Equity effects of congestion pricing

Road traffic is necessary for a successful functioning of market economy and its volume is positively correlated with economic development. However, its rapid increase fostered by economic growth is problematic as road traffic results in numerous externalities. The externalities resulting from traffic are costs that are created but not born by motorists that create them. Among these are such 'classic' externalities as congestion, air pollution and noise, traffic accidents, carbon emissions, etc. However, the recent evidence suggests that apart from these typical traffic externalities there may be many more non-obvious ones, e.g. longer emergency response times and resulting higher average monetary damages from fires (Brent and Beland, 2020). Traffic externalities can be internal to transportation system meaning that they affect motorists only, such as congestion, car crashes, wear and tear of road infrastructure, etc. But many externalities are external to transportation system and affect non-users, such as air and noise pollution, carbon emissions etc. Therefore, it is crucial to find the best tools to deal with the road transport externalities.

This paper focuses on congestion because this externality amplifies other external costs of transport[1] and results in numerous adverse effects: time delays, direct economic costs, air pollution, energy waste, accidents, health depreciation etc[2]. The ever increasing traffic volumes accompanying the economic growth exacerbate an already dire congestion situation in the majority of world's largest urban areas. Each year excessive travel time due to congestion results in cost equivalent to over one per cent of the EU's GDP (European Commission, 2011). And it is evident that traffic problems are expected to aggravate with time because economic growth goes in hand with increased mobility. Therefore there is a need in prompt action that is expected to be taken by authorities and appropriate tools that will allow them to reduce congestion in effective, socially acceptable and cost-efficient way. CP has established itself as fruitful results

Importance of the equity issue

Congestion emerges as the travel demand approaches the infrastructure's limited capacity. The main reason of congestion is that travellers do not take into account time delays that they impose on others when entering traffic, although they themselves have to bear in full the costs of this externality. Since congestion is in principle the demand for road space exceeding supply, there are two main ways to address congestion: either from the supply or demand side. While the former implies an increase the infrastructure capacity, the latter aims is to reduce the demand for transportation by means of, among others, pricing tools. One of them is congestion pricing (CP), which implies charging a fee for driving a motor vehicles at times and locations where road capacity does not suffice to accommodate demand. It aims to reduce congestion by altering travel behaviour: encouraging temporal shift of trips to off-peak periods and spatial shift away from congested facilities or to alternative modes.
Economists widely advocate CP as opposed to road capacity expansion to be the most efficient remedy to congestion problem. The reason for this is twofold. First, congestion in its nature is an issue of

[1] Although congestion and other external effects are not perfectly correlated (Lindsey and Verhoef, 2001).
[2] However, congestion can also have some positive effects such as reduction of severity of traffic collisions (Tang and van Ommeren, 2020).

market inefficiency and optimal CP can internalize traffic externalities and restore market efficiency by bringing marginal private costs of drivers to the level of marginal social costs that they impose on society. Second, the underlying pricing mechanism induces adjustments in all aspects of travel behaviour, both immediate decisions on timing, length and number of trips, route, mode of transport, etc., and long-run decisions such as residential choice, workplace, location of business, etc. (De Palma and Lindsey, 2009), allowing comprehensive influence on all root causes of traffic bottlenecks
Those several CP schemes that were implemented worldwide have empirically proven their effectiveness in reducing overall traffic volumes, congestion and air pollution, increasing traveling speeds and travel time reliability, accumulating revenues (Börjesson et al., 2012; Olszewski and Xie, 2005; Rotaris et al., 2010; Danielis et al., 2011; Santos and Fraser, 2006; Santos and Shaffer, 2004)[3]. Studies that assessed welfare effects of these congestion charges using cost-benefit analysis find them welfare improving and resulting in significant net social benefits (Danielis et al., 2011; Eliasson, 2009; Rotaris et al., 2010; West and Börjesson, 2016; Gibson and Carnovale; 2015).

However, despite this positive evidence only few CP schemes were actually implemented worldwide and there are many more examples where proposed schemes were turned down due to the lack of public acceptability and insufficient political support (Borjesson et al., 2012). Although the reasons for this phenomenon are manifold, the literature distinguishes four prevailing ones, whose relative importance is changing over time: equity, complexity, privacy and uncertainty. With the development of modern technologies, technical and financial concerns are not the most important ones anymore. Currently, along privacy concerns, perceived complexity of charging systems, unfamiliarity and uncertainty of such measures; concerns over equity and redistributive effects are identified as the most important factor contributing to opposition towards CP. Gu et al. (2018) and Selmoune et al. (2020) argue that treatment of the equity issue is often a decisive factor for success or failure. They note that in all cities where congestion charges were successfully introduced (London, Stockholm and Milan) the issue of equity was addressed, while it was ignored in the cities that failed to do so (New York City, Edinburg and Hong Kong). Equity is identified as the main reason for political inertia and public opposition (Langmyhr, 1997; Viegas, 2001; Oberholzer-Gee and Weck-Hannemann, 2002; Schaller, 2010). Eliasson and Mattson (2006) argue that equity effects are important for at least two reasons: because the magnitude of the redistribution can outweight the efficiency gains from the reform and because the CP scheme itself may be regressive and may result in negative equity effects. When looking into the trade-off between efficiency and equity, Levinson (2010) asserts that equity is efficiency. Without addressing equity concerns in a proper manner to win the support of constituents the policy will fail to be implemented and no potential efficiency benefits could be reaped. The examples of Cambridge, Manchester, Edinburgh, New York City and Hong Kong where charging schemes failed to be implemented are a good illustration of this.

Thus, despite high appraisal by experts and proven efficiency, CP policies are extremely difficult to implement in practice. One of the main reasons for this are concerns about equity and distributional effects of such measures that mainly stem from a number of prejudices. Although these concerns that are most frequently brought up by opponents of CP are intuitive and equity issue seems to be

[3] For the brief overview of the main congestion charging schemes implemented in cities' central areas worldwide and their exact impacts on traffic see, for example, Lehe (2019).

straightforward, in this paper we will scutinize the different viewpoints concerning equity in the transportation context and bring them together, which, accompanied by the empirical findings, will allow us to conclude that the precise equity effects are very context-specific and depend on the design of the charging scheme and the underlying characterictics of the place where it is implemented (traffic flows, topography, elasticities, etc.). This is further complicated by the vagueness of the interpretation of the equity concept, which requires creation of the standardized framework according to which different policies should be evaluated.

Definition of equity

Transportation equity assessment is essential when evaluating any transport policies, including different CP schemes, due to the fact that they have significant equity implications and policy implementation itself heavily depends on public acceptability that is largely affected by equity concerns. However, the evaluation of equity in transport is a complex task because it depends on an array of factors: how and according to what criteria individuals are categorized and grouped, what equity impacts are taken into account in the analysis and how these are measured (see Litman (2020) for a detailed discussion on these). How equity is measured depends on how it is defined. The results of equity analysis heavily depend on definition and measurement of equity itself and there is no consensus in this regard.

In the widest sense, equity (justice, fairness) implies a fair distribution of benefits and costs. One notion of equity is that different groups of individuals are affected fairly by policy outcomes: low-income vs. high-income individuals (income categories), males vs. females, city residents vs. commuters etc. This is a standard definition of equity in public finance that focuses on distribution of costs and benefits across socioeconomic strata and individuals and is also known as distributive justice.

Equity theory distinguishes distributive and procedural justice (or fairness)[4]. While the former is concerned with the distribution of outcomes, with the analysis of the distribution of costs and benefits, the latter is the question of whether the processes of decision making pertaining to distribution of benefits and burdens are fair and transparent. It implies that all parties that will be affected by policy should be able to participate in policy-making and should be heard out before actual decisions are made. According to some theories, procedural justice prevails over distributional justice: fair procedure results in fair outcomes even if the requirements of distributive justice are not satisfied (Tyler et al., 1985). This has direct implications for transportation equity: the policies of CP and other transport-related policies should be developed by having a constant feedback from the public at large and those who are going to be directly affected by these measures. The public outreach in the implementation of such policies is of paramount importance both to satisfy procedural justice requirements and to improve the acceptability, which is identified as the main pitfall to successful introduction of CP. Scientific literature acknowledges the necessity of a close-loop interaction between the government and public during development and implementation of the scheme and the need to educate population on the design and effects of such measures (Gu et al., 2018). Familiarity

[4] These can also be called equity of outcome and process equity.

and understanding of the congestion charging scheme is important for its acceptability by public (Shatanawi et al., 2020). Given this joint development of CP schemes and prevalence of procedural justice, its satisfaction would guarantee equitability even if some individuals would gain more than others.

Within distributive justice one can distinguish the following dimensions of equity:

1. Vertical equity – how effects of pricing are distributed among income classes. One would classify affected users by income quartiles for example. For the pricing scheme to be vertically equitable individuals who are able to pay more should pay more; higher income groups should pay more in absolute terms. Here one should look into variation *between* groups. While evaluating policies according to vertical equity, it is customary call policy *progressive* if high income groups pay relatively more (i.e. as proportion of their income) than low income and *regressive* if the opposite is true.
2. Horizontal equity – there should be no discrimination between people belonging to the same socioeconomic group. Individuals who are similar in relevant aspect should be treated in the same way. Users have to bear the costs that they impose on society to ensure equal allocation of public resources. Here one should look into variation *within* groups. With respect to income, individuals who have the same ability to pay should pay the same or similar amounts.

In addition, Litman (2020) distinguishes two types of vertical equity: with respect to income and social class and with respect to need and ability. The former is the classical definition of vertical equity, while the latter introduces an additional dimension of equity and shifts focus from monetary values, which are habitual in policy analysis, to the values of social equity which are an equality of opportunity and equal access to social resources. Equality[5] of opportunity is the one way to measure vertical equity and transportation has a direct impact on it. Every individual has a right to 'equality of opportunity' meaning that everyone in the society should have proper access to education and employment opportunities, including vulnerable and disadvantaged groups. In contrast, equality of outcome is rather controversial as it implies that all people should have equal living conditions and resources.

When looking into variation between groups, one may distinguish other equity dimensions specific to CP (Bhatt, 1993):

3. Gender equity – whether one gender group of road users is affected disproportionally more by congestion (women vs. men).
4. Geographic equity – assessment of distributional effects according to geographical criteria (users of priced vs. unpriced facilities, residents within cordon vs. commuters, etc.).
5. Causal equity – an attempt to align the effects on those who cause congestion and other driving related externalities and those who have to pay. As in case of public good those who bear the costs are not necessarily the beneficiaries.

[5] There is a difference between the concepts of "equity" and "equality". The idea of equality implies that everyone should be equal both in treatment as well as in the provision of the final outcomes. Whereas equity has in focus the most disadvantaged groups who should be helped. However, contrary to the equality, the outcomes here do not have to be identical, rather proportional in a way that the underlying and systemic differences in the society are addressed.

In the same vein, one may distinguish many other focus groups to analyse equity effects (e.g. according to travel mode, trip purpose, age, ethnicity, place of residence, etc.). For example, currently the City of Seattle is implementing a congestion charge and is guided in its design by the City's racial equity toolkit, i.e. the racial equity is assessed (Cohen et al., 2020). Moreover, the equity outcomes may differ significantly depending on the level of analysis. "Procedures which are individually fair can be socially inequitable depending on what groups of people they affect" (Fan et al., 2019).

Hence, there is a plethora of ways in which equity can be defined. And different conceptions of equity may be contradicting. Hence, equity analysis is complex and transport policies often require tradeoffs not only between efficiency and equity, but also between different types of equity.

Main equity and fairness concerns

CP measures are very often perceived as inequitable and unfair because according to *status quo* and prevailing circumstances people perceive that roads have to be 'freely' accessible and granted unconditionally to everyone as a basic benefit. Making people pay for road use seems to be depriving them of their basic rights; especially those who cannot afford to pay road charges and will be forced to look for alternatives. This raises concerns that only rich will be able to travel fast and comfortably at the expense of poor who will have to bear the costs of solution that is needed by the whole society. For instance, high-occupancy toll (HOT) lanes in US, being one type of CP that implies charging for the use of expressway vehicles that do not meet occupancy rate requirements, are often dubbed 'Lexus Lanes' (Weinstein and Sciara, 2006). This moniker reflects the criticism of HOT lanes for their perceived unfairness as they allow rich to buy their way out of congestion, while poor are stuck in free general purpose lanes that are even more congested because the part of free road network is allocated to HOT lanes.

Nonetheless, there are several compelling arguments suggesting rather that the *status quo* without any kind of CP in place is inequitable. The negative externalities of car use stem from the fact that private marginal costs that drivers face are lower than social costs that their travel imposes on the society. The fact that road use is free means that drivers do not pay the marginal external costs and the price of trip is below its social cost. Drivers pay less than the cost that they cause to society, which can be considered as an involuntary subsidiation by society of a car travel. Transportation cost studies indicate that many unpaid costs caused by automobile users, such as congestion, air emissions, accident risk, parking, lead to significant subsidization of car travel. This results in even greater inequity because the size of subsidy increases with the kilometres driven and more-than-average drivers benefit more. Therefore, the situation without congestion charges is horizontally inequitable because drivers as a class benefit more and vertically inequitable because the number of kilometres driven is positively correlated with income (Litman, 2020). Moreover, the absence of direct charges levied for the use of roads is also inefficient as it results in "tragedy of the common[6] situation, where scarce road capacity is inefficiently overused leading to significant time losses and air pollution.

[6] "Tragedy of the commons" theory states that resouces that are commonly held (such as oceans, parklands, fisheries, forests, etc.) are overexploited and are subject to degradation. Common-property resources have two characteristics that make them susceptible to overexploitation: non-excludability (the access to the resource is not controlled) and

One more criticism is that CP entails double taxation whereby drivers have to pay congestion charge on top of other taxes (fuel tax, registration and circulation taxes, etc.) already used to finance road capacity. However, congestion charge is not just another tax, but one of the many tools of transportation demand management intended to reduce the demand for car travel, especially in the most congested areas and during peak hours. It is based on price mechanism and implies the use of economic incentives to bring supply and demand for transportation into equilibrium. CP is mainly applied in heavily congested areas where the external costs of traffic are particularly high and therefore is used to internalize them by making drivers pay for the social costs that they create, which are higher in the urban centers and therefore an additional surcharge there is justified.

Another reason for criticism is that congestion charges are deemed to be strongly regressive[7] as they are of the same size for everyone and charged regardless of the socioeconomic status and level of income. There are several arguments for this:

- Facing the same level of congestion charge, low-income individuals are more likely to spend more on it in proportion to their income than higher income individuals. This stems from the fact that income elasticities of travel demand and vehicle ownership are below one (Litman, 2019), which means that the expenditures on car travel increase in a lesser proportion than income and therefore higher income individuals pay less charges as proportion of their income.
- Middle class and wealthy people rely much more on car travel than lower class and therefore would benefit more from congestion reduction, also during times when there is no charge.
- Motorists have different values of time (VOT) and CP is favourable for those with higher VOT. Since VOT and income are positively correlated and VOT is proportional to the wage rate (Foster, 1974), CP is regressive (Lindsey and Verhoef, 2001). If time savings are the same for all income groups, benefits will be bigger for rich. CP can be beneficial to drivers with high VOT even before revenue recycling (Richardson, 1974; Verhoef et al., 1997)
- Drivers with high VOT are more prone to pay to avoid congestion; others opt for cheaper and slower options. Individuals with low income and low VOT are more likely to be priced off the road to some second-best transportation options which will obviously make them worse off; in case if they stick to driving they will have to pay a charge higher than the value of time gain (Borjesson et al., 2012.) This is more likely to happen to low-income individuals because they have lower VOT.
- Individuals with high income are less prone to change their travel behaviour. People in the highest income category were found to be less price-sensitive and less adapting their travel behaviour in response to road pricing (Ubbels and Verhoef, 2006). Therefore, the reduction in congestion generally happens thanks to poor who are forced to adjust and change transport mode and/or timing. Whereas the immediate benefits of lower congestion are reaped by high-

rivalry (use of the resource by one user decreases the welfare of others) (Hardin, 1968). Roads share these characteristics and are therefore congestion can be considered as a "tragedy of the commons" problem.

[7] A tax or a tax system are called regressive if low income groups pay relatively more (i.e. as proportion of their income) than high income groups and progressive if the opposite is true.

income who continue to drive. In this case poor benefit least while contributing most to the congestion reduction because they are mostly priced off the road.

- Poor are usually less flexible with respect to departure time and cannot adjust their behaviour to avoid paying tolls as effectively as rich can (Giuliano, 1994). This mostly stems from the nature of work activities that generally have more rigid time schedule for lower income classes and more flexible working hours for higher income classes. In Stockholm higher income individuals could easier avoid payment of the congestion toll due to more flexibility in work schedule (Karlström and Franklin, 2009)
- In case of tolling schemes that rely on Electronic toll collection (ETC) technology, associated transaction costs favour high-income drivers as they are more likely than low-income drivers to own transponders and credit cards necessary to use the system (Parkany, 2005).
- Lower income groups tend to live farther away from urban areas and can be stronger affected as they need to commute longer distances to work.

However, there are also some features of progressivity that might offset the potential regressivity of CP. Low-income individuals are less likely to own and drive a car in the first place. Congestion charge can be perceived to be progressive because the share of car owners is higher among wealthier people and hence they would pay more for the use of roads. Cortright (2017) found that average incomes of peak-hours car commuters are about two times higher than of those who use other transport modes or those who do not work, which suggests that road tolls are progressive, or not as regressive as other transportation fees such as transit fares. This effect can be reinforced by the fact that high-income motorists may be highly reliant on car travel. One more argument for progressivity of CP is that public transit users, who are mostly low-income individuals, gain from congestion reduction as well because with fewer cars on roads bus travel becomes quicker and more reliable. For example, in the case of London the bus reliability improved both due to reduced congestion in the charging area and increased spending on improving bus services financed from the net revenues generated by the congestion charging scheme (Santos and Fraser, 2006). In Milan the speed of public transport improved due to reduced traffic by urban area toll Ecopass (Danielis et al., 2011).

Regressivity is inherent in the majority of taxes and prices in general. In the decentralized market, prices are of the equal size for everyone for a number of good reasons. First, the prices of the goods reflect their value and relative scarcity. Second, all individuals when facing the same prices make their own choices on how to spend the budget in order to maximize the consumption utility. These conditions assure the achievement of the Pareto efficient outcome, which means that economy is operating efficiently. The associated equity issues are rather treated by means of the social welfare system, redistributive policies and fiscal system. This allows to reach equitable distributions without undermining the efficiency of the market economy. The worries about low income individuals should be handled at the stage of redistribution and not by avoiding taxes in the first place. Reluctance to introduce CP undermines the ability to reduce negative effects of road transport and improve efficiency. Or how Schweitzer and Taylor (2008) put it: “Concern over a subset of drivers — those with low-incomes on freeways — means that all drivers, rich, middle-income, and poor alike, avoid paying the marginal social costs of their driving.”

The relevance of concerns about distributional effects depends on the purpose of the charge: internalization of negative externalities vs. generation of fiscal revenues (Eliasson, 2016). If the purpose is a pure price correction to make the price of car travel reflect its full social cost and bring an end to the situation where it is socially subsidized, then concerns over fairness are of limited relevance. Here charge makes those who drive more pay more and it is irrelevant if those who pay more have low income, they pay depending on how much they drive. It is fair that those who cause higher marginal damage have to pay more, even if these are low-income groups or rural residents. However, if charges aim to generate fiscal revenues, e.g. for infrastructure financing, then they just serve as another tax and distributional effects are of paramount importance here because it would be unfair if people with low income would have to contribute more to the public revenues.[8] Therefore, the tasks of the correction of externalities and generation of fiscal revenues should be separated into distinct policies. CP should serve to reduce congestion, improve traffic conditions and reduce negative externalities and it should be presented to the public making distinction that this is a main purpose of the charge.

All public policies result in costs that will be spread in some way across different socio-economic groups depending on their behavioural responses and underlying characteristics of the economic environment. The perception of what is "fair" in the society also depends upon the government policy of income and wealth redistribution. If economic inequality that exists in society before introduction of a policy is accepted in society and the current distribution of wealth does not necessitate further redistribution mechanisms in addition to existing ones, the relevant issue is whether the distributional effects of a new policy are "marginal" to distribution of wealth already in place (Nick and Ysé, 2006).

The degree of progressivity or regressivity does not only depend on the first-order effects of policy such as an increase in prices. The distributional effects of CP policy can be affected by the fact that different income groups will adapt differently to the new conditions. Difficulty in predicting the changes in behaviour is the main impediment to evaluation of benefits resulting from a pricing scheme. Whether these differences in behavioural responses will eventually reduce or aggravate the magnitude of the distributional effects depends on the availability of substitution possibilities and price elasticities of travel demand of different income groups. These are likely to vary across distinct income groups and markets and can change over time. One needs to keep in mind that some groups may be disadvantaged due a lower ability to adjust. Therefore the demand for travel needs to be thoroughly analysed in each specific case.

Ater all, it is incorrect to draw conclusions about the distributional impact of the charge basing alone on the analysis of how much different income deciles pay relative to their income as the standard equity study would do. Low-income travellers pay more as a proportion of their income than high-income travellers and consequently are perceived to be affected more severely by such measure. However, such approach is a simplification and in practice the distributional effects of CP depend on many factors: the size and structure of charge, who must pay, what transport alternatives are available,

[8] Although the same logic could be applied and it could be argued that if revenues are accumulated for infrastructure financing, those who cause more wear and tear by driving more should pay more, regardless of the income category.

how revenues collected are used, etc. CP scheme can be made progressive by adjusting these in an appropriate way. For example, the evidence suggests that revenue recycling is decisive for the overall progressivity of the scheme (Levinson, 2010).

Different approaches to analyse equity effects of CP

While in the tax incidence literature the concept of progressivity or regressivity pertains to income, in transportation context it is rather associated with transport-related costs and benefits. Therefore, it is inaccurate to evaluate the degree of progressivity of CP policies basing solely on their income impact and other effects of charges have to be monetized and taken into account. In the transportation literature the standard welfare effects of CP are the following:

1. the amount paid (fees, tolls, congestion charges, etc.);
2. adaptation costs (to change travel time and/or travel mode);
3. the value of time gain/loss;
4. the benefits received due to revenue recycling that was collected by the scheme.

In addition to these, CP also results in other effects such as a reduction of negative externalities and associated with this benefits that could also be monetized. With regard to different income groups, pricing methods can be considered either progressive or regressive, which is the main research object in the transportation equity literature.

A large body of literature performs economic welfare evaluation by focusing on the question of winners and losers from CP (Eliasson and Mattsson, 2006; Franklin, 2005; Franklin et al. 2009; Karlström & Franklin, 2009). 'Winners and losers' literature seeks to analyse the incidence of costs and benefits according to the different socioeconomic classes of users. The most widespread approach to assess distributional effects of CP policies is according to economic status. In its simplest form welfare-based analysis compares welfare gains and losses due to toll payment without taking into account that people will adapt their behavior in response to the policy (aka behavioral response) (Danielis et al. 2011; Rotaris et al. 2010). More advanced approaches take into account welfare effects from behavioural adjustments of drivers (change of route, mode, trip duration, etc) (Franklin et al. 2009; Karlstrom and Franklin, 2009). The most comprehensive studies also take into account the revenue recycling (Eliasson and Mattsson, 2006; Franklin, 2005). The examination of distributional effects without taking revenue use into account determines a so called first order equity effect, while the case when revenue redistribution is taken into consideration is referred to as second order equity effect.

While majority of 'winners-losers' studies analyse an impact on different income groups, dividing population into high and low income groups by income deciles or quartiles; there is a question of how policy will affect separate individuals with specific socio-economic characteristics. This is important as, for example, Franklin et al. (2009) showed that variation within population groups is larger than variation between groups meaning that individual circumstances and characteristics are more important for equity implications than the fact of belonging to some specific group. When using revenues to compensate disadvantaged groups, one needs to take into account heterogeneity within

these groups, otherwise some individuals within low-income groups may be disproportionally disadvantaged even after revenue reallocation is applied.

According to Börjesson et al. (2012) the standard 'winners-losers' analysis is imperfect and tends to underestimate benefits because it ignores dynamics, network effects and user heterogeneity:

- In the dynamic setting motorists can adjust their departure times so that traffic is spread over time in a way that it does not exceed the road capacity; rescheduling costs and charge paid will not exceed the time gains and motorists will not be worse-off. Moreover, in the long run the entire choice set that predetermines travel patterns (workplace, place of residence, work schedule, etc.) is subject to change.
- Due to network effects also motorists that do not pay toll can benefit from its impact on the traffic conditions: the upstream traffic enjoys improved travel time even without going through a paid bottleneck.
- Heterogeneity of motorists ensures that low-value trips are priced off and high-value ones stay on road and benefit from the improved travel conditions.

Furthermore, they note that due to the fact that reality is different from a textbook case, it is possible to identify winners and losers just in the short term, having the impact of first-order effects only. In the long term it is not possible anymore because people can adjust their behavior in a multitude of ways and travel patterns change over time, even without people noticing that they adapt. CP is not an external shock[9] anymore and is taken into account in the decision-making process. Therefore the focus shifts from 'winners-losers' perspective to another notion of equity according to which policy and its outcomes should be consistent with its objectives stated beforehand. The question is what price is fair to charge motorists depending on the circumstances in which trip takes place? Should charge be higher for trips in densely populated urban areas during peak hours? If charging scheme aims to internalize negative externalities then the size of charge should be proportional to marginal damage caused and such trips should be more costly, regardless of the socio-economic profile of motorist. Börjesson and Kristoffersson (2014) extend the analysis and estimate to what extent these three factors discussed above, which are omitted in the standard textbook analysis, contribute to the social benefit of the CP. They use a combination of a dynamic network assignment model with a mode and departure time choice model assuming heterogeneous users and apply these to the case of the Stockholm congestion charging scheme. The results show that each of the factors adds significantly to the benefit of the scheme and that drivers as as group benefit directly from the congestion charging scheme, without compensation.

Eliasson (2016) proposes another view on equity of CP. He distinguishes two different perspectives of equity: the consumer perspective and the citizen perspective. While the former is traditional in equity analysis and implies evaluation of changes in individual travel-related costs and benefits, the latter is based on the individuals' views of equity, procedural fairness and environmental justice as

[9] In the economic theory the term "external shock" designates an unpredictable event that affects the economy. Here it is used to indicate the unpredictable nature of charges for motorists shortly after they are introduced and the fact that the decisions that were made by motorists before did not account for this additional cost.

social issues. Even if individual loses according to the consumer perspective, she still can be a 'winner' from the citizen perspective if her views of what is socially desirable are in line with the policy and its outcomes, disregarding her own self-interest. By using data from four European cities (Stockholm, Gothenburg, Helsinki and Lyon) Eliasson analyses to what extent different income groups win or lose from CP reform according to the consumer perspective, i.e. how much they actually pay, and to the citizen perspective, i.e. to which extent they are satisfied because their views are aligned with the policy. Regarding the consumer perspective, although in all cities high income groups paid much more in absolute terms than low income groups, CP was regressive because poor paid more relative to their income. However, when including in the analysis other variables related to self-interest, CP was found to be 'progressive' in a way that low-income motorists were hurt less than average as perceived by individuals themselves. When turning to the citizen perspective, CP was rather progressive because middle-income groups won most and in Helsinki individuals won more the lower their income is. However, the differences between income groups were in general small.

Equity, however, is not only about money, this concept encompasses many other factors. There are both financial and environmental effects that have to be considered together. Congestion charges help mitigating the externalities caused and exacerbated by congestion[10] by reducing stop-and-go traffic and the overall number of kilometres driven. Although CP is generally considered to be regressive, it may feature much more progressivity when taking into account external environmental effects. In this respect CP can be progressive as it improves public health and liveability of urban areas, reduces air and noise pollution which affects poor more because they tend to live closer to motorways as housing there is cheaper, etc. As has been shown in a large number of studies, areas inhabited by low-socioeconomic status (SES) households tend to experience higher levels of air pollution (Hajat et al., 2015) and noise (Baum et al., 1999; Hoffmann et al., 2003). Since urban road transport is responsible for more than 50% of air pollutants, it is possible to yield a significant exposure reduction of poor households and hence reduce environmental inequality by reducing congestion in some specific areas (Dasgupta et al., 2020).

An emergent stream of research focuses on social equity and considers the effects of road pricing policies on accessibility[11], transport-related social exclusion and social capital that indirectly affect social welfare. This literature aims to investigate whether some groups will be disadvantaged due to deteriorated accessibility and whether this impedes their mobility. Lucas (2012) provides an extensive review of studies on social exclusion approach in transport planning. Some studies that employ ex-ante analysis argue that congestion charging will further contribute to social exclusion of most vulnerable social groups (low-SES households, disabled etc.) (Bonsall and Kelly, 2005; Rajé, 2003; Shaheen et al., 2019). Di Ciommo and Lucas (2014) after performing simulations of potential cordon toll around the Madrid Metropolitan Area, find that proposed toll decreases accessibility primarily in the areas with no viable public transport alternatives. They also discover that costs mostly fall on unskilled and low-income individuals living in the south of the Madrid Metropolitan Area. They are disproportionally affected by increased generalised costs: both in terms of monetary expenses and

[10] Air pollution, noise, etc.

[11] In transport planning, accessibility measures the ability to reach activities distributed over space and time, the ease of reaching valued destinations (El-Geneidy and Levinson, 2006).

time spent in travel. The cordon toll would create a real risk for some low-income individuals to be entirely excluded from the transport system. Munford (2017) found the Western Extension Zone of London's Congestion Charging scheme to have a negative ex-post effect on social capital using the frequency of visits to friends and family as its proxy. The effect was strongest among those who used a car to make visits.

Along with income, environmental conditions and social inclusion, the costs and benefits associated with time lost and gained due to CP directly affect the equitability of the scheme. Helsel et al. (2020) in their study based on analytical Vickrey bottleneck model demonstrate that the socially optimal dynamic tolls designed to maximize the system efficiency by minimizing the total cost incurred in the system are inequitable as they produce time poverty[12]. The reason for this is that system optimal tolling is based on the travellers' absolute value of time only and does not take into account their relative value of schedule delay to travel time delay costs that determines travel patterns in the no-toll case. As a result, although such tolling scheme will minimize system's total cost, it may also widen the time equity gap in society leaving the poor travellers disadvantaged. Therefore, authors argue that aside from income poverty time poverty has to be considered when making policy decisions and equity concerns should be addressed through the design of the CP schemes rather than through the public outreach. As an alternative to the system optimal dynamic toll they propose a time-equitable toll.
that would reduce congestion while also yielding vertically equitable outcomes by imposing different level of charges on different groups of travellers according to their relative willingness to pay. Authors also draw attention to the trade-offs between system-optimal efficiency and equity of CP: when choosing the time-equitable toll over socially optimal toll some social benefits are sacrificed for reduction of inequity.

There are many theoretical studies that address distributional effects of transport pricing policies and they generally come to conclusion that equity effects depend on the policy design and the underlying distribution of travel patterns among different socio-economic groups (e.g. Arnott et al., 1994, Glazer and Niskanen, 2000). The recycling of revenues is also very important: without knowing how collected revenues will be used distributional effects are not clear. Modification of policy itself in order to reduce (mitigate) its regressivity is not likely to be neither efficient nor effective because this would undermine the "polluter pays" principle and the the underlying economic rationale of marginal external cost pricing, the essense of such policy (Nick and Ysé, 2006). But for political reasons, policy should is implemented as a part of a bigger policy package that encompasses some specific revenue reallocation scheme to mitigate the negative distributional impacts and compensate 'losers'. (Goodwin, 1989; Jones, 1991; Small, 1992).

The literature that empirically assesses the quantitative impact of transport policies on equity is rather limited. The main reason for this is that transport models used for analysis of transport policies can predict traffic flows but are not able to measure economic impact on population. And even less so for studies that quantitatively evaluate gains and losses: nearly all of them predict the impact for different

[12] Time poverty is a concept that describes the phenomenon when people do not have enough discretionary time – the time available when excluding necessary activities such as sleep and commited activities of paid and unpaid work – to engage in other activities that contribute to their social and human capital.

socio-economic/income groups and the literature dealing with micro level data (individuals, households) is almost non-existent.

Empirical studies on distribution effects of CP

In general, there is mixed evidence about whether CP is progressive or regressive. Levinson (2010) conducts a thorough literature review of empirical findings on the efficiency and equity effects of road pricing and concludes that findings are ambiguous: in some cases CP was found to be progressive, while in other regressive; the perception of equity is highly subjective; the exact effects of charges are highly context-specific and overall progressivity heavily depends on the revenue recycling (revenues generally need to be reallocated to make scheme progressive).

Eliasson and Mattson (2006) assess the equity effects of congestion-charging scheme in Stockholm by using transport model together with a sample enumeration-based model to account for socioeconomic differences in valuations and travel behaviour. They analyse effects across different socioeconomic groups, i.e. according to gender, income, household type and occupation, and four different revenue use schemes, i.e. lump-sum redistribution, investment into public transport, reduction of the cost of car travel and income tax cut. The main finding is that the most important determinants of the equity impact of CP are initial travel patterns and revenue reallocation. The net welfare impact to a large extent predetermined by a revenue spending. Men, high-income categories and residents of the central part of the city were found to be affected the most by the charge. Lump-sum redistribution and improvement of public transport are the most progressive schemes, while proportional income tax cut benefits men and women about equally and is most beneficial for high-income groups.

Karlström and Franklin (2009) model behavioural adjustments of morning commuters to the Stockholm Trial and compare welfare effects across different socioeconomic groups: motorists versus public transit users, men versus women and across five income groups. Results show that the lowest income group and the two highest income groups were the worst-off, however, the increase in the Gini Coefficient due to the toll was insignificant and authors cannot draw a conclusion on whether there is an overall trend of progressivity or regressivity. There were also no significant differences either due to change of travel mode or between men and women. The variations within gender groups were bigger then between them.

Franklin et al. (2009) also do not find any significant differences in welfare effects among different income categories as a result of the Stockholm Trial. The benefits increased with income, but more importantly, all income categories were on average better-off. The differences *within* income groups were much more significant than *between* them, which suggests that individual circumstances are much more important for welfare than income level. Authors also test two refund schemes: a lump-sum refund to all individuals and reduction in the income tax rate. They find that both refund scenarios increase welfare and the net effect is positive; all income groups benefit on average, with the lump-sum scheme being progressive and the income tax reduction regressive. The overall conclusion is that different ways of revenue reallocation could ensure a positive average welfare effect for all income groups, even if some ways are more regressive than others.

Steininger et al. (2007) employ computable general equilibrium (CGE) approach to analyze the impacts of nationwide road distance-based pricing in Austria with respect to environmental, economic and distributional indicators of sustainability. The analysis suggests that the scheme is in fact progressive, with richer households and intensive car users paying the most. Some revenue recycling schemes are able to improve negative social and economic impacts of road pricing, while preserving achieved positive environmental effects.

West and Börjesson (2020) perform an ex-post cost-benefit and equity analysis of the Gothenburg cordon toll. They analyse the distribution of costs and benefits across income groups, zone of residence, gender and age with a restriction of the distribution analysis to commuting trips. Although the net social benefit of the congestion charge is positive, it was found to be regressive because low income individuals pay a larger proportion of their income due to the three main reasons: (1) there is a big car dependency in Gothenburg, also among lowest income groups; (2) the access to company cars, which make the charge reimbursed or deductible from the income tax, mostly have the high income citizens; (3) higher VOT of high income individuals. Men and women benefit from the charge to the same extent, but women lose more because they have less access to company cars. Regarding the geograthic distribution, citizens just outside of cordon are the most disadvantaged and residens of the inner city gain most.With respect to the age groups, the effects are mostly of the same magnitude with the exception of the oldest group (over 75) who drive the least.

Ke and Gkritza (2018) by evaluating a hypothetical per-mile congestion tax on peak-time travel in Oregon find it to be progressive on income, which makes revenue redistribution scheme no longer required for equitable outcomes, and regressive with regard to rural households as they would be burdened more. Yu (2020) by applying the same methodology to Beijing comes to the same conclusion regarding the spatial distribution and the opposite conclusion regarding the income distribution of equity effects: rural residents would be bearing more tax burden and per-kilometre tax would be regressive.

Conclusions

Theoretical speculations claim CP to be the most efficient solution to congestion problem. Practice shows that it is crucial to address the equity concerns accompanying such measures in order for the policy to be successfully implemented. However, when considering the issue of equity one needs to remember that the concept of equity is ambiguous, controversial and subjective. There are numerous ways to define it and it seems that the underlying idea behind ‘equity’ can differ depending on the context and those who refer to it. Along with traditional view on equity as a measure of distribution across different income categories, there are many more factors that can be taken into account. Therefore, the broad concept of ‘equity’, ‘fairness’ and ‘justice’ pertaining to CP does not only take into account monetary values and is not only based on welfare distributions across income levels, but may depend on a variety of other factors across socioeconomic characteristics of individuals.

In general congestion charges tend to be regressive before revenue recycling. This stems from the nature of the travel demand: its income elasticity is below one, which means that the expenditures on car travel increase slower than income and therefore higher income individuals pay less charges as proportion of their income. However, the relevance of concerns about distributional effects depends

on the purpose of the charge. If the purpose is a pure price correction to make the price of car travel reflect its full social cost and bring an end to the situation where it is socially subsidized, then concerns over fairness are of limited relevance. However, if charges aim to generate fiscal revenues, e.g. for infrastructure financing, then they just serve as another tax and distributional effects are of paramount importance here. Therefore, it is advisable for public authorities to present CP to the public as an environmental measure aimed to correct prices and reduce negative externalities and clearly separate it from the purposes of public revenue accumulation. Public tax revenues and funds for infrastructure financing should be generated by other fiscal measures, e.g. as of this moment by fuel tax, registration and circulation taxes.

The empirical literature is rather inconclusive regarding the overall progressivity of the congestion charging methods. However, it is clear that the final equity outcomes are highly context-specific and depend heavily on the initial travel patterns, city-specific characteristics and the design of the pricing scheme. Especially important for the final welfare impacts the way in which revenues collected by scheme are going to be used. Literature suggests that any regressive charging scheme can be made progressive if revenues are reallocated in a correct way. There are numerous ways in which inequity can be addressed: both at the moment when charges are developed and after they are introduced. During the development process there needs to be a reciprocal communication process between authorities and public, whereby the feedback on the design of the scheme can be incorporated. Here the feedback from different vulnerable groups can assure more equitable outcomes. At the stage when charges are already in place, authorities can affect welfare distribution by channelling revenues in some appropriate manner. Throughout the whole process there is a need in public outreach that will increase familiarity with the policy and thus increase its acceptability.

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