STERILIZED CONGESTION CHARGES: A MODEL ANALYSIS OF THE REDUCED IMPACT OF STOCKHOLM ROAD TOLLS

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Abstract

Before-after comparisons indicate that the impact of the road toll in Stockholm on traffic volumes was considerably smaller when the system was re-opened in 2007, compared to the effect during the trial in 2006. We calibrate a modal-choice model on data for Stockholm from before and during the trial and use it to simulate the effects of some seemingly subtle changes of the design of the congestion-charge scheme. We find that a large part of the impact difference can be explained by the growth of the share of exempted "green" cars and by that charges were made deductible from the income tax. We estimate that this has halved the welfare effect.

Key Words: congestion pricing, equity effects, modal choice.

JEL classification: H23; H54; R48

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1. Introduction

The recent success of congestion charges in London and Stockholm has widely been taken as evidence of the effectiveness of urban road-pricing in mitigating traffic congestion. However, road toll schemes are complex packages of rates, rules, and technical systems for vehicle registration and toll payment. The re-start of congestion charging in Stockholm, after a trial period followed by a referendum, raises questions on whether the traffic impact of a road toll is robust to changes of the design of the system and to changes of external conditions.

The traffic office of Stockholm city in May 2008 (Baradaran, 2008) reports that the number of vehicles crossing the toll cordon during the first three months of 2008 were nine percent larger than in corresponding months during the trial in 2006. In another analysis of road traffic in Stockholm, Brundell-Freij (2009) calculates that the number of vehicles passing the toll-zone limit during weekdays (day and night) in October 2007, after the system was re-opened, was just 6 percent lower than in October 2006 (when the system was temporarily closed), while the corresponding decline between April 2005 (before trial) and April 2006 (during trial) was 16 percent (and 22 percent from 6.30 am to 6.30 pm, i.e., the time of the day when toll charges were levied). The resulting decline of traffic work (in vehicle-kilometres) within the toll zone was a mere 1.6 percent from October 2006 to October 2007, while the April 2005 to April 2006 reduction was 10 percent.[1]

This paper reports a model study on how the modal split, travel times, and welfare of commuters depend on some aspects of the design of the toll-ring congestion charging in Stockholm. A modal choice model with road congestion, subway and train crowding, and competition for street space between buses and cars is calibrated on data from the 2006 trial. The results show substantially smaller traffic effects from tolling when toll rates are made deductible from income tax, nominal toll rates are not adjusted to inflation, and more "green" vehicles are exempted.

The paper is organized as follow. Section 2 describes the background of the Stockholm congestion toll. Section 3 presents the theoretical framework of the numerical modal-choice model used in this paper. Section 4 explains the calibration procedure of the

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[1] Estimation of total traffic work within a whole city, based on data from a limited number of measurement points is rather complicated. Brundell-Freij (2009) uses gradient-adjustment based on an EMME/2 network assignment model of the city. VTI (2006) estimated the relative reduction of the car-traffic work April 2005 – April 2006 to 14 percent, using another (statistical) approach. Both studies come to close results in terms of levels, but VTI gets a steeper slope during this period.

model. Section 5 presents the result of the model simulation. The last section discusses the simulation results and the policy application.

2. Background

For the first time ever in a public referendum on urban congestion charging, a majority yes vote in favour of a road toll was held in Stockholm, September 19, 2006. This result was a triumph for the pragmatic strategy chosen by the city authorities to create legitimacy for the implementation of road tolls, based on a 'trial + referendum' approach (Isaksson and Richardson, 2008). During a seven months "full-scale trial" preceding the public vote, the performance of an inner city cordon toll was demonstrated to the residents of the city, which led to an opinion swing. Close to half of the respondents to a survey of residents stated that they changed their attitudes towards congestion charges during the trial (Winslott Hiselius et al., 2008). Convincingly[2], the toll during the trial visibly delivered a reduction of congestion that was strong enough to be clearly noticed by most people moving around in the city (Eliasson et al., 2008).

[2] The most important factor to the change of attitudes though seems to have been that many realised from the practical experience of a road toll that their own well-being was not much harmed and therefore weakened in their previous resistance (Winslott Hiselius 2008).

Traffic congestion has been a severe problem in Stockholm since long. The inner city is built on islands, giving a limited number of entry and exit points for commuters. More than 2/3 of employees who work in the inner city live outside of it, while 1/5 of the citizens live in the inner city work outside. A large fraction of the morning rush-hour traffic is directed to the central areas and is concentrated on a few main roads from the south and the north. This has made Stockholm suffering from severe congestion for many years.

The congestion pricing trial was performed from 3rd January to 31st July in 2006. Vehicles were charged a time-differentiated toll to travel across the zone cordon during peak hours of work days. During the tolled period of the day, car journeys across the cordon zone declined by 22 percent (Eliasson et al., 2009). Traffic volume of the inner- city roads decreased by 14 or 10 percent according to VTI (2006) and Brundell-Freij (2009), respectively.

Following the yes vote of the referendum, a permanent congestion-charging scheme was opened from August 1, 2007. However, in spite of a rapid national and regional traffic growth, which also puts more pressure on the traffic system of Stockholm, and a non-negligible inflation, the nominal toll rates of the continued scheme were the same as those during the trial. Worse, effective rates were considerably lowered as the road toll was made income-tax deductible. Also, the share of vehicles not paying the toll increased because of a rapid increase of the number of exempted “green cars” and to some extent because of tax evasion by various tricks. By a decision in the autumn 2008, the “green cars” exemption will be phased out over a five-year period. Only such cars registered before January 1, 2009 will be eligible, and the exemption will end by the end in 2014.

In this study, we call these changes, for which we want to assess impact, “the effective toll rate changes”. They all contribute to a reduction of the average real (deflated) after-tax toll rate of vehicles passing the toll ring. The income-tax deductibility was the result of an active change of the design of the tolling scheme, while the reductions due to inflation and the increase of the number of “green cars” were results of passive non-adaption to changed circumstances. The size of the reductions of the effective toll rates depend on various factors that change over time. The reduction of real rates in the absence of inflation adjustment of the nominal toll rates are inverse to the increase of the Consumer Price Index, which rose by 6 percent from January 2006 (start of trial) to August 2007 (start of permanent toll). The green car exemption increased the number of exempted vehicles passing the toll ring from 3 percent during the trial to approximately 10 percent in 2007. Finally, income-tax deductibility potentially reduced effective toll rates by the marginal tax rate, which for most motorists would be 57 percent. However, not all drivers are eligible for thus deduction. They must be commuting to work, have a one-way distance between home and work of at least 5 kilometres and save at least one-hour one-way compared to public transport. The latter requirement takes a big dent in the share of eligible commuters. However, tax authorities’ control of this requirement is not always very strict. Also, an exception is made for everyone who is using the car in their work, which is difficult to control and therefore is a major loophole. Also, it reduces the incentives of both employers and employees to use company cars for such travel. Unfortunately, the share of commuters that are eligible for the tax deduction is unknown, so we have to use alternative assumptions about that in our evaluation of effects.

In the study, we thus want to estimate the magnitude of the possible impact of these effective toll rate reductions on traffic (modal split, road traffic work, congestion) and welfare. For this purpose, it is necessary to use a model as there are several other factors that also may have contributed to any observable before-after differences in these variables (like the April 2006 – to April 2007 differences reported by Brundell-Freij (2009)). Some such factors are the following:

"Hysteresis"-effects. Some part of the traffic reduction during the trial (January – July 2006) may have remained in October 2007. Although tolling during the trial was temporary it may have triggered shifts of habits among some commuters that were not reversed when the trial was over, because of induced learning about the public-transport mode, inertia, etc. Another possible reason could be early adaptation to the coming re-opening of the road toll (which was announced by the ruling coalition of parties already October 1, 2006).Such effects imply that the effect of the continued toll is underestimated by the April 2006 – April 2007 difference.

Income and employment-effects. (Some growth numbers here).

Changes of road capacity. Recently it has been reported that congestion has increased in the congestion charge zone of London, although the traffic work within the zone has remained stable (references: Check London Transport), the main reason being that authorities has transferred road space into other uses. Stockholm has not (so far) experienced a similar development, but there are numerous road works going on that from time to time may have considerable effects on road capacity.

Changes of other prices. The use of cars is affected by changes of prices of various complimentary and substitute goods and services, such as parking fees and fines, the price of petrol, public transport ticket charges, etc.

Although such factors have a plausible role as determinants of changes of aggregate traffic levels, it is not clear that any of them really have had a major influence on the seemingly lowered impact of the road tolls. Against the presence of hysteresis effect is that no big such effects were observed during the trial. On the contrary, it was observed that car traffic rapidly converged to a new level (a 22 percent reduction of toll-ring crossings) and that traffic reversed to a close-to pre-trial level immediately after the trial period expired. And while both income and employment levels are major determinants of car traffic in Sweden in general (reference?), car traffic in the inner-city of Stockholm seems (within some limits) to be an exception. The number of cars entering the inner city (specific data here) has remained stable over a 30 (20?) year period (in spite of xx increments of income, population and employment numbers)[3] Further, road works, and prices on parking and public transport prices did not vary much during this period. Petrol prices, however, increased by 7.5 percent (CPI deflated) from 2006 – 2007.

(This section will be concluded by reference to the evaluation report from the City of Stockholm coming in September 2009 – with no explanation to the causes of the reduced impact).

3. Theoretical Framework

We use a numerical modal-choice model calibrated to data from the Stockholm congestion-charging trial to assess ceteris paribus effects on modal split, travel time, welfare, and equity from the changes of the effective toll rate described in the previous section. The model is an extension of modal-choice models by Arnott and Yan (2000), Glazer and Niskanen (2000), Small and Yan (2001), Armelius (2004), Armelius and Hultkrantz (2006), and Kutzbach (2009). The modal-choice approach fits the Stockholm case because the city has a well developed public transportation system; public transport was used by a majority

[3] Speculate about reasons? Possibly interaction with real estate market –rich people have moved to the inner city and to areas close to the railway and metro stations??

of commuters already before the ring toll; and change to public transport was the main adaptation strategy used by motorists who wanted to avoid paying the toll during the trial (Brundell-Freij and Kottenhoff, 2008).

We used a similar modelling approach in an ex-ante study of the trial (Armelius and Hultkrantz, 2006), but the present model is refined in several ways. While the previous study focused on effects on commuters passing the toll ring, our model also includes travel that has both origin and destination within the cordon. Moreover, as in Kutzbach (2009) we separate public transport by bus from public transport on track (subway and train) and explicitly model the competition for street space between buses and cars. In a slight extension of previous literature we also explicitly model transit crowding, which yields disutility to passengers without affecting travel times, separate from road congestion, that affect motorists and bus passengers negatively by increasing travel times. Finally, for obvious reasons, in an ex-post model we can calibrate on actual responses by travellers to congestion charges, which has not been done before. In addition, we can compare the welfare effects in our aggregate modal-choice model, which lacks spatial dimensions and therefore contains no information on the specific structure of road and public transport networks, to results from a cost-benefit assessment using a detailed network model (Eliasson, 2009).

In this section we describe the structure of the model. To start with, consider a society with a working population of N individuals commuting between home and work.

People can travel with car, bus or rail4. The modal division of commuters affects the intensity of congestion and crowding within each mode. Congestion affects these three modes in different ways. Since cars and busses share road capacity, a change in road congestion condition will change the travel time for cars and busses. For busses there will also be a change in the utility change from discomfort caused by crowding if number of people on board changes. For railways, since the system in Stockholm already runs at capacity, the marginal effect of a congestion toll is the discomfort caused by crowding, instead of travel time. The value of time (*VoT*) is assumed to be equal to after tax income with a stochastic term ε .The income distribution is exogenous.

We consider two groups of individuals: One group is called the commuter group ("commuters"). It includes people who need to travel across the cordon zone to travel to work. This group includes both the individuals living within the cordon zone that commute out to work and individuals living outside the cordon zone and commuting in to work. The other group is called the local group ("locals"), which includes those people who live within the cordon zone, and only travel within the inner city of Stockholm. The society is assumed to be closed, meaning that the number of individuals in each group is fixed.

The model has four main components:

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[4] The rail mode of the model is a combination of metro, tram, light rail and suburban rail.

(1) Utility functions

(2) Volume delay functions

(3) Discomfort functions

(4) Modal-split point

We now describe each of these components.

3.1 Utility functions

Individuals have the following linear utility function:

$$\boldsymbol{U_i\left(C^i, T_j, D_j\right) = C^i - T_j VOT^i - D_j}, \qquad \boldsymbol{i = 1, \dots, N; j = car, bus, rail} \quad (1)$$

Where *i* is the index of individual, *j* is the index for travel mode, each individual can choose from car, bus or railway to travel. C^i is the consumption of market goods for individual *i*, T_j is the travel time using mode *j*, VOT^i is value of time of individual *i*, D_j is discomfort caused by crowding for mode *j*.

The income y^i is allocated to consumption, at a unit price, and travel, at the price p_j .

$$y^i = C^i + p_j + t \qquad (2)$$

p_j is the daily cost of using mode j, t is the average amount of toll commuters need to pay per day. Only commuters need to pay toll, so t is zero for locals. A working day is 8 hours of working, so the maximum leisure time per day is 16 hours. We set the travel time of mode T_j in a range from 0 to 1 ($0 \leq T_j \leq 1$). When $T_j = 0$ travel to work doesn't take any time at all, while $T_j = 1$ means that an individual spends 16 hours to travel to work and return home.

We assume that the distribution of the value of time VOT ~ lognormal ($\mu_{VOT}, \sigma^2_{VOT}$), and the instantaneous value of time is composed by two factors, wage and a stochastic factor containing all other elements that may affect the value of time. Therefore, $VOT^{\mathrm{i}} = y^{\mathrm{i}}\varepsilon$, where y is after tax daily wage, and ε is an error factor. We assume y ~ lognormal (μ_y, σ^2_y), and ε~ lognormal ($0, \sigma^2_\varepsilon$). It follows that $\mu_{VOT} = \mu_y$ and $\sigma^2_{VOT} = \sigma^2_y + \sigma^2_\varepsilon$.

3.2 Discomfort of crowding

Users of public transport experience crowding. This yields discomfort associated with having to stand or sit in cramped conditions. The degree of discomfort is associated with how crowded the vehicle is, how long time the passenger has to travel with the mode, and the value of time for this passenger. Equation (4) describes how these factors are related.

$$D_j = \lambda_j n_j T_j Vot^i, \qquad i = 1, \dots, N; j = bus, train \tag{3}$$

Here D_j means discomfort caused by crowding, λ is a calibrated parameter of discomfort, reflecting to how much degree the crowding increases the utility lose from travelling with the certain mode, n_j is the number of individuals travel with mode j. We can thus view the discomfort D_j as an augmentation of travel time.

3.3 Volume delay equations

The volume delay function describes how the travel time on road link depends on traffic volume. Kutzbach (2009) improved the BPR function[5] by allowing the consideration of the road capacity competition between cars and busses. For car users and bus users the basic form of volume delay function is:

$$T_j = T_{j0}[1 + 0.15\left(\frac{\delta n_{car} + \theta n_{bus}}{K_j}\right)^4] \tag{4}$$

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[5] The BPR function (Bureau of Public Roads function, 1964) is a widely used volume delay function. The BPR function has several pleasant features; it is strictly increasing with volume, it yields the free travel time for zero volumes and twice the free travel time for the volume at capacity and the derivative of the function is strictly increasing (Spiess 1990).

The travel time T_j of mode *j* depends on the free flow travel time T_{j0}; road traffic capacity K_j and the traffic volume on the road. The traffic volume is the sum of number of individuals using car times a car-pooling parameter δ that indicates how many individuals travel together in a car, and the number of individuals using bus times a parameter θ indicating how many individuals travel in one bus, and how much road space a bus uses compared to a car. The travel time of each mode (T_j) depends both on the use of mode j and on the use of the other mode, which means that $\frac{\partial T_{car}}{\partial n_{car}} > 0$ and $\frac{\partial T_{bus}}{\partial n_{bus}} > 0$.

We use L to denote the local group. The volume delay function for car and bus users in this group is:

$$T_j^L = T_{j0}^L \left[1 + 0.15 \left(\frac{\delta n_{car}^L + \theta n_{bus}^L + \delta n_{car}^C + \theta n_{bus}^C}{K^L}\right)^4\right], j = car, bus. \qquad (5)$$

From equation (6) we see that the travel time for mode j depends on the free flow travel time within the toll ring for this mode T_{j0}^L, the inner-city road capacity K^L, and the sum of local vehicles and commuter vehicles since they are competing for inner-city road capacity.

For commuters, denoted by C, travel time is composed of two parts: time spent on travelling in the inner city T_j^I, and time spent on the part of the journey outside of the zone T_j^E, the first part is actually same as the travel time for local road users T_j^L. In other words,

$$T_j^C = T_j^I + T_j^E = T_j^L + T_j^E$$

$$= T_{j0}^E\left[1 + 0.15\left(\frac{\delta n_{car}^C + \theta n_{bus}^C}{K^E}\right)^4\right] + T_{j0}^L\left[1 + 0.15\left(\frac{\delta n_{car}^L + \theta n_{bus}^L + \delta n_{car}^C + \theta n_{bus}^C}{K^L}\right)^4\right] \quad (6)$$

3.4 Modal-split point

For simplicity we assume that individuals choose between either driving to work by car or using public transport, where public transport is a combination of bus and rail. Armelius (2004) proves the existence of a unique modal-split point $\widehat{VOT}$, given that car travel is always faster than public transport. $\widehat{VOT}$ is defined as the daily wage of the individual that is indifferent between both modes. An individual with daily wage higher than $\widehat{VOT}$ therefore chooses to drive car to work, while an individual with lower daily wage chooses to use public transport. The modal-split point is calculated as:

$$\widehat{VOT} = \frac{p_{car} + t - p_{PT}}{(1+\lambda n_{PT})T_{PT} - T_{car}} \quad (7)$$

This concludes the description of the structure of the model. In the next section we describe the numerical calibration.

4. Calibration

4.1 Calibration of initial conditions

Based on toll revenues numbers during the trial, we estimate the total number of cross-toll zone commuters to 162077. The proportion of commuters and road users that only travel within the inner city of Stockholm is approximately 2.56 to 1 (Eliasson et al., 2006). This implies that the total number of local travellers ("locals") during the trial was 63311. We generate the VOT of locals and commuters using VOT ~ lognormal ($\mu_{VOT}, \sigma^2_{VOT}$), y ~ lognormal ($\mu_y, \sigma^2_y$), ε~ lognormal ($0, \sigma^2_\varepsilon$). It follows that $\mu_{VOT} = \mu_y$ and $\sigma^2_{VOT} = \sigma^2_y + \sigma^2_\varepsilon$. μ_y and σ_y are calibrated to be 6. 5568 and 0.6530 to match the mean and median of after tax daily wage6, which are 871 SEK and 705 SEK, respectively7. How σ^2_ε is calibrated will be explained later.

The average daily length is, according to the travel habit survey (Transek, 2006), 5.6 km (locals) and 36 km (commuters). The speeds and travel times for free flow and before toll are listed below. For public transport (PT) passengers, we assume that half of the journey is travelled with bus, and half is travelled by train.

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[6] Using the property of lognormal distribution, median y = exp(μ_y), mean y=exp(μ_y+σ^2_y/2).

[7] These values are obtained by dividing the average monthly wage of 27,700 SEK (SCB, 2007) and median monthly wage of 22,400 SEK(SCB, 2007) by 22 workdays, and then deducting taxes (30.8%) according to official income and tax statistics (SCB, 2007).

The parameter δ is assumed to be 1.27, which is the average number of people sharing a car. Parameter θ, which represents the road space use by bus passengers, is assumed to be 3/35, where 3 means that a bus is assume to require 3 times as much road capacity as a car, while 35 is the assumed average number of passengers per bus. Finally, we assume that the before toll car share for both locals and commuters is 33 percent. After putting all these numbers into equation (5) and (6), we calculate the road capacity for inner city road and commuter road to be 3612 and 2919, respectively.

Table I. Free-flow and before toll speed (km/h) and travel time (min)

	free-flow speed	free-flow travel time	before toll speed	before toll travel time
Local car	38	9	28	12
Local bus	15	22	13	26
Local train	45	7	45	7
Local PT	-	15	-	17
Commuter car	50	43	34	64
Commuter bus	27,2	79	17	127
Commuter train	45	48	45	48
Commuter PT	-	64	-	88

Source: Own calculations based on SL annual report 2006, and Armelius & Hultkrantz, 2006.

Knowing the distribution of VOT, we can find the before toll modal split points $\widehat{VOT}$ are 1250 SEK for both locals and commuters. The public transport fee is set to 33 SEK/day[8] for both locals and commuters. For commuters, to drive a car to work is assumed to cost 3.3 SEK/km[9], implying that the average daily cost is 118 SEK. The daily cost for locals to drive to work is calibrated to be 58 SEK and before toll crowding parameter λ is calibrated to be $7\times10^{-5}$to match the modal split point before toll.

4.2 Calibration of effects of the toll

In the inner city, road traffic is decreased by 15 percent. For commuters, road traffic is decreased by 22 percent (Eliasson et al., 2009). Using the assumption that the before toll car share is 33 percent for locals and commuters, the after toll car share for locals and commuters are calculated to be 34.09 percent and 24.90 percent, respectively. The after-toll travel time is then calculated, which results in the travel times shown in Table I.

[8] Public transport travel card costs annually 7160 SEK (SL, 2006);we divide this by 225 working days.

[9] This cost includes insurance, tax, depreciation, fuel, maintenance, tires, and parking (Swedbank, 2008).

The after-toll modal split points $\widehat{VOT}$ for locals and commuters are 1213 SEK and 1585 SEK, respectively. The after-toll local and commuter crowding parameters λ are 6×10^{-5} and 8×10^{-5}, respectively, to match the modal split points after the toll was levied.

We now have all the information we need to calculate the after-toll utility for each individual. We can then finally calibrate the variance of the value of time distribution σ_{ε}^{2} to be 0.7525, so that the aggregate utility matches the 654 MSEK net social benefits of the toll held in the cost benefit analysis by Eliasson (2008).

5 Simulations results

In this section we present step-wise simulations exploring the reduction of the toll effect. The simulations are therefore made for five scenarios. The first is the trial scenario, simulating the effect of the congestion-toll trial in 2006. Then we put the effective toll rate changes into the scheme one at a time, as listed in Table II. Traffic effects and welfare effects for these scenarios are compared. Traffic effects are measured as modal distribution, travel time, and road-traffic work on inner-city roads. The road-traffic work is indicated by vehicle kilometres travelled (VKT), which is the total kilometres travelled by all vehicles, assuming all locals and commuters have the same travel length in the inner city. The welfare effects are compared by income groups for all scenarios.

Table II. Explanations of five scenarios

name	description	real toll rate[10] (SEK)
trial	congestion-toll trial in 2006	28
inflation	6% inflation rate	26.5
infl + tax50%	6% inflation rate + 50 % of the commuter car users can	22
infl + tax	6% inflation rate + all commuter car users can deduct toll	19.3
infl + tax50% + green	6% inflation rate + 50 % of the commuter car users can	22

5.1 Traffic effects

The traffic effects of these successes are exhibited in Tables III and IV. Table III, shows the decreasing trend in effect of the toll when we add the components of the effective toll rate changes. The number of commuter car travellers decreases initially by 25 percent, becomes 23 percent when we include the inflation effect and 19 (16) percent when in addition half of them (all) can deduct the toll from the income tax. Finally, when the proportion of “green cars” increases to 10 percent, the toll effect is down to a 9 percent reduction of the number of car commuters. As a result, the reduction of VKT in the inner city decreases from 15 percent to 4 percent, as shown by Table IV.

[10] Average daily real toll rate per vehicle.

The magnitude of the travel-time reduction of car commuters goes from 10 to 4 percent. Travel time for local PT is slightly reduced in the trial case but is instead increased by 5 percent when we take into account all the effect toll rate changes.

Table III. Changes of the estimated number of travelers and VKT compared to the no-toll case

	trial	inflation	infl+tax 50%	infl+tax	infl+tax50%+green
local car	3.30%	4.03%	4.22%	4.41%	5.12%
local PT	-1.63%	-1.99%	-2.08%	-2.17%	-2.52%
commuter car	-24.55%	-22.33%	-18.88%	-15.79%	-8.82%
commuter PT	12.09%	11.00%	9.30%	7.78%	4.35%
VKT	-15.01%	-13.40%	-11.12%	-9.07%	-4.40%

Table IV. Changes of estimated travel time compared to the no-toll case

	trial	inflation	infl+tax 50%	infl+tax	infl+tax50%+green
local car	-10.15%	-9.24%	-7.89%	-6.61%	-3.40%
local PT	-0.52%	0.26%	1.43%	2.53%	5.30%
commuter car	-9.58%	-8.90%	-7.77%	-6.69%	-3.92%
commuter PT	-8.60%	-8.10%	-7.30%	-6.52%	-4.54%

5.2 Welfare effects

Table V shows the welfare implications. The total welfare gain of the toll decreases from 666 MSEK to 359 MSEK, i.e., by close to half. Still, all income quartiles gain from the toll. However, richest quartile alone gets around 63 percent of the total welfare gain.

Table V. Estimated welfare changes compared to the no-toll case, by income quartiles (MSEK**)**

	trial	inflation	infl+tax 50%	infl+tax	infl+tax50%+green
1	419.4	346.1	339.0	295.8	226.8
2	141.6	119.2	114.1	102.0	75.8
3	74.4	62.1	60.0	53.1	40.0
4	30.4	26.1	24.4	22.3	15.9
Total	665.8	553.6	537.5	473.2	358.5

Note: The income quartiles are listed in descending sequence, where group 1 is the richest quartile.

6. Discussion

The models presented here indicate that inflation, tax deduction and the increase of the use of the “green” car exemption all reduce the effectiveness of the congestion toll. These three factors together seem to be able to explain a reduction of the toll effect of a similar magnitude as the one that has been observed. Of these factors, the “green” car exemption plays the dominant role. The moral, hence, echoes Jan Tinbergen´s observation that the number of means should equal the number of objectives.

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