, the index will be zero; a progressive spending profile (more is spent on low income groups) yields a negative concentration index, and vice versa. The index can be compared across time and countries. It has previously been used to measure for instance to what extent subsidies and public spending in the health sector are distributed across income groups (Doorslaer et al., 2006; O'Donnell, 2007). To our knowledge, this is the first application of it in the transport economics literature.

In the sample of passengers that we analyse, excluding children, the average subsidy rate is 44% (excluding cost for infrastructure investments and maintenance), but the variation among trips is high: 34% of trips are not subsidized at all but yield an economic surplus, while 16% of trips have a subsidy rate higher than 2/3. The average subsidy per person is similar across the income range, except for the top income quintile which get a lower subsidy per person because they make fewer transit trips. The subsidies are therefore only mildly progressive with a concentration index of -0.217. This holds not only for the current flat-fare system, but also for distance-based fares and fares with a constant subsidy rate; increased fare differentiation does not reduce progressivity appreciably. However, reducing fares across the board, or setting fares to zero, *reduces* progressivity, because of the current discounts for students and retirees.

While the redistribution effect among income groups is small, the redistribution effect among residential areas is huge: the average subsidy per person is five times higher in the outer residential areas compared to the regional core, and the corresponding subsidy per trip is ten times higher. Whether this can be motivated by efficiency arguments is unknown and out of the scope of the present paper, but we will list a number of potentially relevant motivations. Of course, it is also conceivable that the main reason for this is that voters and decision-makers are unaware of the distribution of subsidies.

2 METHODOLOGY

2.1 Calculating the subsidy per trip

Imagine two residential areas served by identical transit services with the same fare. One area is occupied by low-income residents, and the other by high-income residents. If the low-income residents make more transit trips per person, the load factor on their transit service will be higher, and hence require less subsidies (if any). In this example, the rich group will effectively receive more transit subsidies per person, and the transit subsidies will hence have a regressive distributional profile – even though the poor make more transit trips per person. This simple example shows why detailed calculations are necessary to unveil to which groups transit subsidies accrue.

The subsidy of a trip is the production cost of the trip minus the fare. The production cost of a trip, in turn, is the sum of the production cost per passenger on each of the links the trip uses, "link" meaning the connection between two adjacent nodes (stations or stops) with a particular service (such as a bus line). The starting point is hence to calculate the production cost per passenger for each link. To do this, one must decide how the production cost of a transit service (which of course consists of many links in a sequence) should be allocated among passengers on that service. There are several potentially reasonable ways to do this. We choose to split the total weekly production cost of each service over all trips on that service in proportion to trip length. In other words, we do not separate the production cost of the service into separate costs for peak and off-peak hours, weekdays and weekends, or segments (groups of links) along the service line. It can be argued that not distinguishing between time periods in the analysis introduces cross-subsidization between trips, since both service frequencies and load factors vary with time of day and day of the week. However, we do not analyse peak, off-peak and weekend period separately for two reasons. First, staff, vehicle and infrastructure costs are fixed or semi-fixed in the sense that they do not change much depending on how service frequencies vary over a week. Second, overall transit capacity is set to meet the peak demand. Therefore, the high peak capacity results in high capacity also in the off-peak, implying lower load factors and therefore seemingly higher subsidies in the off-peak. Because it is unclear how to distribute fixed or semi-fixed production cost between peak, off-peak and weekends, we spread total production costs equally over all passenger kilometres on the service. (The topic of this paper is not optimal subsidies in this paper, but in passing we note that the optimal subsidy is higher for the off-peak than for the peak because the marginal user cost is substantially lower in the off-peak, precisely because it is the peak capacity that constrains the passenger volume.)

It can also be argued that spreading production costs equally over all passenger kilometres on the service implies a cross-subsidization across different links of the service. For example, imagine that for a given service, load factors are higher on central links and lower on peripheral ones. The production cost per passenger would then be higher on the peripheral links, and vice versa. However, we assume that services have to be served in their entirety, and cannot be split into shorter sub-services. If that assumption is reasonable, it is logical that all passenger kilometres share the total production costs of the service equally. If this would not be the case, our assumptions will tend to underestimate the subsidy rates on peripheral links, since they tend to have lower load factors, and vice versa for central links.

To describe our calculation method formally, let T_{ij} be the number of transit trips from i to j, during a representative week, and p_{ij}^{n} the fare for this ij-trip for individual n (allowing for individual-specific fares, since there may be discounts for e.g. students and retirees). Let d_k be the length of transit link k. Let δ_{ij}^{k} be 1 if link k is part of the route from i to j with the lowest generalized cost in the transit network and 0 otherwise. Each link belongs to exactly one service R, so a service is a set of links in the network; let $R(k)$ be the service that link k belongs to. Let C_R be the total weekly production cost of service R. Given this, we get

number of trips on link k	$T_k = \sum_{ij} T_{ij}\delta_{ij}^{k}$

production cost of a single trip on link k	$c_k = \frac{C_{R(k)}}{\sum_k T_k d_k} d_k$
production cost of a single ij-trip	$c_{ij} = \sum_k \delta_{ij}^k c_k$
subsidy for an ij-trip for individual n	$p_{ij}^n - c_{ij}$
average subsidy accruing to a member of group N (with $\|N\|$ members)	$\frac{\sum_{n\in N} \sum_{ij} T_{ij}^n (p_{ij}^n - c_{ij})}{\|N\|}$

Note that the last step takes into account that trip frequencies and origin-destination distributions vary across population groups.

Production costs by service are calculated using data from the Stockholm Public Transport Agency (see Section 3.2), link flows T_k and (implicit) route/link indicators δ_{ij}^k are taken from a transport model (see Section 3.2), and individual trip patterns T_{ij}^n are taken from a travel survey (see Section 3.3).

2.2 Comparing distributional profiles of public spending

To summarize the distributional profile of subsidies across income groups, we will use the concentration index (CI) (Kakwani, 1977). The CI is based on the concentration curve $s(x)$, which shows the share of total spending accruing to the poorest x percent of the population. The CI measures the total difference between the actual spending profile and lump-sum spending:

$$CI = 2\int_0^1 \big(x - s(x)\big)dx = 1 - 2\int_0^1 s(x)dx.$$

The CI is bounded to the interval (-1,1). A lump-sum spending, where all individuals get the same amount, means that $s(x) = x$ and that CI equals zero. If a disproportionate share of spending accrues to the poor, the CI is negative, and the spending profile is defined as progressive. Conversely, if a disproportionate share of spending accrues to the rich, the CI is positive, and the spending profile is defined as regressive.

The CI can be compared across scenarios, points in time, cities and countries. It has been widely used in health economics to calculate the progressivity of healthcare subsidies and spending. To our knowledge, it has not been applied to analyze public spending in the transport sector before.

The CI can be compared to the Suits index and the Gini index. The Suits index (Suits, 1977) is used to measure the distributional profile of taxes; transport-related applications can be found in West (2004), CPPP (2007) and Eliasson et al. (2018). The Suits index is bounded to the interval (-1,1) just as the CI, but they differ in that the Suits index defines a neutral tax as one where each everyone pays the same share of their income, while the CI defines a neutral spending scheme as one where everyone gets the same amount in absolute terms. The Gini index measures wealth distribution, and is bounded to the interval (0,1). Perfect equality, where everyone has the same wealth, gives a Gini index of 0.

3 DATA

3.1 Stockholm

The total population of the Stockholm County was 2.2 million in 2015. The population growth has increased in recent years, from around 1% per year before 2000 to over 1.5% after 2000. The county consists of 26 municipalities, where the City of Stockholm is by far the largest with nearly half the county's population. For purposes of presentation, we have divided the municipalities into five groups according to proximity to the city centre, taking not just distance but also transport opportunities into account. The categorization is shown in Figure 1: the *core* includes Stockholm, Solna and Sundbyberg; the *inner suburbs* include Lidingö, Sollentuna, Huddinge, Danderyd, Nacka and Järfälla; the *outer suburbs* include Botkyrka, Haninge, Tyresö, Täby; the *peripheral suburbs* include Upplands Väsby, Salem, Södertälje, Ekerö, Upplands Bro; the *periphery* include Nykvarn, Sigtuna, Nynäshamn, Värmdö, Vaxholm, Östertälje, Österåker, Norrtälje and Vallentuna. The core corresponds roughly to the area served by the metro network, and contains nearly half of the county's population.

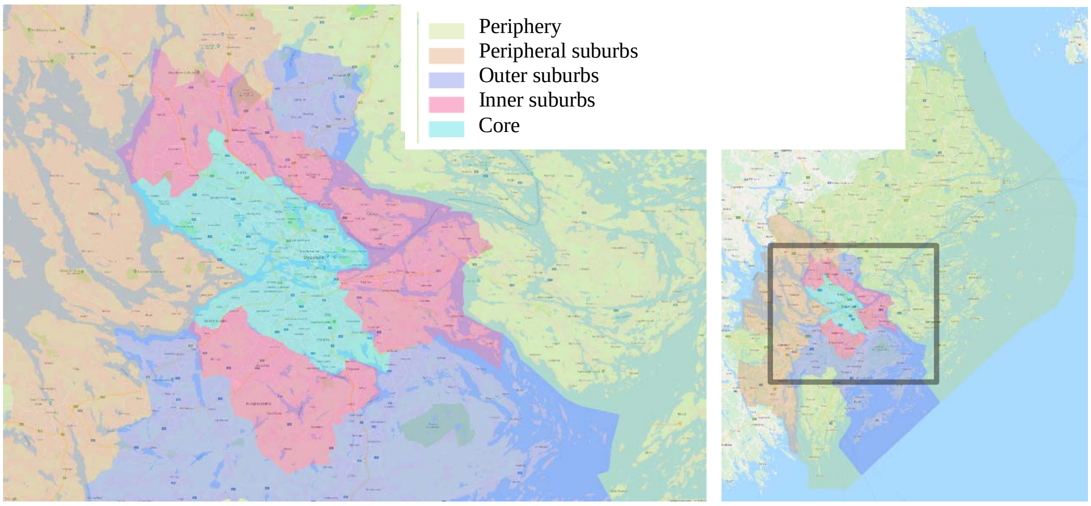

Figure 1: Stockholm County, with categorization of municipalities. Background data ©2017 Google

The average income in the core is close to the regional average (Table 1), while it is higher in the inner suburbs. The outer suburbs are characterised by high-density housing surrounding commuter train stations, where the average income is low, and more sparsely populated areas with single family houses and higher average incomes. The periphery is dominated by single family housing, and the income increases again.

The Stockholm Public Transport Agency is responsible for transit provision in the county. The average subsidy for the entire system cost is 42% (the ratio between the subsidy from the regional government and the total costs of the system, excluding investments in physical infrastructure and operation and maintenance cost for the infrastructure for bus and commuter trains[1]). The total production costs I is 16.3 BSEK/year. Of this 6.8 BSEK/year are subsidies, 3.1 BSEK/year are revenues from property rents and advertisements, and 6.4 BSEK/year are ticket revenues (resulting in the subsidy rate 6.8/16.3=42%). The total cost of the system, 16.3 BSEK/year, can be split into a direct production cost of the transit services, 13.1 BSEK/year, and other costs 3.2 BSEK/year. We will base the calculation of the costs and the revenues generated per trip on the production cost of the services (13.1 BSEK/year) and the ticket revenues (6.4 BSEK/year) only, resulting in a subsidy rate of 52% (6.4/13.1). This is because the other costs and the other revenues (property rents and advertisements) cannot be broken down to services.

Transit trips make up 31% of all trips in the county (47% of motorized trips), but this varies widely in the county. The transit share is highest for trips to and from the inner city, where it reaches 80 percent for work trips.

Trip counts show that the number of transit boardings has been increasing at the same rate as the population, and faster than the number of car trips to and from the regional centre. Since the 1950s, Stockholm has followed a transit-oriented planning strategy (Cervero, 1995; Stockholm City Planning Administration, 2009), meaning that land use is concentrated around stations and along transit corridors. This in an important explanatory factor of the high transit share compared to many other cities.

In the inner city the number of car trips has declined since 2005. One of the main reasons is that Stockholm introduced congestion charges in 2006, designed as a toll cordon around the inner city (Eliasson, 2008). This reduced traffic across the cordon persistently by around 20% (compared to pre-2006 levels) during weekdays, and traffic levels has remained approximately constant ever since. The peak charge was increased and an additional charging point was added in 2016, which reduced traffic across the cordon even further (Börjesson and Kristoffersson, 2017). Congestion charges, fuel taxes and parking charges together internalize much of the external effects from driving. Hence, subsidizing as a second-best pricing of road traffic externalities is much less justified in Stockholm than in most other comparable cities (Börjesson et al., 2018, 2017). This makes the distributional effects of subsidies even more relevant to analyse.

3.2 Transit production costs

Production costs for transit services are calculated based on vehicle kilometres and vehicle hours, using the production cost functions summarized in Table 1. The production costs are constructed by the Stockholm Public Transport Agency using detailed internal data on all types of staff, operations and maintenance costs. Capital and maintenance costs for all vehicles and maintenance costs for bus stops and stations are also included. Maintenance

[1] These costs are covered by the municipalities and the national government, respectively, and are therefore not included.

and operation costs are included for the metro tracks, but not for rail infrastructure used by commuter trains or road infrastructure used by buses. Investment costs for road and rail infrastructure are not included. All costs are then broken down proportionally to vehicle hours or vehicle kilometres, depending on whether they depend mostly on vehicle hours or kilometres.

Capital and operation cost	Bus	Tram	Metro	Commuter train
Vehicle cost/h [SEK/min]	936	5271	8575	9728
Vehicle cost/km [SEK/km]	15	67	109	146

Table 1: Transit production costs.

To calculate production cost per link and per passenger, we need passenger link volumes (see section 2.1). These are calculated using the transit network model VISUM, using an origin-destination matrix stemming from the national Swedish transport model SAMPERS, and then calibrated against observed passenger volumes, boardings and alightings. Production cost per origin-destination-trip is then calculated by coding passenger production cost per link as link attributes and summing these link attributes along the route connecting each origin-destination pair.

3.3 The Travel Survey

The basis for calculating distributional effects is a large cross-sectional travel survey, representative for trips and citizens in Stockholm County. Using a travel survey is preferable to breaking down data from a transport model by population group, since all correlations between socioeconomic characteristics and travel patterns are accurately represented, provided of course that the sample is representative and large enough.

The travel survey was conducted among Stockholm County residents September-October 2015. The respondents were a random sample of Stockholm County residents aged 16-84, who were asked to report all trips made during a randomly assigned survey day. The respondents could choose between a mail-back paper survey and a web-based survey. The final sample was weighted to be representative for the county population with respect to age, gender and residential location. The sample of individuals responding to the survey matches the census statistics with respect to employment and driving licence shares. The survey days are uniformly distributed among all days of the week (workdays and weekends). The response rate was 35%, and the final sample included 45 467 respondents making 102 588 trips, of which 31 961 were transit trips.

3.4 Population and trip characteristics

Table 2 shows population characteristics based on the travel survey. The respondents report household income in 11 categories, family status, gender, age, occupation: employed, student, retired, others (unemployed, sick leave or parental leave). We approximate the income per individual by dividing the mid-point of the household income interval reported by the respondents by the number of adults in the household. Note that for many of the students and the young adults (16-24 years old) the computation of the individual income from the household income is misleading or unreliable because many of them live with their parents. The students' monthly income will also vary with the season (i.e. they might have a larger monthly income during the summer if they are working then) which also makes the meaning of the monthly income difficult to interpret.

	# ind. sample	% ind. Sample	# transit trips /ind.	# trips /ind.	Average trip length all trips	Averag e trip length transit trips	Average income per household SEK/m
Monthly gross income (SEK)							
<= 10 000	3677	8%	0.59	1.29	14.00	14.67	7 741
> 10 000 & <= 20 000	5090	11%	0.88	2.51	16.29	17.49	15 152
> 20 000 & <= 30 000	5810	13%	0.85	2.61	16.40	18.21	22 833
> 30 000 & <= 40 000	10727	24%	0.81	2.90	15.78	17.74	32 566
> 40 000 & <= 60 000	7410	16%	0.72	2.67	16.03	17.92	47 458
> 60 000 & <= 80 000	3691	8%	0.43	1.70	14.85	16.16	67 720
> 80 000	3749	8%	0.36	1.46	16.17	16.21	127 079
Not reported	5311	12%	0.63	1.80	17.20	17.81	-
Total	45467	100%	0.70	2.31	15.99	17.51	41 482
Occupation							
Employed	28748	63%	0.74	2.59	15.89	17.81	43 622
Student	5069	11%	1.26	2.22	16.18	18.23	38 529
Retired	7971	18%	0.34	1.58	18.54	15.14	39 663
Other	3679	8%	0.79	1.82	15.24	16.81	30 257
Total	45467	100%	0.70	2.31	15.99	17.51	41 482
Age							
16-24 y	6212	14%	1.13	2.13	16.47	17.62	44 921
25-39 y	12999	29%	0.84	2.57	14.21	16.78	34 097
40-64 y	18359	40%	0.61	2.48	16.67	18.72	45 866
65-84 y	7897	17%	0.36	1.63	18.54	15.14	41 667
Total	45467	100%	0.70	2.31	15.99	17.51	41 482
Gender							
Women	22774	50%	0.82	2.36	14.71	17.25	39 984
Man	22693	50%	0.59	2.25	17.39	17.89	42 944
Total	45467	100%	0.70	2.31	16.0	17.51	41 482
Residential area							
Core	21723	48%	0.87	2.39	12.7	13.4	41 232
Inner suburbs	8365	18%	0.65	2.37	15.6	17.5	46 420
Outer suburbs	5791	13%	0.58	2.15	17.9	22.2	40 730
Peripheral suburbs	4164	9%	0.46	2.13	21.5	28.4	36 802
Periphery	5425	12%	0.42	2.16	26.2	37.3	39 254
Total	45467	100%	0.70	2.31	16.0	17.51	41 482

Table 2: Population and trip characteristics.

The number of transit trips is highest for the mid-income groups, although the difference between income groups is small (note that daily trip frequencies in the table refer to all days, not just weekdays). The mid-income groups also make slightly longer trips, both with transit and in general. Students make considerably more transit trips than other groups. On average, women make shorter transit trips than men, but slightly longer trips with other modes (although the latter difference is small). The largest differences in travel patterns can be seen between residents in different areas. Residents in the more central areas make slightly more trips overall, many more transit trips, and considerably shorter trips.

4 DISTRIBUTIONS OF SUBSIDIES

This section describes the distributional profile of subsidies given the current fare structure, while the next section (section 5) compares this to alternative fare structures. The current fare structure is described in 4.1 and the distribution of the trip production costs is described in 4.2. Based on the fare and the trip production cost the subsidy per trip for all reported trips in the travel survey is computed. Section 4.3 shows how the subsidy per person and per trip is distributed across population groups using descriptive statistics. Since the current fare is hardly differentiated across trips, the current distributional profile of transit subsidies is almost entirely driven by three factors: differences in production cost per trip, differences in transit trip frequencies, and fare discounts for retired and students.

4.1 Fare structure

As in many cities, fares in Stockholm have a low degree of differentiation. The only substantial differentiation is the discount for students and retired. To some extent, travel cards also introduce a differentiation between occasional and habitual transit users. But apart from that, fares are uniform across distance, time of day, area and transport mode.

Fares are paid either with single-trip tickets or with travel cards which allow unlimited travel during a week, month or year. Travel cards are more common than single-trip tickets: 82 percent of all trips are paid for by travel cards. Fares are discounted for students and retired, who pay 38 percent less. The price for single-trip tickets vary depending on type of payment (e.g. cash is more expensive than prepaid cards); the average single-trip full fare is 28 SEK (10 SEK ≈ 1€). Holders of travel cards make 40 trips per month on average (this does not vary among population groups), which implies an average fare per trip for travel card holders of 20 SEK (without discount). Taking single-trip tickets and travel cards together, the average fare for a non-discounted trip is 22 SEK. Taking discounts into account, the average fare for all types of passengers and payments is 19 SEK.

4.2 Distribution of trip production costs

This section presents differences in production cost per trip across several population groups; the subsequent section calculates subsidy per trip and per person by subtracting fares from production costs and taking transit trip frequencies into account.

Table 3 presents mean and quantiles of production costs per transit trip. The distribution is skewed; while the median production cost per trip is just under 27 SEK, the mean is 34 SEK, the 75-percentile is nearly 43 SEK, and the tail of the distribution stretches far beyond 100 SEK per trip. At the same time, there are also many cheap trips: almost 25% of trips have production costs below 15 SEK.

Table 3 shows production costs per trip for two income groups (low and high). We restrict the presentation to two income groups because, remarkably, production costs per trip vary very little by income group. High-income groups make slightly longer trips on average, but this is counteracted by low-income groups using more services with low load factors. Together, the below-average income group has a slightly higher production cost per trip than the highest income group.

Students have the highest average production costs, followed by workers, since these two groups make longer transit trips. The difference between occupation groups is relatively small, however.

The segmentation that really matters is by residential area (Table 3). There are huge and consistent differences in trip production costs depending on where in the county passengers live: the further away from the centre, the higher is the production cost per trip. Trip production costs in the periphery are almost three times higher than in the core. The differences arise partly because the passengers residing further from the centre make longer transit trips, and partly because load factors in peripheral areas are lower. (Note that the core encompasses a rather large area, much larger than e.g. the inner city; it coincides roughly with the extent of the metro network.)

	1st quartile	Median	3rd quartile	Mean
All trips	15.4	26.6	42.9	33.9
Income groups				
Low income (<=20 kSEK/month)	15.5	26.5	42.9	33.8
High income (>=40 kSEK/month)	14.8	25.2	41.1	32.6
Occupation				
Work	15.7	26.5	43.3	34.2
Student	16.8	28.2	42.9	35.0
Retired	12.3	24.3	42.0	31.8
Others	11.3	20.7	38.0	28.5
Residential area				
Core	12.3	21.1	33.3	25.4
Inner suburbs	21.5	31.6	45.7	36.4
Outer suburbs	26.4	38.1	51.6	43.3
Peripheral suburbs	33.4	49.6	68.3	54.9
Periphery	34.3	59.5	98.0	76.9

Table 3. Distribution of trip production costs (SEK/trip), by population group.

4.3 Distribution of subsidies

The subsidy per trip is computed as the production cost minus the fare. Table 4 shows how subsidies are distributed across population groups. The last column shows subsidy per person by group. Table 4 shows how the distribution of subsidy per person depends on how three factors vary: production costs per trip, transit trip frequencies, and fares. In the second column of Table 4, production costs per trip are repeated from Table 3. As shown in the previous section, production cost per trip is similar across income groups and gender, varies slightly with occupation, and varies substantially across residential areas. The third column shows average subsidy per trip.[2] For the purposes of this study, it is convenient that the only variation in Stockholm transit fares is the discount for students and retired – it makes results easy to interpret: it means that the variation in average subsidies per trip essentially only depend on the variation in production costs and whether the passenger is a student/retired or not. The fourth column shows average transit trip frequencies per group, which results in the last column, average subsidy per person by group.

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[2] Note that the average subsidy rate for trips in the sample is 44% (14.9/33.9) according to Table 4. This differ from the total subsidy rate on the aggregate level which is 52%, calculated from the production costs (13.1 BSEK/year) and ticket revenues (6.4 BSEK/year), see section 3.1. The lower subsidy rate per trip in our sample is partly due to sampling error, but also because children (who pay low ticket price or are free of charge and therefore have a high rate of subsidies) are not included in the sample.

	% of population	Average production cost per trip	Average subsidy per trip	# transit trips per person	Average subsidy per person
Income (SEK/month)					
<= 10 000	8%	33.8	18.5	0.6	10.9
> 10 000 & <= 20 000	11%	31.4	13.8	0.9	12.2
> 20 000 & <= 30 000	13%	34.5	15.1	0.9	12.9
> 30 000 & <= 40 000	24%	34.5	14.4	0.8	11.7
> 40 000 & <= 60 000	16%	33.7	13.8	0.7	10.0
> 60 000 & <= 80 000	8%	30.7	11.0	0.4	4.7
> 80 000	8%	30.5	10.9	0.4	4.0
Not reported	12%	38.8	22.2	0.6	14.0
Total	100%	33.9	14.9	0.7	10.5
Occupation					
Employed	63%	34.2	13.2	0.7	9.8
Student	11%	35.0	22.1	1.3	27.7
Retired	18%	31.8	17.0	0.3	5.7
Other	8%	28.5	6.5	0.8	3.0
Total	100%	33.9	14.9	0.7	10.5
Age					
16-24 y	14%	35.5	21.2	1.1	23.9
25-39 y	29%	31.5	11.1	0.8	9.3
40-64 y	40%	36.0	14.5	0.6	8.9
65-84 y	17%	31.2	16.4	0.4	5.9
Total	100%	33.9	14.9	0.7	10.5
Gender					
Women	50%	33.5	14.6	0.8	11.9
Man	50%	34.4	15.3	0.6	9.0
Total	100%	33.9	14.9	0.7	10.5
Residential area					
Core	48%	25.4	6.2	0.9	5.4
Inner suburbs	18%	36.4	17.7	0.7	11.6
Outer suburbs	13%	43.3	24.6	0.6	14.4
Peripheral suburbs	9%	54.9	36.7	0.5	17.0
Periphery	12%	76.9	57.9	0.4	24.4
Total	100%	33.9	14.9	0.7	10.5

Table 4. Subsidies by population group.

The first part of Table 4 shows subsidies per income group. The subsidies turn out to be mildly progressive; the concentration index (see section 2.2 and section 5.1) is -0.217. This is mainly due to lower transit trip frequencies in the top income quintile (over 60 000 SEK/month), while differences in the rest of the income range are small. In income groups below the top quintile, the transit trip frequency lies around 0.8 trips per person and day, but in the highest quintile it drops to around half of that. Production costs per trip are also slightly lower in the highest income ranges. This is because high-income groups are overrepresented in central areas, which means that their average trip length is shorter and that they travel on services with high load factors, implying lower production costs per trip.

In the rest of the income range, trip frequencies and production costs are broadly similar. Overall, this leads to subsidies per person less than half for the top income quintile compared to the rest of the income range. For the rest of the income groups, subsidies per trip and per person are similar. The bottom income group – with a high share of students and retired – receives a considerably higher subsidy per trip (due to discounts), but on the other hand makes fewer trips, resulting in a subsidy per person on par with the other low and middle-income groups.

Turning to occupation, the variation is larger. Students are the big winners, getting nearly three times more subsidies per person than employed persons. This is partly because students make more and longer transit trips than any other group, and partly because of the student discount. Retired and others (unemployed, sick leave or parental leave) receive less subsidies – a half and a third, respectively, of what the employed get. This is partly because they make fewer transit trips, but also because the average production cost is lower and the average fare higher (despite the discount for retired), since fewer of them use travel cards.

As to age groups, results are as expected, given the findings for students and retired persons: young people get the most subsidies, because of the student discount and their high trip frequency, while old people get the least subsidies despite the retiree discount, since their average fare is higher and they make fewer trips. Young adults (25-39 years) have lower production costs per trip but make more transit trips than older adults (40-64 years). A likely explanation is that the older group to a larger extent live in single-family houses and hence further from the centre. Since these effects counteract each other, however, subsidies per person are similar for the two groups. Women get an appreciably higher subsidy per person than men (around 30% more), because they make more transit trips per person.

However, all differences discussed above are negligible compared to the huge geographic differences. For example, residents in the periphery get almost five times more subsidies per person than residents in the core. Even comparing adjacent areas, differences are substantial: for example, residents in the inner suburbs get more than twice as much subsidies as residents in the core. Looking at subsidies per trip, differences are even bigger: for example, the subsidy per trip is nearly ten times higher for residents in the periphery than for residents in the core.

The results in Table 4 only shows average subsidies per group, but now we turn to the distribution of subsidies in the full sample and within the groups. Figure 2 and Table 5 show that the distribution of subsidies exhibits a large variability. The first column of Table 5 shows the share of trips that are not subsidized (hence yields a financial surplus), since production costs are lower than the fare. The second column shows the share of trips with a higher subsidy rate than 2/3.

The third column shows the share of trips generating a profit higher than 2/3 of production cost. Table 5 shows that 34 percent of trips are not subsidized, while 16 percent have a subsidy rate higher than 2/3 and 7% of the trips generate a profit higher than 2/3.

Broadly speaking, Table 5 shows the same differences across groups as the results in Table 4. Differences across income groups are small (see Figure 3). A majority of the trips of others (including unemployed and people on sick leave or on parental leave) yield a surplus to the operator, and 13 percent of their trips generates a profit higher 2/3 of the distribution cost. However, only 18 percent of the students' trips generates a surplus. Geographic differences are again substantial (see also Figure 4). A majority of the trips made by the residents of the periphery have a subsidy rate higher than 2/3.

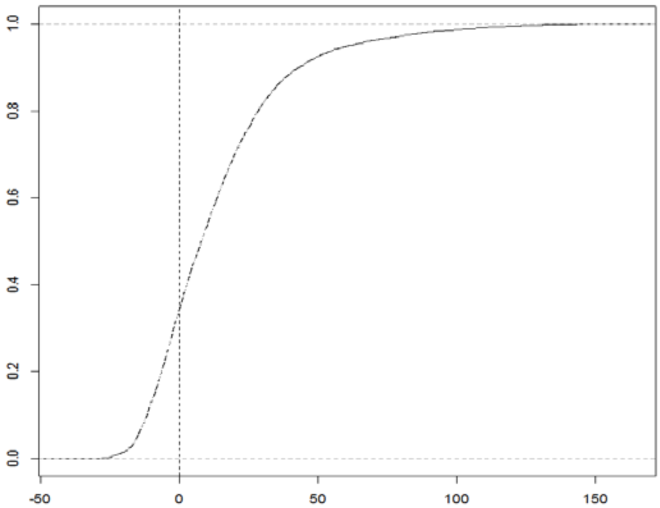

Figure 2. Cumulative distribution of subsidies per trip.

	Share of trips with production cost lower than the fare (negative subsidy)	Share of trips with production cost more than three times higher than the fare	Share of trips with fare more than three times higher than the production cost
All trips	34%	16%	7%
Income groups			
Low income (<=20 kSEK/month)	34%	15%	6%
High income (>=40 kSEK/month)	38%	13%	9%
Occupation			
Employed	37%	11%	7%
Student	18%	32%	3%
Retired	30%	21%	7%
Other	55%	6%	13%
Residential area			
Core	45%	8%	9%
Inner suburbs	20%	17%	3%
Outer suburbs	14%	23%	2%
Peripheral suburbs	10%	42%	3%

Periphery	13%	53%	3%

Table 5. Share of trips with high and low subsidies.

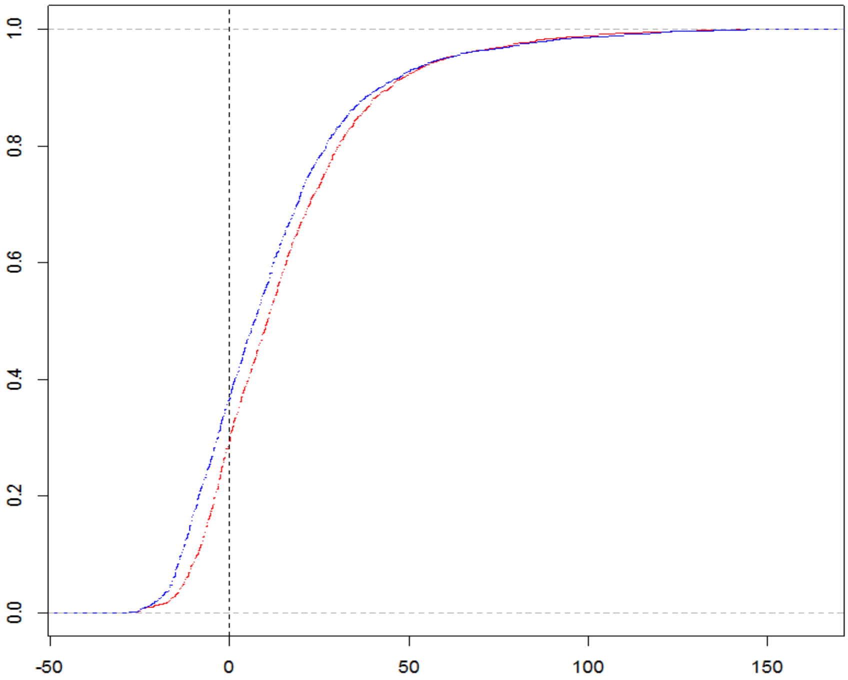

Figure 3. Cumulative distribution of subsidies per trip by income group. Blue = high incomes, red = blue incomes.

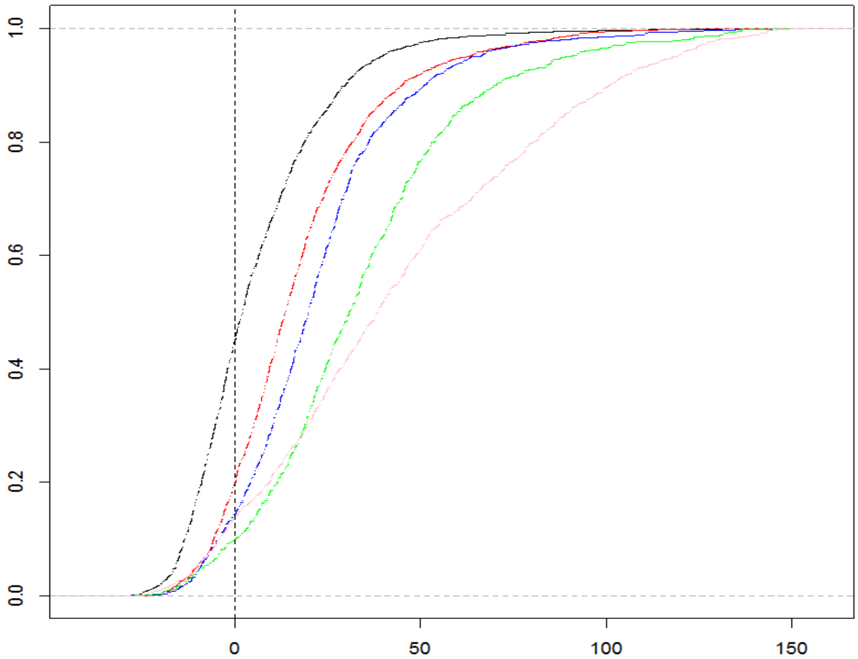

Figure 4. Cumulative distribution of subsidy per trip by residential area. Black=core, red = inner suburbs, blue= outer suburbs, green = peripheral suburbs, pink = periphery.

5 ALTERNATIVE FARE STRUCTURES

The previous section presents results for a current fare structure – essentially a flat-fare system with discounts for retired and students. In this section, we explore the distributional profiles of some alternative fare structures. To avoid getting lost in detail, we will only present distributions across income groups and residential areas.

5.1 Progressivity of different fare structures

As discussed in section 2.2, the progressivity of public spending (in our case subsidies) across income groups can be defined and computed by the concentration index. The index lies in the interval (-1,1). A negative index means that the spending profile is progressive (poorer groups get a larger share of total spending) and vice versa.

Table 6 shows concentration indices for seven alternative fare structures. They are computed under the assumption that the travel behaviour says unaffected by the changes in fare structure. As long as the changes in the fares are reasonably small, this assumption should be appropriate. However, the assumption can be questioned for large changes in fares - such as assuming zero fares. Still, since the behaviour is so similar across income groups in the base case, there are no strong reason to believe that the possible changes in travel behaviour would differ across these groups. For this reason, not taking behavioural changes into account would not have any large impact on the concentration index.

The first row of Table 6 ("Base") shows that the current fare structure in Stockholm, described in previous sections. The concentration index shows that subsidies are mildly progressive. As shown in the previous section, this is partly due to the fare discount for students. It is also due to the lower transit trip frequency for the highest income groups (top quintile). The former effect is illustrated in the second row, showing that the concentration index increases to -0.187 (i.e. less progressive) if the fare discount for students and retired is removed.

Reducing fares is often advocated as a policy with positive distributional effects. However, the third and fourth rows show that this is not true in Stockholm. Reducing fares by 10 percent, or all the way down to zero, implies less progressive subsidies, because this effectively reduces or takes away the discounts for the students and the retired. However, reduced fares would not necessarily be less progressive in a city where there the transit trip frequency differed more between income groups. Then, the reduced fares would benefit the low-income groups relatively more than high income groups than what is the case in Stockholm.

Fare structure	Concentration index
Base (flat fare with student+retired discount)	-0.217
Base without student+retired discount	-0.187

10% reduced base fare	-0.209
Zero fares	-0.177
No travel cards, only single-trip fares	-0.214
Same subsidy rate for all trips	-0.205
Distance-based fare	-0.203

Table 6. Concentration indices for seven alternative fare structures.

From an efficiency point of view, it is obvious that social gains can be made by moving from flat fares to differentiating fares in various dimensions to account for variations in e.g. crowding, production costs and externalities. Moreover, moving from travel cards allowing unlimited trips to single-trip fares would also allow fares to more accurately reflect the marginal cost (i.e. the social cost) of the trip, resulting in social efficiency gains.

However, more differentiated fares are often resisted with the argument that this would have regressive distributional effects. The last three rows show that this argument is not valid in Stockholm: the concentration indices remain virtually unchanged. The three fare structures analyzed in the three rows are constructed such that the aggregate fare revenues are equal to the base case (assuming no changes in travel behaviour).

In the "No travel cards" fare structure, travel cards are abolished, and all trips are paid for with a single-trip fare, chosen such that the total revenues remain unchanged but such that the students and retired still pay 38 percent less. This would in itself increase the social efficiency of system, but more importantly it makes it easier to introduce other kinds of fare differentiation, such as peak/off-peak differentiation or distance differentiation. As it turns out, there are no appreciable impacts on the distributional effects across income groups (or any other population groups) of abolishing travel cards and replacing them with a revenue-neutral single-trip fare. One reason for this is that the share of travellers with travel cards and the transit trip frequencies are so similar across income groups. Moreover, many retirees and others (unemployed, sick leave or parental leave) make so few transit trips per month that they cannot benefit from the travel card deal.

The next row shows the concentration index of a fare where all trips get the same subsidy rate (again chosen such that the total revenues remain unchanged). This is of course not necessarily an efficient fare, but it might be a fairer structure. Interestingly, this structure has virtually the same distributional profile as the base structure; the concentration index changes marginally. The subsidy per trip and per person by income group for this fare structure is presented in Table 7. The subsidy per trip and per person is slightly higher than in the base structure for the bottom and the top income quintile, but the effect is small. We can conclude that moving from a fare structure where subsidy rates vary widely to one where they are uniform does not change the distributional profile of subsidies appreciably – and hence, distributional concerns are not an argument against increased spatial differentiation of fares.

	BASE		Same subsidy rate for all trips		Distance-based fare	
Monthly gross income (SEK)	*Subsidy per trip*	*Subsidy per person*	*Subsidy per trip*	*Subsidy per person*	*Subsidy per trip*	*Subsidy per person*
Not reported	22.2	14.0	19.9	12.6	20.4	12.9
<= 10 000	18.4	10.9	18.6	10.9	20.0	11.8
> 10 000 & <= 20 000	13.8	12.2	14.7	13.0	14.7	13.0
> 20 000 & <= 30 000	15.1	12.8	14.6	12.5	14.2	12.1
> 30 000 & <= 40 000	14.4	11.7	14.0	11.4	13.5	10.9
> 40 000 & <= 60 000	13.8	9.9	14.1	10.2	14.5	10.4
> 60 000 & <= 80 000	11.0	4.7	12.7	5.5	13.0	5.6
> 80 000	10.8	4.0	12.9	4.7	13.8	5.0
Total	14.9	10.5	14.9	10.5	14.9	10.5

Table 7. Distribution of subsidies across income groups for three alternative fare structures (same aggregate revenue).

The same conclusion is reached when analysing the last fare structure, where fares are proportional to trip distance (still revenue neutral). Again, the centration index and the distribution of subsidies across income groups remain virtually unchanged, which can be seen in the last row of Table 6 and the leftmost columns of Table 7.

5.2 Distribution of subsidies across residential areas

In section 4.3 we show that subsidies vary hugely by residential area given the current flat fare. Residents in the periphery get subsidies per person and per trip which are several times larger than residents in inner areas. Changing from the initial flat fare to a constant subsidy rate, or to a distance-based fare, has considerable spatial distributional effects, despite the marginal effect on progressivity. Results are shown in Table 8 and Figure 5.

	BASE		Same subsidy rate for all trips		Distance-based fare	
Residential area	*Subsidy per trip*	*Subsidy per person*	*Subsidy per trip*	*Subsidy per person*	*Subsidy per trip*	*Subsidy per person*
Core	6.2	5.4	11.0	9.6	12.0	10.4
Inner suburbs	17.7	11.6	16.1	10.6	16.9	11.0
Outer suburbs	24.6	14.4	19.1	11.2	16.4	9.6
Peripheral suburbs	36.7	17.0	25.4	11.8	21.4	9.9
Periphery	57.9	24.4	33.2	14.0	29.2	12.3
Total	14.9	10.5	14.9	10.5	14.9	10.5

Table 8. Distribution of subsidies across residential areas for three alternative fare structures (same aggregate revenue).

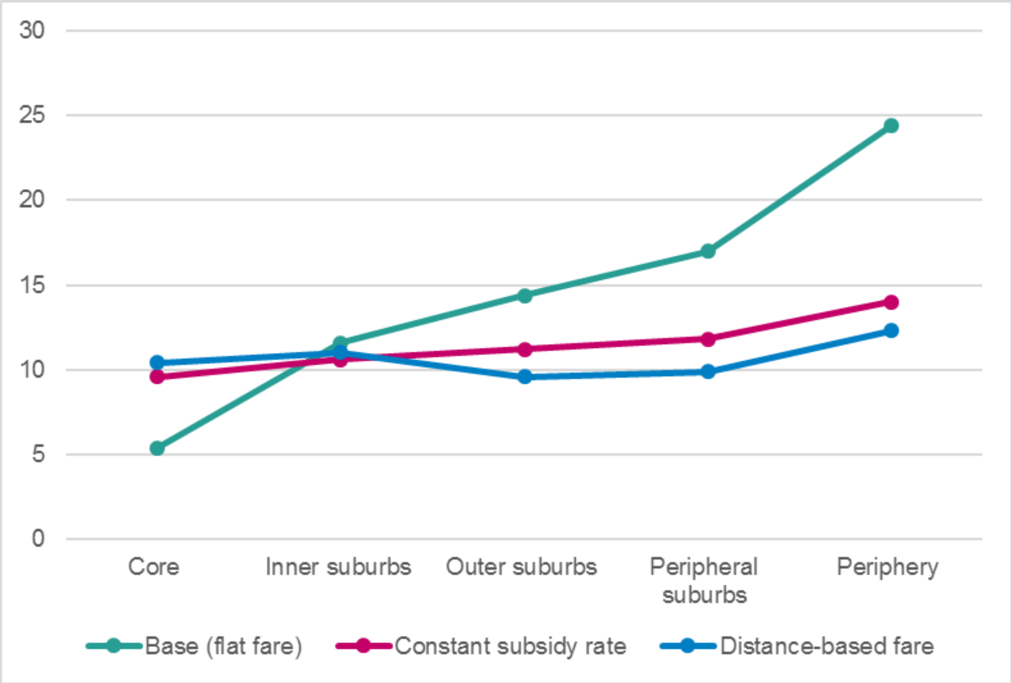

Figure 5. Subsidy per person with three alternative fare structures.

The two fare structures constant subsidy rate and distance-based fares result in a similar spatial distribution of the subsidies, contrasting that of the base structure. Distance-based fares imply similar subsidies per trip and per person in all residential areas. Moreover, constant subsidy rate implies similar subsidies for all residential areas, but residents of the periphery still get slightly higher subsidies than the core.

The focus of this paper is not to design fares that optimize social efficiency, considering road traffic externalities, crowding, and economies of scale and density etc. Our focus is to analyze the distributional profiles of subsidies and we have found that the periphery gets many times higher subsidies. A relevant question, however, is whether there are arguments that might potentially justify from an efficiency point of view the current subsidy structure with its extreme differences between the core and the periphery. Since this is not the focus of the paper, we constrict ourselves to listing a number of potentially relevant arguments, and leave exploration of their validity for future research.

It turns out that there are arguments both in favour of and against having higher subsidies in peripheral areas:

- Crowding and capacity constraints are higher in the core, at least in the peak, implying a higher marginal user cost there. This supports having lower subsidies in the central areas.
- Economies of density, i.e. the Mohring effect (Mohring, 1972), are presumably lower in the core due to higher frequencies. This also supports having lower subsidies in the central areas.
- On the other hand, road traffic externalities are higher in central areas. Even if they are to large extent internalized through congestion charges and parking charges they might not be fully internalized even in Stockholm, and

therefore this tends to support having higher subsidies in central areas. In cities without congestion charges this argument would be stronger.
- Higher subsidy rates for trips from the periphery to the regional centre, where most jobs are concentrated, might be a way to compensate for income-tax wedges on the labour market. This would tend to improve matching by decreasing access costs between workers and jobs.
- Having higher subsidy rates for residents in peripheral zones can be a way to reduce the differences in attractivity across residential zones, making centrally located housing more affordable and peripheral locations more attractive for residents and eventually constructors. In fact, most transit investments in Stockholm historically have been motivated by opening up new areas for housing construction. The population in the Stockholm region has been growing rapidly over years and is still growing, and there is a substantial shortage of housing, especially cheap housing. Since the cost for housing construction for logistical reasons increases the denser the area is, trying to make ever more remote parts of the region attractive for housing construction by subsidizing transport can in principle be a sensible policy. However, this urban development has also contributed to suburban transit-oriented sprawl (Cervero, 1995), which is supported by the higher transit subsidies to residents in the periphery. This highlights the downsides of the current fare system essentially promoting urban sprawl.

As pointed out above, we cannot say to what extent any of these arguments are valid arguments for the high subsidy rates in peripheral zones; exploring that would require separate studies. However, our understanding of Swedish transport policy is that they all (valid or not) are considered to some extent when setting transit fares.

6 CONCLUSIONS

Governments spend vast sums on transit subsidies, often based on the argument that it is an effective income redistribution policy instrument. Conventional wisdom seems to be that spending money on transit subsidies is a progressive policy, since it is assumed that most of the money go to low-income groups. Moreover, suggestions to differentiate transit fares – which has a considerable potential to increase the social efficiency of the transit system – is often dismissed with the argument that this would hurt low income groups. However, few studies before this one has explored the redistribution effects taking into account the variation in subsidies across links and trips in the network, and how this would change with increasing differentiation of the transit fares. Our results of course pertain to Stockholm, so our specific conclusions cannot be extrapolated to other cities without caveats. However, the purpose of the present paper is also to present a methodology and framework that can then be applied in other contexts, and results can then be compared.

Our analyses of transit subsidies in Stockholm show that transit subsidies are mildly progressive, to a large extent due to discounts for students and retired, but also because the citizens in the top income quintile make fewer transit trips per person. Still, the progressivity is weak because a wide range of income groups get roughly equal subsidies. As a policy for redistribution among income groups, hence, subsidizing transit is not an effective policy. Moreover, changing the fare structure from the current flat-fare system to differentiated fares (proportional to trip distance or constant subsidization rate) does not impact the progressivity of the subsidies. Hence, concerns about regressive distributional effects is hardly a valid argument against differentiating transit fares.

Students and retirees enjoy discounted fares in Stockholm, and this has an appreciable progressive effect: without these discounts, the concentration index would change from -0.22 to -0.18. Students get by far the highest subsidy per person, partly because of the discount, and partly because they make many and long trips. Retirees and others (unemployed, sick leave or parental leave), however, get the lowest subsidy per person of all occupancy groups despite the subsidy, partly because they make few transit trips, and partly because fewer of them have travelcards and hence pay a higher average fare.

By far the largest distributional effect is between residential areas. The difference in subsidies per person and per trip between residential areas is huge. For example, residents in the periphery get almost five times more subsidies per person as residents in the core. Even comparing adjacent areas, differences are substantial: for example, residents in the inner suburbs get more than twice as much as residents in the core. Differences get even bigger for subsidies per trip: the subsidy per trip is nearly ten times higher for residents in the periphery than for residents in the core. From an equity point of view this might be considered problematic: in essence, it means that low-income residents in central areas effectively contribute to subsidizing the trips of high-income residents in peripheral areas.

Differentiating the fares by making them proportional to trip distance or setting a constant subsidy rate for all trips would of course imply a more uniform spatial distribution of the subsidies. These two fare structures yield subsidies per person and per trip that are broadly similar across residential areas, although the outermost areas still get slightly higher subsidies.

This begs the question if there is a logical reason why current subsidies increase so much with the distance from the regional core. The pattern is very consistent and is just not about the periphery: subsidies increase quickly and monotonically all the way from the regional centre outwards, so even the difference between the core and the inner suburbs is substantial. Political economy reasons seem unlikely, since residents in the core make up a majority of voters in the county, so a proposal to differentiate fares proportional to trip distance, for example, would get a majority of voters behind it (assuming they are voting according to self-interest).

There may be good reasons for this subsidy structure, for example increasing the amount of affordable and attractive housing, or improving matching on the labour market, but exploring whether these are valid arguments is out of the scope of this paper. On the other hand, the current subsidy structure clearly conflicts with another common argument, namely that transit subsidies are justified as a second-best pricing of road traffic externalities, since these largest in central areas.

It is also conceivable that voters and decision makers are not quite aware of the actual distribution of subsidies across income groups or residential areas. Analyses like the one presented in the present paper can then hopefully inform the debate.

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8 APPENDIX: MORE TABLES

Data för alla kommuner enskilt (data blir ibland ganska tunt)

Municip.	Index	Mean	1st q.	Median	3rd q.	Pay more than twice actual cost	Pay more than actual cost	Pay less than 1/3 of actual cost
Stockholm	80	24.4	10.9	19.4	32.3	34%	69%	1%
Solna	84	25.6	13.2	20.2	30.1	28%	71%	2%
Sundbyberg	83	26.1	15.6	23.9	33.2	19%	65%	0%
Nykvarn	40	28.2	7.5	15.1	30.3	47%	69%	6%
Lidingö	86	30.2	18.8	26.0	36.6	11%	57%	2%
Huddinge	26	32.7	20.9	29.5	41.7	9%	46%	1%
Danderyd	62	34.7	24.0	34.0	45.1	8%	33%	0%
Järfälla	23	38.3	26.3	34.6	46.4	7%	31%	2%
Sollentuna	63	38.6	23.3	33.2	43.6	9%	36%	6%
Botkyrka	27	39.1	26.2	36.6	47.1	9%	27%	3%
Nacka	82	41.0	20.0	35.6	55.7	15%	39%	9%
Täby	60	41.1	27.7	37.0	49.4	9%	26%	4%
Haninge	36	47.0	31.1	43.7	56.6	7%	20%	6%
Tyresö	38	47.7	20.4	33.8	53.8	12%	40%	12%
Upplands Väsby	14	50.2	36.9	47.0	57.7	6%	12%	9%
Salem	28	50.7	36.5	54.2	63.3	5%	16%	6%
Upplands-Bro	39	52.8	33.7	45.7	67.0	4%	15%	11%
Sigtuna	91	54.6	34.1	52.6	72.1	5%	18%	15%
Södertälje	81	59.0	27.4	51.7	71.4	11%	25%	18%
Nynäshamn	92	59.9	25.2	54.4	79.3	5%	32%	21%
Ekerö	25	60.2	39.7	58.0	77.9	3%	16%	17%
Värmdö	20	63.9	19.9	48.8	103.0	16%	32%	33%
Vaxholm	87	72.3	45.2	52.7	97.5	5%	7%	30%
Österåker	17	83.6	53.2	76.3	106.9	4%	7%	43%
Norrtälje	88	95.1	61.3	86.6	119.1	7%	11%	53%
Vallentuna	15	109.3	37.6	54.9	92.3	7%	14%	28%

Table 9: Sample statistics

Monthly gross income (SEK)	# individuals in the sample	# transit trips in the sample	transit trips/individual
5000	577	332	0.6
5750	728	225	0.3
7500	834	361	0.4
9750	952	572	0.6
10000	585	676	1.2

11500	520	683	1.3
12500	1310	899	0.7
15000	615	640	1.0
16000	1725	1505	0.9
19500	920	774	0.8
21750	3874	3397	0.9
25000	1936	1549	0.8
32000	2640	1824	0.7
32750	8087	6877	0.9
43501	2898	1370	0.5
50000	4512	3972	0.9
65501	2521	671	0.3
72500	1171	920	0.8
100000	1043	746	0.7
100000	1430	250	0.2
145000	474	97	0.2
200000	802	273	0.3
Not reported	5311	3349	0.6
Total	45467	31961	0.7