University of Tartu

Faculty of Social Sciences

School of Economics and Business Administration

Kaupo Koppel

DISTRIBUTIONAL EFFECTS OF

VEHICLE TAX

IN THE FRAMEWORK OF

TRANSPORTATION EXTERNALITIES

Master's thesis

Supervisor: Helen Poltimäe (PhD)

Tartu 2017

Name and signature of supervisor……………………………………………………

Allowed for defence on...

(*date*)

I have written this master's thesis independently. All viewpoints of other authors, literary sources and data from elsewhere used for writing this paper have been referenced.

....

(signature of author)

Acknowledgements

My biggest and sincerest gratitude goes to the remarkable Helen Poltimäe. While appreciation of timely pointers and tips could almost go without saying, I am foremost thankful for the continuous faith and sincere interest in this work. Thank you for providing motivation needed!

Sincere acknowledgement is reserved to Katrin Pihor and colleagues of Praxis for full support and understanding for enabling time to write this thesis when needed. This cannot be treasured enough.

Further thanks go to QE professors, program manager and students who no doubt share a part in development of this thesis one way or another. Special mention here belongs to Andres Võrk for his detailed and handy feedback during pre-defence and Kerttu Lääne for unforeseen positivity and never-ending uplifting attitude throughout these two years.

Abstract

This paper assesses the distributional effects of different vehicle registration taxes, while placing them into context of external costs in Estonian transportation. It is found that proposed Estonian vehicle registration tax is strongly regressive, as tax share decreases with income in every income decile. However, as these tax revenues do not cover external costs of 366 million euros in passenger car transport that are found in thesis beforehand, alternative tax scenario taking into account EU emissions goals and former figure is designed and studied. It is established that while focusing on new registrations, tax of approximately 18000€ per vehicle would internalize the external costs caused by passenger cars.

Keywords: externalities, distributional effects, internalisation, environmental tax, transportation

1 Introduction

Over the recent past, European Union member states and other countries in general have set targets for the reduction in pollution and emission of greenhouse gases, which have facilitated the use of environmental taxes across the world, especially in the EU. As a result of recent concerns relating to the harmful effects of global warming, policy makers have become increasingly interested in the use of environmental taxation as a means of combating the problem, in order to meet targets set at the 1997 Kyoto protocol and Paris agreement 2015 to reduce greenhouse gases. Beginning with the Scandinavian countries in 1990s, there has been a number of attempts to introduce Environmental Tax Reform in EU member states by aiming to shift the burden of taxation away from factors of production to pollution and the users of natural resources (Abdullah & Morley, 2014).

As environmental tax revenue predominantly consists of taxes on transport and energy products, one way of to address said goal is to set focus on vehicle taxation, which further relates to the ownership and use of motor vehicles.

Travelling in a private vehicle does bring benefits to individual using it; however, alongside entails external costs to society as a whole, as it involves noise, pollution, accidents etc. All of this means negatively affecting public health and quality of life, a fact not taken into account during the decision-making process when choosing whether and which type of vehicle to purchase. In a sense, this is a market failure due to ignored external costs, as marginal costs of using a car by the owner are lower than the marginal social costs (OECD, 2016). Governments can combat this by implementing market-based instruments to internalize external costs, one way being to introduce car purchase tax based on its emissions. For example in 2016, 20 out of 28 EU member states have implemented carbon dioxide (CO_2) based motor vehicle taxes (ACEA, 2016). Some countries, such as Israel, have approached the issue by including more pollutants in addition to CO_2 - for instance emissions of PM_x (particular matter) and NO_2, two of the influential measures connected with causing local health effects (Pope & Dockery, 1995) (OSHA, 2016) - as to further address the extent of externalities in road transportation (OECD, 2016).

As any tax, vehicle tax, whether registration or ownership based, will have distributional effects on members of society. In literature, distributional effects of transportation taxes have often been examined as a part of environmental taxes, as is done in (Aasness & Larsen, 2003) and (Ahola, Carlsson, & Sterner, 2009). In these cases, distributional effects have been investigated for taxing motor fuel (Tuuli, 2009) or looking at excise taxes (Kosonen, 2012). There is, however, little work done to examine if and to extent will vehicle owners be influenced by taxation of car emissions. Even more profound research gap exists in Estonia, where despite the oldest and most polluting vehicle park in Europe (ACEA, 2014), no methodical research has been published proposing or analysing vehicle tax countering said fact.

Current dissertation will *ex ante* analyse planned Estonian car registration tax[1] and its share of owners' income to better perceive which income deciles are influenced to greater extent. That is to say, potential progressivity or regressivity of tax will be under focus. For this, vehicle emission and owners' income data from Estonian Tax and Customs Board is used and complemented with available emission information from car manufacturer. Distributional effects will then be examined looking at tax-to-income shares and several distributional measures.

In addition to analysis of Estonian vehicle tax, tax scenarios of other nations and their application in Estonian context will be explored, with focus on countries that include wider range of external costs in establishing their respective taxation. To further investigate

[1] Dicussed registration tax would be implemented on registration and based on CO2 or in case of older vehicles on engine capacity, however proposal was withdrawn as of May 2015.

taxation of road transport externalities, a tax taking into account CO2 and NO2 emissions; European vehicle emission standards and future goals (ACEA, 2017) will be designed and its distributional effects analysed. Significant element is matching tax revenues with external costs of passenger car transport that are found in present thesis beforehand. This evaluation can provide relevant evidence for policymakers, as to what extent vehicle tax ought to reach in order to internalize the costs caused by car owners and whether the quantity is genuinely reachable or would the taxable sum stand at undesirably large share of peoples income. This process makes it the first case in literature where tax is designed and analysed to fully account for external costs of transport sector. All research is done separately for personal car owners and company car owners.

Following structure of paper is used. Section 2 will provide a theoretical framework of environmental and transport taxes arising from concept of external costs. Third section will give an overview of transport taxes in effect in OECD countries, while section 4 will present an overview of data and used methodology. Empirical findings of tax scenarios, their analysis and possible policy implications will then conclude the research.

2 Literature review

2.1 Externalities from road transport

This section discusses the concept of environmental taxation, more specifically incentives and background for such taxation while also examining distributional effects of environmental and transportation taxes.

The idea of environmental taxation is based on the theory of market failures, more specifically externalities. Externalities can be either positive or negative, i.e. one can differentiate between external costs and external benefits, based on whether consumption or production of some good creates negative or positive effects to a not involved – external – party. The party(-ies) causing such externalities does not receive or pay compensation for influencing others' utility levels; in other words, supplier does not take effects of his behaviour into account in one's decision making process (Baumol & Oates, 1995).

Essentially, existence of externalities leads to a market failure via deviation from socially optimal resource allocation to a situation, where market prices no longer reflect social costs or benefits (Verhoef, 1994). This means additional taxes or subsidies, respectively, are needed to restore efficient allocation. For instance in case of negative externalities depicted in Figure 1, this altogether results in inefficiently high quantity of any good that can be associated with such externality. On said figure, amount of externalities would be vertical difference of social(MSC) and private cost(MPC) lines, measured at same quantity. Ideal equilibrium reflecting social costs is at P_{opt} in the crossing of marginal social costs and marginal social benefits, while actual equilibrium in unfettered market is at P1.

Here, in framework of road transportation, it is of importance to distinguish between (1) social costs that reflect all costs which occur in result of provision and use of transportation (wear of infrastructure, capital costs) and (2) private costs, directly borne by the transport user (transport taxes and charges, wear and energy cost of vehicle use). External costs here reflect the difference of social and private costs (Handbook, 2014). According to economic welfare theory, all marginal social costs occurring in result of transportation activity ought to be paid by transport users. Considering private marginal costs, optimal infrastructure charges should reflect the marginal external costs of use of infrastructure such as wear of infrastructure, congestion and environmental costs. These costs are connected to fixed infrastructure capacity and thus not relevant in the short run, however opposite is true in the long run as construction of additional roads alters capacity. This means for efficient pricing of existing roads, short run marginal costs are of concern, whereas the long run marginal costs in addition have to consider the financing of infrastructure extensions The separation between short and long run marginal costs is based on treatment of existing infrastructure costs – both fixed and variable – and connected financing schemes as transport taxes and fees (Handbook, 2014). Hence, it is useful to differentiate between infrastructure related costs, and taxes from other external cost components.

One general feature of externalities is that effect produced is not a deliberate creation rather than unintended by-product of some legitimate activity (Mishan, 1971), meaning intentional criminal activity or altruism do not qualify as external costs or benefits, as do not barter trade and occurrence of pecuniary benefits (Verhoef, 1994).

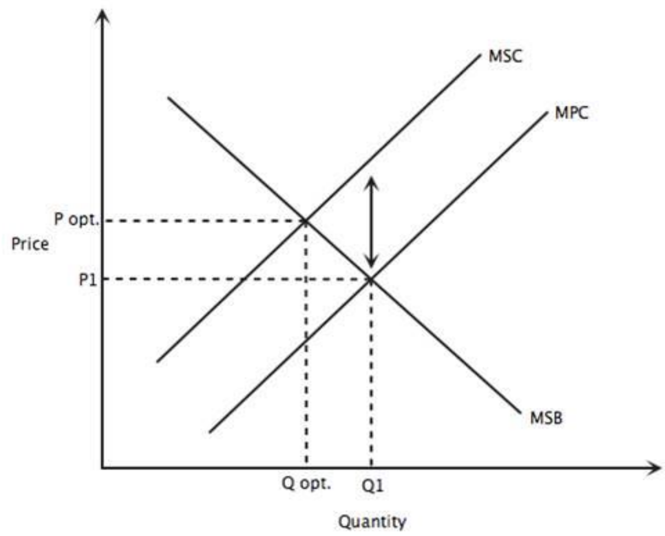


Figure 1: Negative externalities (Dietz, 2012)

In road transportation, the existence of externalities has been established in literature, although external benefits - which are not discussed in current thesis - and their relevance are still a matter of dispute[2]. External costs of road transportation are more agreed upon on. Arguably one of the most extensive research on valuation of external costs to date (Handbook, 2008) has defined three main cost components of external costs in transport to be (1) congestion and scarcity costs; (2) accident costs; (3) environmental costs. Each component influences different extent of people, as when environmental externalities are imposed on society at large, congestion costs are relevant to collective withheld in traffic, whereas external accident costs are typically enforced on clearly identifiable individuals.

Significant consideration of road transport market is simultaneous treatment of externalities, meaning level of one externality can influence the level of others with of congestion and air pollution being clear example. Hence, any policy intervention directed towards such externality will have an influence on others (Calthrop & Proost, 1998). Therefore in principle emission standards, congestion taxes etc. have to be decided simultaneously.

Of environmental pressures, most literature has focused on costs of air pollution, noise, accidents, congestion and climate change, while effects of odour, vibrations, water and soil pollution are more rarely used, although not ignored.

[2] Whether to include benefits of infrastructure as external benefits and effects to general well-being as external benefits of transportation are cause of many arguments, see for example (Diekmann, 1991) (in German, summarized by (Johansson, et al., 1996)) and (Rietveld, 1989).

Several valid methods have been used for quantifying pressures monetarily. However, one that considers technology, site specific parameters[3] and effect of time on costs is impact pathway (IPA) method (HEATCO, 2005). IPA follows a progression from emission of pollutants to quantification of each impact monetary wise (Figure 2). Although IPAs principles are applicable for all pressures, it is mostly used for quantifying air pollution, soil pollution and externalities of noise.

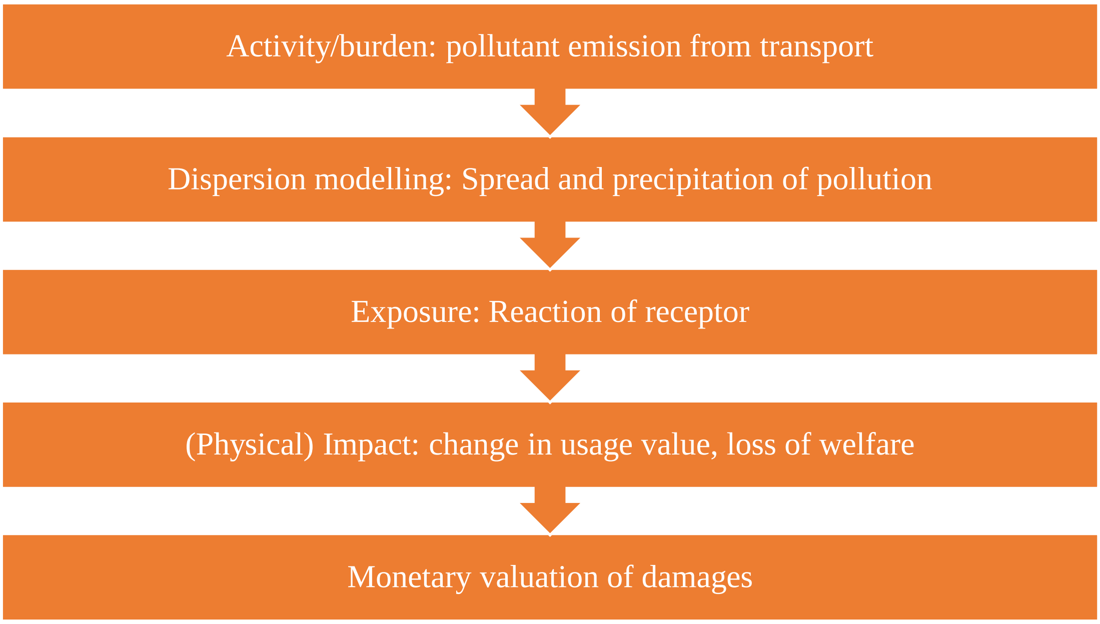


Figure 2: Impact Pathway approach to quantifying road externalities. Compiled by author based on (HEATCO, 2005).

In case of external congestion costs, it is of essence to differentiate between congestions in cities and that in highways. In latter case, it is necessary to evaluate speed-flow curves for which data for traffic intensity, speeds and information about cross section of roads is needed. In case of cities, traffic is modelled comparing current time costs of rush hour to simulated optimal case, which can be seen as free-flow speed in streets. Cost of time and giving monetary values is then dependent on length and purpose of trip, for example in minimal there ought to be differentiation between trips made for purpose of business and non-business (Jüssi, Anspal, & Kallaste, 2008). For former, marginal productivity of worker should be estimated for further valuation of such congestion costs; in case of non-business trips, willingness-to-pay estimations for saved time are used. Until last decade in urban transport, often used function was one relating average speed exponentially to traffic flow,

[3] E.g. noise impact in densly populated city at nighttime vs noise in sparsely populated rural area.

measured by passenger car units per hour. Monetary values were then given by willingness-to-pay approach. (Mayers, Ochelen, & Proost, 1996).

For accident costs, severity and location of accidents, under-reporting coefficients, distribution of accidents by types of transportation and estimated value of statistical life are needed. Costs of climate change are calculated based on fuel types, driver kilometres and are not location specific due to their global nature.

As most described data is often not available on detailed and country specific levels, inputs from two papers, “Handbook on estimation of external cost in the transport sector” (IMPACT, 2007) and its later update (Handbook 2014) are used. IMPACT study is based on scientific works done at EU level and recommends best available input values for calculating external costs figures for EU member states, which can be used to produce necessary outputs with relatively high level of accurateness. Alongside, with lower reliability, estimated default unit values of external costs for direct use are provided.

2.2 Principles of taxation and distributional effects

Using taxation to correct negative externalities is to a large extent traced to Arthur Pigou and “The Economics of Welfare”, work on which term “Pigouvian tax” is based upon. In words of Pigou, “it is plain that divergences between private and social net product cannot ... be mitigated by a modification of the contractual relationship between any two contracting parties … it is, however, possible for the State to remove the divergence in any field by “extraordinary encouragements”” (Pigou, 1920).

Under “extraordinary encouragements” taxes or subsidies are meant. Pigouvian tax is intended to correct suboptimal outcome, by equalling tax to social costs of negative externalities (Sandmo, 2008). Contrasting this is Pigouvian subsidy, which is used to encourage behaviour with positive external effects in order to increase production and thus countering possible under-supply by society.

In current thesis, however, emphasis will be on taxes and not subsidies and thus definition of environmental tax is hereby provided. OECD explains environmentally related tax as “a tax whose tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment” (OECD, 2005). Similar definition is used by European Environment Agency, where environmental taxes are defined as “compulsory, unrequited payment to general government levied on tax-bases deemed to be of particular environmental relevance”

(EEA, 2002). Given comparable description, one could conclude with definition of two critical elements: environmental tax is (a) a compulsory payment which is (b) levied on some negative environmental matter.

The level of environmental taxation is not one uniquely agreed upon. Whereas (Pigou, 1920) suggests tax level equating marginal costs of environmental damage, other authors have seen different approaches, not all of which are based on externalities. One approach is described in (Ramsey, 1927), where it is suggested to tax goods for which demand is most inelastic. More recent papers suggest that environmental tax levels should be set such to obtain environmental objectives by least-cost method (Baumol & Oates, 1995), others counter argue that imposed environmental taxes are arbitrary and do not express “right prices” at all (Common & Stagl, 2005). In (Bovenberg & Mooij, 1994) it was shown level of environmental levy will be dependent on already existing - mainly labour – taxes, and of how employment reacts to tax changes. Nonetheless, as focus in current thesis will be on road transportation externalities, Pigouvian tax concept shall thus attain most attention in following sections.

Pigou tax is not without complications. Said tax rate should equal marginal costs of external cost, however following polluter-pays principle several difficulties occur, either related to quality and availability of monitoring or to the fact that external costs varies by source, amount of pollutants, number of people affected, location etc. (Williams, 2016) illustrated this simply by comparing marginal damage from emissions upwind of a major city to those in sparsely populated rural area. In addition to time and space variance, in practice estimating marginal damage is particularly complicated in cases where the potential harm will occur in the future. When emissions cannot be directly measured, taxing agencies often impose tax on some proxy of said emissions, such as amount of fuel burned. However, in case of applying proxies, tax would differ from its theoretical ideal. More of tax systems and how environmental and transport taxes fit into these frames will be discussed subsequently.

Properties of a good tax system were defined by (Stiglitz, 1988) as efficiency, administrative simplicity, flexibility, political responsibility and equity. These were mostly mirrored by (Mirrlees, et al., 2011), where tax system objectives are described as minimizing negative effects on welfare and economic efficiency, low administration costs, transparency and fairness other than in distributional sense. Environmental taxes, however, have added dimensions, as ecological objectives, to address externalities, are now included. Among many others, (OECD, 2010) has set following guidelines in "Taxation, Innovation and the Environment" on how to design environmental taxes:

- Environmental tax bases should be levied as directly as possible to the pollutant or action causing the environmental damage, with few, if any, exceptions.
- The scope of tax should ideally be as broad as the scope of the environmental damage with credible and predictable tax rate similar to environmental damage.
- Environmental tax revenues can assist fiscal consolidation or help to reduce other taxes.
- Distributional impacts can and generally should be addressed through other policy instruments.

Here, latter suggestion can be traced to first two. Designing tax to address both distributional environmental goals and distributional issues can challenge its ability to do either. Creating income based exemptions diminishes tax's environmental incentives and increases its administrative complexity; therefore it is suggested to address possible distributional matters by other policy measures as providing low-income supports or lowering income tax (Serret & Johnstone, 2006).

Altogether, environmental taxes essentially serve two major purposes: in addition to focusing on environmental effectiveness, as a tax it correspondingly ought to bring funds to state without causing unnecessary distortions.

As any other tax, environmental tax has distributional effects within taxpayers, as connections between income and tax burden will now be presented. Theory behind this linkage is based on horizontal and vertical equity, introduced by Richard Musgrave in 1959. Horizontal equity means people with same position should pay the same amount of tax, whereas vertical equity was defined as "requiring an appropriate pattern of differentiation among unequals" (Musgrave, 1959), which is to say those who are able ought to pay more tax.

Related concepts are elasticity and the progressivity or regressivity of tax. The association between income and consumption of a good can be linear, decelerating or accelerating. In case of latter, where demand elasticity is higher than unity, the product is luxury good and taxing it will affect affluent people more, thus the tax is progressive. If connection is decelerating and unity lower than one, taxed good is a necessity. Here, if proportion of taxed good decreases as income rises, it might indicate a regressive tax, where lower income people might be more affected (Poltimäe, 2014).

To further analyse the distributional effects of taxation, mostly descriptive measures of income are commonly applied. These measures are usually based on Lorenz curve, showing deviation of person's income from perfect equality (Kakwani, 2010). Originally meant by Max Lorenz to be solely descriptive graph, it was later modified for use of numerical calculations (Gini, 1912) as the information of Lorenz curve could be captured by some form of Gini index. Less used method of analysing changes in equality is normative approach, where commonly used measurement is the Atkinson index, constructed on idea of equally distributed equivalent level on income (Atkinson, 1970).

Distributional effects of environmental taxes have been subject of numerous empirical studies since 1990s. Although measuring welfare changes might be of real interest, in papers income is mostly used as a proxy, as simply not enough information on individual utility function is available (Sen & Foster, 2003). Comprehensive summary of such studies has been done by (Poltimäe, 2014), with both direct and indirect effects under focus. Although results are not always in union, most studies find poorer people to pay greater proportion of environmental taxes in relation to their income level (Bork, 2006), though distributional effects clearly depend on the tax.

Distributional effects of vehicle taxes, which are of concern in current dissertation, are dependent whether income or consumption data is used. As (Ahola, Carlsson, & Sterner, 2009) found tax burden to increase up to eight decile using total expenditure of households, when using disposable income as denominator, burden of taxes was seen slightly higher in low-income classes. Tax was found to be strongly progressive in (Jacobsen, Birr-Pedersen, & Wier, 2003), where using expenditure data, transport taxes increased with income until 9th decile. Similar result was obtained in (Aasness & Larsen, 2003), which calculated Engel elasticities[4] using Norwegian consumer data, showing progressivity (elasticity of 1.21) of transport as a whole, which was higher on vehicle purchases and road tolls, lower on bus rides and mopeds. In Finland, results from (Tuuli, 2009) indicate similar conclusions, as the share of taxes increased up to eight decile and lowered for highest consuming households. Outside Nordics, (Bureau, 2011) found carbon tax to be regressive with income before revenue recycling. Regressivity was mitigated while taking into account reduction of

[4] Percentage change in spending on a good as total expenditure increases 1%

congestions, whereas different reallocation methods after tax made poorer households better off.

Results on motor fuel taxes are slightly more mixed, as although they have been proposed to be progressive in most studies including (Tuuli, 2009), (Sterner, 2012) and in EU overall (Kosonen, 2012), some countries (USA, Italy) with regressive conclusions have been found (Sterner, et al. 2012), (Aasness & Larsen, 2003).

In Estonia, the main tax object of direct environmental taxes is motor fuel, even though recent years have seen a rise in excises on heating fules and electricity. Currently this means distributional impacts of environmental taxes to be progressive, this both with income and expenditure data. For indirect effects, environmental charges are considered additionally to aforementioned excises. Concerning different sectors, land transport stands out, as it obtains highest share of environmental taxes per production unit and highest proportion of environmental tax share in price. Yet, as in transport the share of expediture increases with income, this is not the case for most others sectors, namely housing, electricity and food industry. Alltogether, regressive pattern of indirect tax load of environmental taxes is prevailing. However, when accounting for both direct and indirect effects, total tax load remains progressive, ranging from 2.5% of expenditures for the lowest income decile to 3.6% for the highest decile. (Poltimäe, 2014)

3 Environmental and transport taxes in Europe and OECD

In European Union, the highest share of overall environmental tax revenue is represented by energy taxes[5], accounting for over 75% of EU-28 total. Transportation taxes signify one fifth of total environmental tax revenues for all member states, however this share changes from 40% in Malta to 3.5% in Lithuania and 2.1% in Estonia (Eurostat, 2016). Furthermore, in Estonia transportation taxes account for 0.06% of total GDP and 0.2% of total tax revenues, both figures rank last among OECD countries (Annex 1).

One element of such figures in two Baltic countries is that both in 2014 and currently in 2017, there is no tax based on car ownership or related to vehicle emissions. This is contrary to most of developed world, as in 2016, 20 out of 28 EU member states had implemented CO_2 based motor vehicle taxes, exceptions being Bulgaria, Czech Republic, Estonia,

[5] This includes taxes on transport fuels

Hungary, Italy, Lithuania, Poland and Slovakia (ACEA, 2016). However, out of eight countries listed, Bulgaria, Italy and Poland have implemented a tax based on either cylinder capacity or engine kilowatts, while Slovakia is notable for taxing vehicles based on its weight (Zahedi & Cremades, 2012).

Pollutants with local health and welfare effects as NOx and PMx are usually not included in tax system. This expresses in rise of the share of diesel vehicles all over Europe (ACEA, 2014), which, while producing significantly more NOx, on average emit less CO_2. It is further shown climate mitigation policies can have negative effects on local air pollution, if CO_2 savings are the result of switching fuel type to diesel, as was the case in Ireland (Leinert et al., 2013). One of few exceptions where NO_x is taxed are Norway and Israel, where in latter the costs of NO_x make up 71% of total costs of transport emissions (OECD, 2016). Simulations made there show twofold increase of NO_x emissions if percentage of diesel car registration would be 20% instead of current 2%, showing dangers to public health of purely CO_2 based programmes (Roshal & Tovias, 2016).

In general, CO_2 emission based taxes on vehicles are imposed either during registration or annually, in some cases both ways of taxation are used. There exists no clear trend whether to apply one or the other, as usage of recurrent and registration based taxes is roughly equal in Europe (ACEA, 2016), in spite of the fact that a political suggestion by OECD has been to rely on differentiated purchase taxes due to its immediate visibility and likely more powerful impact (OECD, 2009).

Exact amount of tax depends on CO_2 emission per km, occasionally further differentiation exists based on registration date and vehicle engine size or type (***Table 1***). For instance in United Kingdom, all mentioned dimensions are considered: Vehicles registered before 1st of March 2001 are taxed based on engine size; those registered before 1st of April 2017 are taxed based on fuel type[6] and CO_2 emissions; vehicles with later registration are taxed on CO_2 in first year and fuel type each year after that. The exact payments for the most recent (April '17) tax rates vary from £10 (CO_2 emissions 1-50 g/km) to £2000 (CO_2 emission over 255 g/km) in year 1 and up to £450 annually until year 5 after registration (GOV.UK, 2016).

Different approach is used in Denmark, where "Green owner's tax" is applied according to fuel consumption (km/l) of the vehicle for those registered after 1997, while older vehicles

[6] Fuel types are separated as (1)electric, (2)alternative, including bio-ethanol, hybrids and liquid petroleum gas and (3)petrol or diesel.

are subject to vehicle weight tax. Yearly tax rates range from 310 DKK (ca 41€) in case of 20+ km/l up to over 20 000 DKK (2 700+ €), when consumption is less than 4.5 km/l. However, Denmark also sees the highest vehicle registration tax among EU countries. (ACEA, 2016) Registration fee of a vehicle is progressive, as 105% of its value is paid for vehicles bought for less than 84 600DKK (11 378€) and 150% of the values for vehicles over said price. (Danish Minisry of Taxation, 2017).

Only yearly tax higher than in Denmark, according to (Zahedi & Cremades, 2012), is found in Netherlands, where tax is built on weight and fuel type. For private vehicles, said tax rate can reach up to 994€ in every 3 months (Belastingdienst, 2017). The registration tax *Belasting Personenauto's Motorrijwielen* (BPM) is progressive and differentiated for petrol and diesel. In case of latter, owner must pay €86.69 per each gram of CO_2 that exceeds benchmark of 65 grams per kilometre. More steps are included for petrol engine vehicles.

As most registration and circulation taxes are CO_2-related, Israel has gone step further to by adopting a "Green Grade" formula including other pollutants (CO, hydrocarbons - HC, NO_x and particulate matter - PM_{10}) (OECD, 2016). Due to its resemblance to external cost methods used in empirical part of current dissertation, Israeli Green Tax and its social and environmental effects will here attain extended review.

Green Grade formula, aimed at internalising part of private car external costs of 2.6% of GDP (EXTERNE, 2005), differentiates car models by levels of pollution, taking into account CO_2 and four other pollutants listed above. Emissions of pollutants is weighted by estimated relative cost of each pollutant to the society (Green Tax Report, 2008), to obtain a "green grade" for each vehicle. Grade is split into 15 tax bands.

Short term effects of Green Tax were noticeable, although somewhat bilateral. Since implementing tax in 2009, effect of the policy on the composition of vehicles by pollution level was apparent: Average pollution grade of 10 in 2009 fell to 7 in 2010 and further to 4 in 2012, at the same time share of heavy-polluting vehicles fell from 23.5% to 7%. (OECD, 2016). However, as differentiation between the levels of pollution by new cars became less noticeable, the tax had lost its effect on the distribution of emissions by 2012, witnessed correspondingly by sharply declining returns after year 2. What is more, with tax per vehicle lowering, cars became more affordable, thus increasing motorisation rate and causing a rise in total emissions even though average vehicle was now less polluting.

Therefore, pollution brackets were modified to recreate more differentiation between lower grades of tax system and extensive study (Becker, Rosenthal, & Gabay, 2012) was carried out to update the parameters in green grade formula by better estimation of external costs of pollution. Using results obtained by dose-response and benefit transfer methods, the study gave considerably more weight to health-related emissions of NO_x and PM_{10}. Updated formula in 2013 increased tax revenues by 25%, similar to original effect in 2009. Learning from this, Israeli government has called to update formula every two years in the future.

The main effect of Green Tax scheme is thus considered to be slowing the increase of health related pollution and even lowering total PM emissions, whereas economic results based on tax revenues differ for first two years and later.

Table 1: Private vehicle taxes in selected countries

Country	***Purchase or annual***	***Tax base***	***Notes***
Denmark	Both	Price, CO2, fuel type and fuel consumption	Registration based on price, with steps of 105% of vehicle's value up to 84 000 DKK and 180% for remainder. Progressively differentiated annual tax based on fuel consumption and fuel type. Highest vehicles taxes in EU.
Estonia	None*		*Quarterly levied heavy goods vehicle tax. Can reach up to 232€, most rates below 100€.
Finland	Both	CO2, age, weight, fuel type	First registration tax dependent on age and CO2, annual tax on CO2, fuel type and weight. Registration tax varies from 5% to 50%, annual tax can reach 600€.
France	Both	CO2	Registration and annual tax based on CO2, but considerable bonuses apply for purchasing low-emitting vehicles. Maximum registration tax 8000€ in case of emissions over 250g/km, yearly maximum 160€ for CO2 emissions over 190.
Israel	Both	CO2, CO, NOx, HC, PM10; age and price	Registration based on "Green Grade" formula, which creates 15 tax bands. Highest registration tax 83% of price, annual fees up to 995€ with most fees around 300€
Italy	Annual	Weight, engine capacity.	Additional tax for cars registered less than five years ago – 20€ per kW over 185 kW.
Latvia	Both	Weight, age	From 17€ (under 1500 kg) to 143€ (12 000+ kg) annually. 12.6€ per year if older than 20 years.
Netherlands	Both	CO2, price, weight, fuel type	One of the highest taxes in EU context. Ownership of a lorry up to 1400€ annually, diesel cars 663.8 € at 1000 kg net weight per year + 104.08€ per extra 100 kg with other types cheaper; CO2 tax differentiated with numerous steps.

Norway	Purchase	CO_2, NOx, weight, power	4.97 € per mg NOx emitted per km driven, CO_2 tax starting from 4900, however benefits for emissions under 50 g/km, rises with each g/km but with increasing speed at higher emissions.
Spain	Purchase	CO_2	CO_2 based registration tax, differentiated regionally. Varying from 4.75% of car price in most regions in case of 121-159 g/km up to 16.9% for 200+ g/km in Andalucía.
Sweden	Annual	CO_2, fuel type	Progressive circulation tax based on CO_2. 38€ per year + 1.6€ per g/km exceeding 100 g/km for petrol and respectively + 5€ for diesel vehicles. Considerably higher for vehicles registered before 2006. Premium is granted for low emitting vehicles.
Switzerland	Annual	Engine capacity	Regionally differentiated. For example in Canton de Fribourg: rates from 204€ annually for cylinder volume below 400 cc up to 712€ + 33 for each 200 cc above 6000.
UK	Both	CO_2, fuel type, age.	Based on age of vehicle, engine type and CO_2 emissions with numerous steps. Circulation tax different in year 1, years 2 – 5 and later. For example registration is free for private vehicle registered after March 2001 but before April 2017 and can reach up to 531€ in case of 255+ g/km. After April, same amount results in tax of 2400€ in Y1 and 150€ in later years.

Source: Compiled by author based on (ACEA, 2016) and (OECD Policies, 2017).

4 Data and methodology

4.1 Methodology

Comprehensive list of data sources and layout of empirical part of current dissertation is listed below and can be seen in Figure 3.

For analysing distributional effects of various tax scenarios, income and vehicle ownership data from Estonian Tax Board (EMTA, in Estonian - *Eesti Maksu- ja Tolliamet*) was requested and used. It consists of physical or legal person[7], one's vehicle and its registration year and his or hers total personal income[8] in 2015. Said data was available for vehicles registered in Estonia after 2008. For vehicles registered for legal persons, number of users and their combined incomes in said year were included. As no additional information in case of multiple users was available, average income of user was taken. For natural persons only

[7] Term "legal person" is used throughout thesis to signify persons using company car, hence not company/institution itself but those using its vehicles. "Natural" represent persons who use their personal car.

[8] TSD (income and social tax declaration) registered personal income (i.e. salaries and fees taxable with social tax + board membership fees + contracting/agency agreement or other contractual agreement fees) + pensions + dividends + foreign earnings + other revenues

owners' income was brought i.e. there was always only one user. Second EMTA dataset included CO_2, fuel consumption and kilowatt records for roughly 50% of car park.

Externalities in Estonian road transport: COPERT 2007

- Existing model, updated by following

Data request and updates by author

- EMTAK 2030+ : Energy use prognosis
- Estonian Environment Ageny: Relevant emission and mileage data
- Statistics Estonia - population prognosis
- Ministry of Finance: financial prognosis

Model update by author: externalities in road transport COPERT 2015

Data request from Statistics Estonia

- Calculating already internalized costs of road transport obtained by COPERT 2015

Collecting vehicle data

- EMTA: Vehicle ownership and individual level income data
- Road Administration: CO_2, kW and fuel consumption data
- autoevolution.com, NextGreenCar.com; car manufacturer websites: Missing CO_2, fuel, kW data, NO_2 data estimations

Testing tax scenarios

- Vehicle tax preposed 2018
- Including localised health effects through NO_2
- Tax internalizing passenger car transport externalities

Analysis of distributional effects of previous scenarios

- Share of income
- Gini, Kakwani, Reynolds-Smolensky

Discussion of policy implications

Figure 3: Data sources and thesis methodology

To include further information of CO_2 emissions and additional data of fuel consumption, vehicle park data from Estonian Road Administration (*Maanteeamet*) was used and merged with EMTA datasets. NOx emissions, additional missing gaps and available evolution of figures for all variables listed above was obtained from databases of car manufacturers or collective databases including most vehicle-pollutant relations.

During current dissertation, road transportation external costs were obtained by updating external cost model of 2007 with recent relevant emission data for CO, NMVOC(Non-methane volatile organic compound), CH_4, NO_x, N_2O, PM_x, CO_2, SO_2, several metals; vehicle count and mileage by engine type; future energy use prognosis[9] and various macro prognosis. Longer explanation on assumptions and COPERT is brought in Annex 2. All steps listed apart from calculating external costs in 2007 were completed by author of dissertation.

Additionally to describing vehicle tax as a share of income, for assessment of distributional effects of vehicle taxes, descriptive distributional measures are used. These include the Gini coefficient, the Kakwani index and the Reynolds-Smolensky index, where Gini is to describe the inequality of incomes and latter two to appraise the progressivity of taxes.

All measures named are essentially derived from the Lorenz curve (Figure 4), which orders people by the size of their incomes and plots the percentage of earnings by various shares of the populations, showing the deviation of person's income from equality (Gastwirth, 1971).

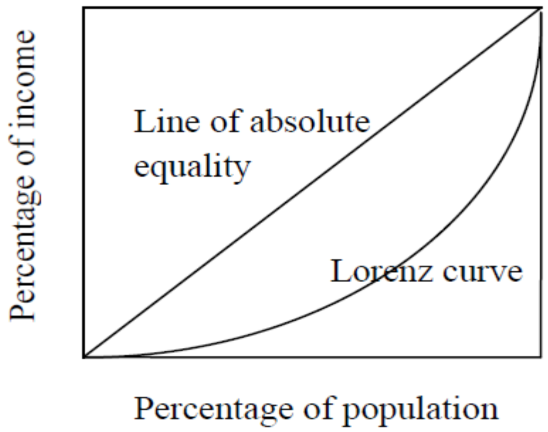


Figure 4: Lorenz curve *(Sen & Foster, 2003)*

The Gini coefficient, one of the most commonly used measure of inequality, is a number expressing deviation of income of a particular Lorenz curve from absolute equality (Farris, 2010), in other words showing the inequality in income distribution. Ranging from 0 to 1,

[9] Mainly "Eesti energiamajanduse arengukava aastani 2030" (ENMAK 2030+), „Transpordi arengukava 2014-2020" and GDP and population prognosis by Statistics Estonia and Ministry of Finance.

larger coefficient marks greater inequality. Mathematically, Gini index is twice the area between Lorenz curve and the absolute equitability line:

(1) $G \coloneqq 2\int_0^1 [p - L(p)]dp$

where p is the fraction of population representing 100p% of poorest population and $L(p)$ represents the fraction of the whole quantity of income owned by respective fraction of the population. Alternative way of finding Gini index is computing the covariance between the income values y_i and their ranks i:

(2) $G = \frac{2cov(y_i, i)}{n\mu_y}$

where μ_y is mean of income, n is number of people.

The Kakwani index calculates the extent to which the inequality in the distribution of tax sizes differs from the inequality in income distributions, thus finding the level of progressivity (P>0) or regressivity (P<0) of tax (Padilla & Serrano, 2006). Mathematically

(3) $P = (C - G)$

where G is the Gini index of before-tax income and C is concentration index of taxes, derived accordingly to G, however instead of income, the amount of taxes paid is used. With Kakwani, population is now ordered by amount of tax paid. Kakwani index, however, is not seen as proper indicator to show the impact a change in the tax on income distribution, as while tax might by strongly regressive, the real effect is marginal due to the size of the tax. For such purpose, The Reynolds-Smolensky (R2S) measure of redistributive capacity (Reynolds & Smolensky, 1977) can be used, which captures the change amid pre-tax (G_y) and post-tax (G_{y-T}) Gini index (Haughton & Khandker, 2009).

(4) $R2S = G_y - G_{y-T}$

Positive index value shows decrease in inequality, whereas negative indicates increase.

4.2 Data

Overall, there were 63108 vehicles in dataset, of which 22432 were owned by natural persons and 40676 people used company cars. Data only included car owners i.e. any person from general population without a vehicle is not included.

On average, most common years for registration were 2011 and 2012 - each with roughly 11000 persons - least common were 2009 and 2015 with 8000 and 5100 respectively. However, differences occurred by person types, as for natural persons most common year of registration was 2009, followed by decrease in each new year. With company cars, years 2011 – 2014 saw most registrations with least coming in 2009 i.e. company cars were newer on average.

Average CO_2 emission was 152 g/km, with 149 and 154 for natural and legal person vehicles respectively. A decrease in CO_2 emission over the years is evident, with 165 g/km in 2009, 156 g/km in 2011 and 138 g/km in 2015. This is in range of figures by Environmental Ministry, which set average CO_2 emission of new vehicle in 2013 at 140 g/km (Ministry of Environment, 2016) and slightly below numbers of European Federation for Transport and Environment, where Estonian average CO_2 emission of new cars was 147.2 g/km, ranking last in Europe and considerably below 126.8 g/km of EU27 average (European Federation for Transport and Environment AiSBL, 2014). Descriptive figures of vehicle park can be seen in Annex 3.

Average power in dataset was 116 kW and has remained constant over the years, with 106 and 122 for natural and legal persons. Figure exceeds one reported by AMTEL[10] by 20 kW. NO_x emissions were 120 mg/km with little differences by person type, larger emissions of 130 can be seen in 2009 and 2010, with 116 in later years.

To analyse distributional effects of various tax scenarios, dataset was split into 10 deciles by users' income (see footnote 8 on p18). Overall, little differences between deciles can be seen in vehicle fuel consumptions and NO_x emissions, whilst in power and CO_2 ninth and tenth decile saw higher emission figures, with same trend when differentiating natural and legal persons. While similar tendencies, clear alterations occur in all variables, as legal persons' income and vehicle figures are higher in every decile, as can be seen in Table 2.

4.3 Data limitations

57% of Estonian vehicles are over 10 years old, while roughly 22% are registered between 2009 and 2015 (ACEA, 2014), dating Estonian vehicle park as oldest in EU. Current analysis includes vehicles registered after 2008, which may be ground for biased results while analysing distributional effects. As stated above, natural persons, who had lower

[10] Maanteeameti ja Autode Müügi- ja Teenindusettevõtete Eesti Liit (AMTEL)

incomes in every decile, had more registrations in each earlier year in dataset, while for legal persons registration saw later years be more common. However, as average new vehicle's emissions show trend of decreasing in time, restriction of data for studying only newer vehicles might diminish or weaken actual tax effects under assumption that less well-off people own older cars, which emit more and hence be the cause of bigger taxes.

Simplifications were made while merging EMTA main dataset (D1) of vehicle owners with kW and fuel consumption dataset (D2), as while D2 had data based on year, manufacturer, model and engine type (petrol vs diesel), in D1 engine type was missing. Hence, either average of two types or the available one was assigned to D1, leading to reduced differentiation of vehicle park. To fill missing gaps in data and find possible yearly changes in emissions through models, manufacturer data and broad databases[11] were used. However, mostly with NO_x, as some gaps still remained, average values of similar vehicles (based on year and kW) were assumed to fill missing values. Additionally, NO_x data is seen as unreliable and not meeting EEA standards (Department for Transport UK, 2016), thus related figures and implications ought to be used with cautionary.

Whether this is a limitation or not might be of discussion, however aspect differentiating current thesis from most other in literature is use of individual level income instead of household level measures. In addition, only car owners are used in analysis, meaning distributional effects are found to owners of vehicles, not to general population.

Possible questions arise with low income deciles. In 2015, minimum gross wage was 390€, which after considering taxes and minimum taxable income (EMTA, 2014) accounts for minimum net wage of 344€ and according yearly figure 4130€. In current dataset, there are 4100 natural and 3000 legal persons with total yearly income below said number. Of legal causes, sickness and unemployment could be main factors for that. Unemployment allowance in 2015 was 4.01€ daily for 270 days, accounting for 1082€ yearly (Eesti Töötukassa, 2017). Unemployment insurance benefit in case of minimum wage of 2014 would be lower, hence it is reasonable to assume in minimum wage case allowance would be chosen as two cannot be used simultaneously. Dataset contains 955 natural and 445 legal person with income under 1082€, which strongly influences tax effect on lowest decile.

[11] http://www.nextgreencar.com/used-cars/ with NOx data, https://www.autoevolution.com/ for other variables

Table 2: Owner-vehicle characteristics by income deciles

Decile	*Yearly income (€)*	*Power kW*	*CO_2 g/km*	*NO_x mg/km*	*Fuel consumption l/100km*
1	2014	112.6	151.8	120.0	5.8
1 legal	2884	125.1	157.8	128.0	6.0
1 natural	1150	104.9	149.1	112.5	5.7
2	4932	115.0	153.8	120.6	5.8
2 legal	6435	122.2	157.1	129.0	6.0
2 natural	3550	101.8	146.0	114.6	5.6
3	7907	114.6	152.8	122.1	5.8
3 legal	9698	118.3	154.8	125.0	6.0
3 natural	5139	106.0	149.6	112.2	5.7
4	11 008	111.4	151.2	119.2	5.8
4 legal	12 916	114.9	151.9	124.1	5.8
4 natural	7887	105.3	148.1	114.0	5.6
5	14 040	110.2	149.4	120.3	5.7
5 legal	16 295	114.3	149.7	122.0	5.8
5 natural	10 790	102.7	146.8	111.2	5.6
6	17 425	110.5	148.4	118.5	5.7
6 legal	20 096	113.8	149.1	122.5	5.8
6 natural	13 512	102.7	146.2	112.6	5.6
7	21 553	112.3	149.9	120.9	5.8
7 legal	24 507	116.5	150.7	124.1	5.8
7 natural	16 536	104.5	147.4	113.5	5.6
8	27 191	115.3	150.3	120.4	5.8
8 legal	30 547	119.6	150.3	120.0	5.8
8 natural	20 662	106.4	149.5	114.8	5.7
9	37 147	121.7	153.4	121.4	5.9
9 legal	41 425	126.9	155.4	124.0	6.0
9 natural	28 164	108.2	150.2	116.2	5.7
10	108 838	141.0	163.0	124.6	6.3
10 legal	118 976	149.9	166.0	126.2	6.4
10 natural	87 059	119.3	157.0	119.1	6.0

5 Results and discussion

5.1 External costs in Estonian road transport

Estonian external costs have seen several estimation during recent decades. In 2002 (Loog et al. 2002) estimated external costs in land transport to range from 600 to 1000 million euros, however without including congestion costs. Using improved methodology and guidance based on (IMPACT, 2007) by European Commission, COPERT model was used in 2007[12] to estimate total cost of road transport to be 488 million euros, accounting for 3.1% of country's GDP at time (Anspal & Poltimäe, 2008).

During current dissertation model of 2007 has been updated by author by including 2015 data of various emissions; car park with engine and mileage specifications; updated macro variables and using new energy use prognosis[13].

In 2015, total external costs in Estonian road transport estimated at 556.8 million euros, which accounts for 2.7% of country's GDP (Table 3). Largest share of externalities are due to air pollution, accidents and climate change, which altogether take up 1.8% of GDP. While the total sum of externalities has increased since 2007 (Anspal & Poltimäe, 2008), there can be seen a slight decrease in share of GDP with most modelled components, which is countered by rise in climate change. Explanations and presumptions used with all components can be seen in Annex 2.

Roughly 62% or 340 million euros (Table 3) of total external costs in 2015 are internalized by various taxes or fees, mainly by fuel excise and insurance payments. Consequently, 216 million are left uninternalized. However, part of excise tax is directed at road maintenance, which is classified under infrastructure costs and is kept separate from external costs in (IMPACT, 2007). When accounting for whole roadwork-related quantities, 104% or 580 million are internalized.

Principal segment of total external costs of 556 million is due to passenger cars with 366 million external costs caused. Passenger cars see the largest share in all external cost types except for noise and soil/water contamination, where biggest costs are caused by trucks.

---

[12] Methodology and results described by (Jüssi, Anspal, & Kallaste, 2008) and (Anspal & Poltimäe, 2008).
[13] Mainly "Eesti energiamajanduse arengukava aastani 2030" (ENMAK 2030+), „Transpordi arengukava 2014-2020" and GDP and population prognosis by Statistics Estonia and Ministry of Finance.

Table 3: External costs in Estonian road transport in 2007 and 2015

	External costs in 2007 and 2015				*Internalizing taxes and their amounts, 2015*		
	2007 mln €	**2007 % of GDP**	**2015 mln €**	**2015 % of GDP**	**Tax/fee**	**Internalized 2015, mln €**	**% internalized**
Up- and downstream processes[14]	49.1	0.3	51.7	0.2	Fuel excise;	204(444)[15];	
Climate change	54.3	0.3	116.4	0.5	Heavy vehicle tax	5.1	
Congestion	27.7	0.2	19.5	0.1	Parking fees	6.9	
Accidents	138.2	0.9	137.2	0.7	Registration fees	7.1	
Additional costs in urban areas	11.4	0.07	14	0.06			
Noise	80.1	0.5	90.6	0.4			
Soil and water pollution	9.8	0.06	9.7	0.04			
Air pollution	117.2	0.8	117.4	0.6			
Internalized by fuel excise, heavy vehicles and parking fees	**488.1**	**3.1**	**556.8**	**2.6**		**223 (463)**	**41% (83%)**
Accidents Internalized by traffic insurance	138.2	0.9	137.2	0.7	Insurance payments	**71**	**51.2%**
Internalized by excises and environmental fees[16]					Electricity. natural gas	46.9	
TOTAL	**488**	**3.1**	**556.8**	**2.7**		**340(580)**	**61% (104%)**

Source: Author's calculations

[14] These are indirect transport costs as producing, maintainance and final disposal of means of transport.
[15] Until 2014, 75% went for road repairs by law, since then road repair share is not legally fixed, although government has declared not to decrease total sum. In 2015, around 240 mln € was directed to roadworks which is represented in „internalized" column as difference between first number that excludes roadworks and number in brackets that includes it.
[16] Electricity and natural gas excise, electricity procuding fees, liquid stock tax,

5.2 Distributional effects of selected tax scenarios

5.2.1 Vehicle tax in effect 2018

In March 2017[17], vehicle tax proposal was approved by Government of Estonia to set in effect in 2018. According to proposal, vehicles registered before 2015 would be taxed based on kW, starting from 150€ for registration or first change of ownership for cars under 50kW, then moving up 30€ or 60€ with each increase of 10 kW. Older cars are taxed less as tax is multiplied by 0.9 for 4 year old vehicles, with coefficient dropping to 0.2 for those over 10 years old. Vehicles registered 2015 or later are taxed based on CO_2 emissions, with 150€ for first registration or first change of ownership for emissions below 50 g/km up to over 600€ for emissions over 180 g/km.

Share of said taxes for income deciles is depicted in **Table 4.** In general, both cases are alike, showing clear regressivity and higher shares of tax to income for natural persons. Strong regressive effects can be reasoned by small differentiation of tax sums, which is to say incomes differ more than characteristics of vehicles (see also Table 2) and said gap is not covered by small monetary alterations between different levels of emissions. Lesser effects for legal persons are due to income differences.

Table 4: Government tax proposals, share of income

	Kilowatt based tax (registration until 2015)				*CO_2 tax (from 2015)*			
Decile	**Yearly tax €, natural person**	**% of income**	**Yearly tax €, legal person**	**% of income**	**Yearly tax €, natural person**	**% of income**	**Yearly tax €, legal person**	**% of income**
1	343.8	29.8	422.6	14.6	433.9	37.7	478.5	16.5
2	330.6	9.3	410.1	6.3	414.3	11.6	471.1	7.3
3	347.3	6.7	394.7	4.1	437.9	8.5	458.8	4.7
4	344.2	4.3	380.7	2.9	428.4	5.4	443.8	3.4
5	344.5	3.1	378.6	2.3	423.0	3.9	433.4	2.6
6	333.9	2.4	375.3	1.8	419.6	3.1	422.9	2.1
7	341.0	2.0	385.8	1.5	429.9	2.6	432.6	1.7
8	347.0	1.6	396.4	1.3	438.6	2.1	426.5	1.4
9	352.1	1.2	423.9	1.0	442.6	1.5	452.2	1.1
10	396.1	0.4	510.0	0.4	479.0	0.5	514.5	0.4

Source: Author's calculations

[17] Press release was issued through ERR: http://www.err.ee/584652/autoloiv-tuleb-astmeline

CO_2 tax sum for natural persons ranges from 414€ for 2nd decile to 479€ for 10th and is roughly 5 to 45€ higher for legal persons. Tax stands at one third of yearly income for lowest income, share but is less than 4% for 5th and higher deciles, all figures are approximately 40% lower for legal persons. Kilowatt based tax is nearly lower 90€ for every decile, while smaller differences are present for legal persons.

To further analyse regressivity of vehicle tax, the Gini, Kakwani and Reynolds-Smolensky measures were calculated (Table 5). For CO_2 case, as pre-tax Gini measured at 0.543 and post-tax Gini at 0.5527[18], Reynolds-Smolensky net redistribution effect was therefore slightly negative, showing increased inequality. Kakwani progressivity index was strongly negative at -0.5, confirming regressive character of tax design. Nearly identical figures were obtained for kilowatt based tax.

Table 5: Progressivity/regressivity measures for all reviewed persons

Measure	***CO_2 tax***	***kW tax***
Pre-tax Gini	0.543	0.543
Post-tax Gini	0.552	0.550
Reynolds-Smolesky	-0.099	-0.072
Kakwani	-0.536	-0.502

Source: Author's calculations

Years 2011 to 2014 have 18 000 to 20 000 yearly new car registrations with steady rise in numbers (ACEA, 2014). While latter figure would create revenues of 7 million euros for kW tax and 8.9 million euros for CO_2 tax, assuming increase in registrations to 25 000 would mean respective numbers of 8.8 and 11.1 million euros. In total, however, there are 45 000 car registrations (Statistics Estonia, 2017) - counting new vehicles and change of ownership - although only estimates can be given how many ownership changes have occurred with same vehicle[19]. When using 45 000 registrations, CO2 tax would return 20.9 and kW tax 16.1 million. In every case, all figures remain magnitude below 360 million passenger car external costs and 200 million total uninternalized external costs from 2015 transport sector.

[18] In dissertation, individual level Gini is found. As a comparison, OECD calculates household level Gini index in Estonia at 0.386 (OECD Stat, 2017).

[19] Followingly only number of new registered vehicles will be used

If regressive quality of tax might not be desired and flat nature is preferred, a CO_2 tax forming 1.77% or kW tax making up 1.4% of yearly income for every decile would keep expected revenues constant. According CO_2 tax sums for deciles are represented in Figure 5 below.

Attaining such quantities is unrealistic in reality, considering low differentiation between vehicle emission levels among deciles (Table 2*).* While steps and constants could be artificially added to connect CO_2 levels to suggested tax levels for extreme deciles, the resemblance of vehicle emissions of first to ninth decile makes finding linear or exponential relationship unachievable without additional policy measures not connected to emissions.

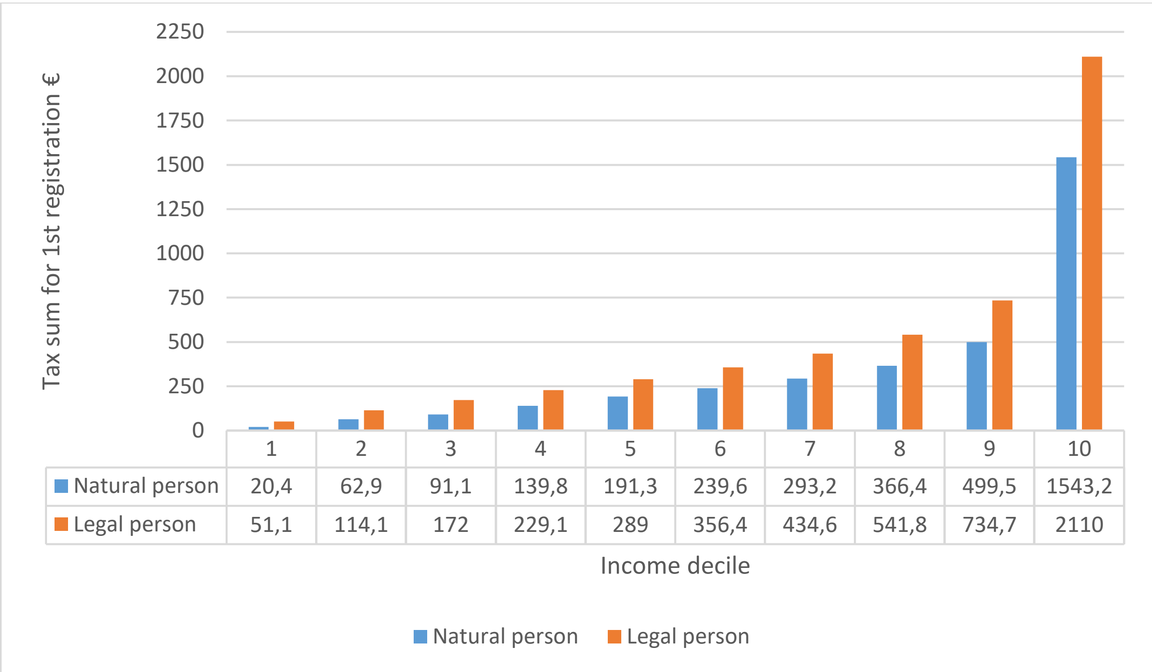


Figure 5: Sums (€) corresponding to distributionally flat CO_2 tax

Source: Author's calculations

5.2.2 Including localised health effects by nitrogen emissions – scenarios of Norway and Israel

In most OECD countries, aim of taxation is CO_2 and climate change (***Table 1***), other pollutants with local health and welfare effects as NO_x are typically not included in tax system. NO_x is taxed in Norway and Israel, where in latter the costs of NO_x make up 71% of total costs of transport emissions (OECD, 2016).

Current dissertation will first simulate effects of Norwegian tax (Table 9 in Annex 4), where NO_x emissions are taxed linearly with 5€ increase of registration tax with unit (mg/km) escalation in vehicle NO_x emissions. Two scenarios are analysed, either implementation of whole Norwegian vehicle tax[20], in which case tax sums are adjusted by proportion of disposable income in two countries (Eurostat, 2016) or applying only NO_x part of tax to proposed Estonian tax system (chapter 5.2.1). Hence, purpose of current subsection will be to analyse whether and to what extent it is possible to transfer one nation's vehicle tax quantities and apply them to another country, i.e. in this case Estonia.

Using Norwegean vehicle tax levels (for CO2, kW and weight) in Estonia would mean average tax of 4865 euros for legal and 3810 euros for natural persons, while still showing strong regressive effects (Annex 5). Due to similar NO_x emission levels, NO_x share is roughly constant of whole tax sum for each decile in both legal and natural case. Tax would result in total of 150 or 190 million euros tax revenues in case of 20000 or 25000 yearly registrations, however behavioural effects are to be expected, resulting in lower quantities in total revenues. Regressivity is further upheld with Kakwani index of -0.5. What is more, Reynolds-Smolensky net redistribution index measures at -0.12, showing considerably increased inequality post-tax.

Adding merely NO_x (and not CO2, kW or weight) part of same amount to proposed Estonian CO_2 based system would result in tax increase of roughly 650€ per vehicle registration compared to case in chapter 5.2.1, with tax share decreasing with income. Regressivity measures indicate similar results as above, although to somewhat decreased extent. Total tax revenue now amounts from 22 to 27 million euros when disregarding behavioural effects, falling short of uninternalized 216 million in whole transport.

In Israel, average emissions level (g/km) from CO_2 of new vehicles is about 6600[21] times larger than NOx (OECD, 2016), however in the Green Grade formula, to reflect relative cost to society, per tonne cost of NO_x is weighted 750 times more heavily than same amount of CO2. In Norway, a gram of NO_x is 14 to 58 times more taxed than same quantity of CO_2[22]. When applying Israeli NO_x-to-CO_2 ratio of 750 to Norwegian formula using found figures,

---

[20] Due to current data limitations, weight could be included by using EU average of 1390 kg (ICCT, 2015), however here this part of formula is omitted.

[21] In present dataset according gap of average emission levels is 1200, representing low average NOx emissions of newly registered Israeli cars (0.021 g/km in 2014) (OECD, 2016) with respect to corresponding European figures (ICCT, 2014). However, while in Israel the share of diesel cars can be considered marginal at 2%, the respective figure in Estonia stands below 40% (ACEA, 2014), contributing relatively more to health effects

[22] Based on Table *9*, when vehicle emits 106g CO2, NOx to CO2 tax ratio is 4960/85.6=57.9. When CO2 emissions approach infinity, NOx to CO2 ratio is 4960/$\{\lim_{CO2\to\infty}(18423.1 + 351.4 * CO2)/CO2\}$ = 4960/351.4 = 14.1. As vehicles emitting below 106 are recipients of bonuses, these need to be focused separately.

instead of 4.96€/mg, milligram NO_x emission would be taxed from 64.1€ to 265.7€. While such robust application would already be questionable in Norway, further use in Estonian context is not realistic. While direct calculation ignoring every behavioural, political and social aspect leads to 184 to 729 million euros of tax revenues (exceeding total transport externalities in Estonia), these figures only serve to illustrate potential complications and dangers of direct and robust application of another nation's tax system without adjusting for local framework.

5.2.3 Externalities based vehicle tax

Following tax is designed to internalize external cost of 366 million caused by passenger cars, while taking into account Euro emission standards of NO_x (ACEA, 2017), target to reach average CO_2 emissions of new vehicles at 130 g/km in 2015 and restrict respective emissions at 95 g/km in 2020 (European Commission, 2017). This is to study the extent of which vehicle tax must reach in order to internalize the costs caused by car owners. Exact design of the tax and further comments can be seen in Annex 6.

Table 6: Externalities tax

	Vehicle registration tax			
Decile	**Yearly tax €, natural person**	**% of income**	**Yearly tax €, legal person**	**% of income**
1	17084.1	1484.5	19562.9	678.0
2	16312.6	459.4	19278.2	299.5
3	17200.0	334.6	18468.8	190.4
4	16879.7	214.0	17838.1	138.1
5	16519.1	153.0	17032.1	104.5
6	16436.3	121.6	16674.5	82.9
7	16889.4	102.1	17113.4	69.8
8	17463.6	84.5	16530.5	54.1
9	17535.9	62.2	18061.9	43.5
10	19402.0	22.2	20694.4	17.3

Source: author's calulations

With 20 000 first registrations annually, tax results in 361 million euros yearly revenues assuming no behavioural effects. Mean tax sum would be around 16 000€, lowest for middle-income deciles and highest for 10th, with legal persons paying a higher quantity but a lower share of income. Tax is strongly regressive with Kakwani index of -0.53, and increases inequality, illustrated by Reynolds-Smolensky index of -0.03.

If flat tax is aimed, rate of 70.4% would result in equal tax shares, meaning first eight deciles would pay less than in original case in Table 6, however last two would see sizeable increase of tax. Precise tax sums within deciles are presented in Annex 7.

Summary of all basic tax scenarios analysed in chapter 5 is shown in Table 7 below, with longer discussion of possible implications in following subchapter.

Table 7: Summary of tax scenarios for natural person

	Government CO_2		NO_2 - Norway		Externalities tax	
Reference	5.2.1		5.2.2, Annex 5		5.2.3, Annex 6	
Decile	Yearly tax €	% of income	€	%	€	%
1	433.9	37.7	6929	602.5	17 084.1	1484.5
2	414.3	11.6	6583	185.4	16 312.6	459.4
3	437.9	8.5	7069	137.6	17 200.0	334.6
4	428.4	5.4	6828	86.6	16 879.7	214.0
5	423.0	3.9	6599	61.2	16 519.1	153.0
6	419.6	3.1	6510	48.2	16 436.3	121.6
7	429.9	2.6	6643	40.2	16 889.4	102.1
8	438.6	2.1	6837	33.1	17 463.6	84.5
9	442.6	1.5	6933	24.6	17 535.9	62.2
10	479.0	0.5	8055	9.3	19 402.0	22.2
Gini pre-tax	0.543		0.543		0.543	
Gini post-tax	0.552		0.670		0.577	
Kakwani	-0.536		-0.501		-0.538	
R2S	-0.099		-0.127		-0.036	

5.3 Discussion and policy implications

Taxation of vehicles based on their emissions, whether on registration or recurrently, is one directional trend, with gradually more nations using some way of taxing cars (ACEA, 2014).

Estonia, as one of the last countries with no vehicle tax (OECD Policies, 2017), has proposed kW and CO_2 based taxation, where latter is used with newer and former with vehicles registered before 2015.

Study of distributional effects shows strong regressive character of both systems, which falls in line with results on transport taxes obtained in Nordics (Ahola, Carlsson, & Sterner, 2009), when income was used as denominator. In Estonia, although tax on motor fuels has been shown to be progressive (Poltimäe, 2014), no real comparable studies have been conducted. While regressive effects are consistent with nearby countries, the extent of regressivity is not, as in every scenario analysed, both Kakwani index of -0.5 and monotonously falling shares of tax-to-income indicate very strong regressivity. This is here reasoned with three following potential explanations:

(1) In current dissertation, the income data is measured at individual level for car owners and not household level as is usually the case. This is to say, the author analyses tax effects not to whole population, but to vehicle owners, hence causing more variations indicated by indexes above.

(2) Analysis of vehicle park by income indicates little differences within most deciles and only 10th decile can be seen to noticeably differ from others. In other words, while the wealthiest do register more powerful and polluting cars, the rest drive vehicles with comparable emission figures. Hence, person with higher income is due for same tax quantity as one with lower income, resulting in regressive tax. While small differentiation is undeniably magnified by occasional limitation of identifying engine type of vehicle, in which case average emission figures of gasoline and diesel was attributed, it is not solely sufficient to explain large similarities. Rather, registration year or age of vehicle could be seen as a more considerable reason. If hypothesizing that well off people may purchase newer, yet powerful and more polluting cars (Yurko, 2008), it is also evident that vehicle emissions have considerably decreased in recent years (ACEA, 2014), resulting in a trade-off.

(3) Tax steps proposed are too marginal, rise relatively less than income and thus will not tax higher deciles with similar share as lower ones. This applies particularly to most polluting vehicles owned by 10th decile, as while they are recipients of highest tax quantity in both CO_2 and kW case, the average difference is measured in tens of euros, whereas yearly income gap is quantified in tens of thousands. Therefore, a suggestion to oversee and

escalate tax rates of highest polluting vehicles is given, which serves as a possibility to raise further revenues for internalizing external costs caused. This, however, ought to be done with consideration that extreme increase may lead to vehicles being registered in another country with more favourable conditions.

Due to one-off character of proposed tax, CO_2 tax of roughly 430€, making up between 3 and 4 percent of annual income for medium deciles, will not serve as a considerable share of income over several years. However, while medium income person would possibly less affected, due to considerable share for first two deciles, suggestion to prolong payment and redistribute it to shares over extended amount of time needs to be made. While questions about potential remissions related to income can be of further discussion, this topic will remain beyond the scope of current dissertation.

Proposed tax did not include other pollutants besides CO_2. One possible reason is undoubtedly availability and reliability of other relevant pollutant emissions from vehicles. Likewise, should collection of missing data result in considerable costs, comparison of said costs and more complicated tax system vs benefits from elaborated tax system needs to be made. However, it is apparent that while CO_2 is main cause of global climate change, localized health effects are more connected with PM_x, NO_x, HC and several other compounds[23]. Therefore, including these to tax formula would serve to internalize costs caused by vehicles to health. While this work would be suggested by author, it is of essence that when using research done and applied in other countries, simple robust transformation cannot be pragmatic solution, as was evident in chapter 5.2.2.

With several updates to inputs of 2007 external costs model and tax return data of Statistics Estonia, uninternalized sum of approximately 200 million euros from land transport was calculated. Covering such quantity, assuming 30 000[24] new vehicle registration or 60 000 total registrations annually (Statistics Estonia, 2017), would result in tax starting from 3300€ to 10 000€ assuming no behavioural effects which is unreasonable assumption. Under the scope the thesis the main focus shifted to external costs of 366 million euros, which were caused by passenger car transport. Designed tax in 5.2.3 was to reach said figure, while considering EU emission targets (European Commission, 2017) and Euro fuel standards in place (ACEA, 2017). Resulting regressive tax near 18 000€ for new registrations yields over

---

[23] See, for example, (WHO, 2003) and (Orru, 2008)
[24] Including passenger cars, lorries, buses, motorcycles, mopeds

100% of median persons income (~15600€) in dataset, and would be in range of projected average yearly income in 2018 so it is possible some considered vehicle registrations will be decided against, meaning in reality target is not reached. Distributionally, once again lower income deciles are significantly more affected, although now with wider scope. However, tax this size would matter relatively less for purchase of new vehicles, as if hypothetical car would cost 40 000€ pre-tax, additional 18 000€ results in 45% increase in price, whereas in case of used vehicles in range of few hundred up to 10 000€, tax share would be considerably larger and likely with more influence towards purchasing decision. Hence, tax sum in this range could be reasoned with environmental policy purpose of lowering average vehicle emission, while potential distributional concerns ought to be handled with other policy measures (OECD, 2010).

6 Conclusion

Taxation of transport is based on the theory of externalities, which lead to market failure through deviation from social optimum to a state where market prices no longer reflect social costs or benefits. Externalities investigated here, in framework of car transport, are negative, i.e. usage of cars will create negative effects to a not involved external party. Most notable externalities are air pollution, climate change, noise and accidents. Hence, additional taxes are needed to internalize caused costs and to restore efficient allocation.

During current research, external costs in Estonian road transport in 2015 were calculated at 556 million euros, of which 60% were internalized by various taxes and fees. Most of externalities - 366 million euros - were caused by passenger cars.

While until now, taxing cars has not been used in Estonia, one-off vehicle registration tax based on engine power and carbon dioxide has been proposed to set in 2018. However, evaluation of proposal reveals strong regressive character of tax, as share of tax decreases with each income decile. Possible reason is large similarities of vehicle park emissions, as respective figures are not closely related to person's income.

For potential policy implications, two scenarios were created and analysed. Firstly, it became evident that tax design cannot be robustly transferred from another country without more extensive research of local and target country's natural and socio-economical dissimilarities. When applying Norwegian and Israeli NO_x part of vehicle tax into Estonian tax design to address caused localized health effects, previously obtained tax revenues increased by magnitude, creating unrealistic and not applicable conditions. To investigate the effects of internalizing whole 366 million external costs of passenger cars, a tax based on EU wide emission goals and standards was designed to meet said quantity. Average tax sum collected at registration showed at 18000€ and as with base scenario, design possessed strong regressive character.

While regressive effects obtained here fall into line with empirical results from Nordic countries, results are influenced by limitations that must be acknowledged. In some cases, data was missing clear indication, whether vehicle model was diesel or gasoline type. In such circumstances, average of two emissions was attributed, thus increasing similarities of average vehicles through dataset. Secondly, only vehicles registered after 2008 were used, leaving out older and likely more polluting vehicles that could have had further impact on distributional effects. Results are further affected by use of personal and not household income measures.

For future research, one possible direction is to replicate present study with improved data and investigate current tax with respect to consumption, as is done commonly in papers studying distributional effects of transport as a whole. For wider research, study of behavioural effects in addition to distributional ones would reveal a more complete image of vehicle registration tax.

References

Executive Agency of the United Kingdom Department for Transport. (2017, March 30). *The Environmental label explained.* Retrieved from VCA: http://www.dft.gov.uk/vca/accessibility/description-of-the-new-car-environmental-label.asp

Aasestad, K. (2008). The Norwegian Emission Inventory 2008. Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants-. *Statistisk sentralbyra*, *Reports 2008/48*.

Aasness, J., & Larsen, E. (2003). Distributional effects of environmental taxes on transportation. *Journal Of Consumer Policy, 26*, 297-300.

Abdullah, S., & Morley, B. (2014). Environmental taxes and economic growth: Evidence from panel causality tests. *Energy Economics*(42), 27-33.

ACEA. (2014). *ANFAC Vehicles in Use Report 2014. European Motor Vehicle Park.* Retrieved from http://www.acea.be/uploads/statistic_documents/ACEA_PARC_2014_v4.pdf

ACEA. (2016, May 9). *CO2 tax overview 2016.* Retrieved from http://www.acea.be/publications/article/overview-of-co2-based-motor-vehicle-taxes-in-the-eu

ACEA. (2017, March). *Euro Standards.* Retrieved from European automobile Manufacturers Association: http://www.acea.be/industry-topics/tag/category/euro-standards

Ahola, H., Carlsson, T., & Sterner, T. (2009). Is gasoline tax regressive. *Ekonomisk Debatt no 2*, 71-77.

Anspal, S., & Poltimäe, H. (2008). *Transpordi ühiskondlike kulude mudel. Metoodika ja arvutuste tulemused.* Tallinn.

Atkinson, A. B. (1970). On the Measurement of Inequality. *Journal of Economic Theory, 2*, 244 - 263.

Bandersnatch, S. (2011, February 28). *Negative externality*. Retrieved from https://en.wikipedia.org/wiki/Externality#/media/File:Negative_externality.svg

Baumol, W., & Oates, W. (1995). *The Theory of environmental policy. 2nd edition.* Cambridge: Cambridge University Press.

Becker, N., Rosenthal, G., & Gabay, D. (2012). *Calculation of the external costs of air pollution from transportation and industry in Israel, final report.* Ministry of Environmental Protection of Israel.

Belastingdienst. (2017). Retrieved from Tax and Customs Administration of Netherlands: https://www.belastingdienst.nl/rekenhulpen/motorrijtuigenbelasting/

Bork, C. (2006). Distributional effects of ecological tax reform in Germany: evaluation with microsimulation model. In Y. Serret, & N. Johnstone, *The Distributional Effects of Environmental Policy* (pp. 139 - 168). OECD & Edward Elgar.

Bovenberg, A., & Mooij, R. (1994). Environmental Levies and Distortionary Taxation. *The American Economic Review, 94, 4*, pp. 1085-1089.

Bureau, B. (2011). Distributional effects of a carbon tax on car fuels in France. *Energy Economics, Elsevier 33 (1),* 121-130.

Calthrop, E., & Proost, S. (1998). Road Transport Externalities. Interaction between Theory and Empirical Research. *Environmental and Resource Economics 11*, 335 - 348.

Common, M., & Stagl, S. (2005). *Ecological Economics. An Introduction.* Cambridge: Cambridge University Press.

Danish Minisry of Taxation. (2017). *tax.dk.* Retrieved from Registreringsafgift for nye og brugte motorkøretøjer: https://tax.dk/skat/registreringsafgift.htm

Department for Transport UK. (2016, July 7). *Vehicle Emissions Testing Programme. Policy report.* Retrieved from GOV.UK: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/548148/vehicle-emissions-testing-programme-web.pdf

Diekmann, A. (1991). Kosten en baten van de auto: Poging tot een juiste afweging. *Mobiliteitschrift*.

Dietz, R. (2012). *Negative Externalities are the Norm.* Retrieved from Center for the Advancement of Steady State Economy: https://www.steadystate.org/negative-externalities/

Dresner, S., & Ekins, P. (2006). Economic Instruments to Improve UK Home Energy Efficiency without Negative Social Impacts. *Fiscal Studies, Vol 27*, 47-74.

EEA (European Environment Agency). (2002). *Environmental Signals 2002. Benchmarking the millenium.* Luxembourg: Office for Official Publications of the European Communities.

Eesti Töötukassa. (2017). *Financial benefits.* Retrieved from Eesti Töötukassa: https://www.tootukassa.ee/eng/content/financial-benefits

EMTA. (2014, October 15). *2015. aasta maksumäärad ja maksuvaba tulu suurus.* Retrieved from Raamatupidamis- ja maksuportaal: http://www.rmp.ee/maksud/maksud_yldiselt/2015-aasta-maksumaarad-ja-maksuvaba-tulu-suurus-2014-10-15

European Commission. (2017, April 3). *Reducing CO2 emissions from passenger cars*. Retrieved from European Commission: Climate Action: https://ec.europa.eu/clima/policies/transport/vehicles/cars_en

European Federation for Transport and Environment AiSBL. (2014). *CO2 emissions from new cars in Europe: Country Ranking. How national car tax systems helped boost sales of lower-carbon cars across Europe in 2013.* Brussels: T&E.

Eurostat. (2016, February 7). Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_tax_statistics

Eurostat. (2016). *Gross disposable income*. Retrieved from Eurostat: http://ec.europa.eu/eurostat/web/products-datasets/-/teina090

EXTERNE. (2005). *Externalities of Energy. Methodology 2005 Update. Edited by Peter Bicket and Rainer Friedrich.* Luxemburg: European Communities.

Farris, F. A. (2010). The Gini Index and Measures of Inequality. *Mathematical Association of America*.

Gastwirth, J. L. (1971). A General Definition of the Lorenz Curve . *Econometrica Vol 39, No. 6*, 1037-1039.

Gini, C. (1912). *Variability and Mutability.*

GOV.UK. (2016, October 3). Retrieved from UK vehicle tax rate tables: https://www.gov.uk/vehicle-tax-rate-tables

Green Tax Report. (2008). *"Report of the inter-ministerial comission for Green Taxation".*

Hamilton, K., & Cameron, G. (1994). Simulationg the Distributional Effects of a Canadian Carbon Tax. *Canadian Public Policy, Vol 20*, 385-399.

Haughton, J., & Khandker, S. R. (2009). *Handbook on Poverrty + Inequality.* Washington DC: The World Bank.

HEATCO. (2005). *Developing Harmonised European Approaches for Transport Costing and Project assessment. Deliverable 2 State-of-the-art in porject assessment*. Retrieved from http://heatco.ier.uni-stuttgart.de/hd2final.pdf

ICCT. (2014). *EU CO2 Emissions standards for passenger cars and light-commercial vehicles.* Brussels: INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION.

ICCT. (2014, October). *Real-world exhaust emissions from modern diesel cars.* Retrieved from The International Council of Clean Transport: http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars

ICCT. (2015). *European Vehicle Market Statistics. Pocketbook 2015/16.* Berlin: The International Council on Clean Transportation.

IMPACT. (2007). *Handbook on estimation of external cost in the transport sector. Internalisation Measures and Policies for All external Cost of Transport.* Delft, CE.

Jacobsen, H. K., Birr-Pedersen, K., & Wier, M. (2003). Distributional Implications of Environmental Taxation in Denmark. *Fiscal Studies Vol 24*, 477 - 499.

Johansson, O., Pearce, D., Maddison, D., Calthrop, E., Litman, T., & Verhoef, E. (1996). *Blueprint 5: True Costs of Road Transprt.* Eathscan.

Jüssi, M., Anspal, S., & Kallaste, E. (2008). *Transpordi väliskulude hindamine: hindamismetoodika ja sisendandmete kaardistus. Uuringuraport Majandus- ja Kommunikatsiooniministeeriumile.* Tallinn.

Kakwani, N. (2010). The Lorenz Curve. In M. Blaug, & P. Lloyd, *Famous Figures and Diagrams in Economics* (pp. 432 - 438). Cheltenham: Edward Elgar Publishing Limited.

Korzhenevych, A., Dehnen, N., Bröcker, J., Holtkamp, M., Meier, H., Gibson, G., . . . Cox, V. (2014). *Update of the Handbook on External Costs of Transport.* Ricardo-AEA.

Kosonen, K. (2012). Regressivity of environmental taxation: myth or reality? In J. Milne, & M. Andersen, *Handbook of Research on Environmental Taxation.* Luxembourg: Cheltenham: Edward Elgar.

Labandeira, X., & Labeaga, J. (1999). Combining Input-Output Analysis and Microsimulation to Assess the Effects of Carbon Taxation on Spanish Households. *Fiscal Studies, Vol 20,* 305-320.

Leinert, S., Daly, H., Hyde, B., & Gallachoir, B. O. (2013). Co-benefits? Not always: Quantifying the negative effect of a CO2-reducing car taxation policy on NOx emissions. *Energy Policy 63,* 1151-1159.

Loog, T., Lass, K., Villemi, M. V., Himanen, V., & Idstrom, T. (2002). *UNIfication of accounts and marginal costs for Transport Efficiency.*

Maibach, M., Schreyer, C., Sutter, D., van Essen, H., Boon, B., Smokers, R., . . . Bak, M. (2008). *Handbook on estimation of external cost in the transport sector. Produced within the study Internalisation Measuers and Policies for All external Cost of Transport (IMPACT).* Delft.

Majandus- ja kommunikatsiooniministeerium. (2013). *Transpordi arengukava 2014-2020.*

Majandus- ja Kommunikatsiooniministeerium. (2015). *Eesti energiamajanduse arengukava aastani 2030.* MKM.

Mayers, I., Ochelen, S., & Proost, S. (1996). The marginal externals costs of urban transport. *Transportation Research D 1 (2)*, 343-363.

Ministry of Environment. (2016, January 13). *Eesti autopargi ökonoomsus*. Retrieved from Keskkonnaministeerium: http://www.envir.ee/et/eesmargid-tegevused/kliima/energiamargis/eesti-autopargi-okonoomsus

Mirrlees, J., Adam, S., Besley, T., Blundell, R., Bond, S., Chote, R., . . . Poterba, J. (2011). *Tax by Design: the Mirrlees Review.* Oxford University Press.

Mishan, E. J. (1971). The postwar literature on externalities: AN interpretative essay. *J. Economic Literature 9*, 1-28.

Musgrave, R. A. (1959). *The Theory of Public Finance 160.*

OECD. (2005, July 5). *OECD Glossary of Statistical Terms*. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=6437

OECD. (2009). *The scope for CO2-based differentiation in motor vehicle taxes.* London: ENV/EPOC/WPNEP/T(2009)1/FINAL.

OECD. (2010). *Taxation, Innovation and the Environment.*

OECD. (2015). Retrieved from OECD.Stat: http://stats.oecd.org/Index.aspx?DataSetCode=ENV_ENVPOLICY#

OECD. (2016). *Car Purchase Tax: Green Tax Reform in Israel.*

OECD. (2016). *Car Purchase Tax: Green Tax Reform in Israel. Working Paper.*

OECD. (2016, July). *Israel's Green Tax on Cars.* Paris: OECD Publishing.

OECD Policies. (2017, March 13). *The OECD database on Policy Instruments for the Environment*. Retrieved from Taxbases - Tax Rates of Environmentally Related Taxes: http://www2.oecd.org/ecoinst/queries/Query_2.aspx?QryCtx=3

OECD Stat. (2017, April 5). *Income Distribution and Poverty*. Retrieved from OECD.STAT: http://stats.oecd.org/index.aspx?queryid=66670

Orru, H. (2008). *Välisõhu kvaliteedi mõju inimste tervisele Tartu, Kohtla-Järve, Narva ja Pärnu linnas. Peentest osakestest tuleneva mõju hindamine.* Tartu.

OSHA. (2016). Retrieved from Chemical Sampling Information. Nitrogen Dioxide: https://www.osha.gov/dts/chemicalsampling/data/CH_257400.html.

Padilla, E., & Serrano, A. (2006). Inequality in CO2 emissions across countries and its relationship with income inequality: A distributive approach. *Energy Policy 34*, 1762-1772.

Pigou, A. C. (1920). The Economics of Welfare. *Macmillian*.

Poltimäe, H. (2014). *The distributional and behavioural effects of Estonian environmental taxes.* Tartu: University of Tartu Press.

Pope, C. A., & Dockery, D. W. (1995). Health Effects of Fine Particulate Air Pollution: Lines that Connect. *Journal of the Air & Waste Management Association 56 (6)*, 709-742.

Ramsey, F. (1927). A Contribution to the Theory of Taxation. *The Economic Journal Vol. 37*, 47-61.

Reynolds, M., & Smolensky, E. (1977). Public Expenditures, Taxes, and the Distribution of Income: The United States, 1950, 1961, 1970. *Academic Press*.

Rietveld, P. (1989). Infrastructure and regional development: A survey of multiregional economic models. *The Annals of Regional Science*, *23*, 255-274.

RMP. (2011, January 1). *Raskeveokimaksu määrad.* Retrieved from Raamatupidamis- ja maksuinfoportaal: http://www.rmp.ee/maksud/raskeveokimaks/raskeveokimaksu-maarad-2011-01-01

Roshal, V., & Tovias, A. (2016). *Car purchase tax: green tax reform in Israel.* Paris: OECD.

Sandmo, A. (2008). Pigouvian taxes. In S. N. Durlauf, & L. E. Blume, *The New Palgrave Dictionary of Economics.* Palgrave Macmillan.

Sen, A., & Foster, J. (2003). On Economic Equality. *Ofxord University Press*.

Serret, Y., & Johnstone, N. (2006). Distributional effects of environmental policy: conclusions and policy implications. In Y. Serret, & N. Johnstone, *The Distributional Effects of Environmental Policy* (pp. 286-315). Cheltenham: Edward Elgar Publishing Inc.

Statistics Estonia. (2017). *First registrations of Vehicles.* Retrieved from Statistics Estonia Web : https://www.stat.ee/34665

Statistics Estonia. (2017, March 17). *Registered motor vehicles.* Retrieved from Statistical Database: http://pub.stat.ee/px-web.2001/I_Databas/Economy/34Transport/07Registered_motor_vehicles/07Registered_motor_vehicles.asp

Sterner, T. (2012). Introduction, Fuel Taxes, Climate and Tax Incidence. In T. Sterner, *Fuel Taxes and the Poor* (pp. 1-20). New York, London: RFF Press.

Sterner, T., Cao, J., Carlsson, E., & Robinson, E. (2012). Conclusions. In T. Sterner, *Fuel Taxes and the Poor* (pp. 309 - 332). New York: RFF Press.

Stiglitz, J. E. (1988). *Economics of Public Sector, 2nd ed.* New York: W.W. Norton & Company Inc.

Zahedi, S., & Cremades, L. V. (2012). Vehicle Taxes in EU Countries. How Fair is Their Calculation? *XVI Congreso Internacional de Ingeniería de Proyectos.* Valencia.

Tuuli, J. (2009). *Distributional effect of fuel and other environmental taxes.* Helsinki: VATT muistiot, Valtion taloudellinen tutkimuskeskus.

Verhoef, E. (1994). External effects and social costs of road transport. *Transpn. Res. A. Vol 28A, No 4*, 273-287.

WHO. (2003). *Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide.* Bonn.

Wier, M., Birr-Pedersen, K., Jacobsen, H. K., & Klok, J. (2005). Are CO2 taxes regressive? Evidence from Danish experience. *Ecological Economics, 52*, 239-251.

Williams, R. C. (2016). Environmental Taxation.

Yurko, A. V. (2008). From Consumer Incomes to Car Ages: How the Distribution of Income Affects the Distribution of Vehicle Vintages.

Annex 1

Table 8: Environmental and transportation tax revenues in OECD countries, 2014

	Environmental tax revenue, % of GDP	*Transport taxes, % of GDP*	*Transport taxes, % of total tax revenues*	*Transport taxes, % of environmental taxes*
Australia	1,91	0,66	..	34,5
Austria	2,88	1,35	3,15	36,0
Belgium	2,03	0,73	1,63	34,0
Canada	1,15	0,26	0,84	22,6
Chile	1,20	0,25	1,25	20,8
Czech Republic	2,65	0,43	1,29	6,5
Denmark	4,11	1,52	3,03	36,6
Estonia	2,56	0,06	0,20	2,1
Finland	2,88	0,92	2,10	31,2
France	1,97	0,29	0,64	13,9
Germany	1,94	0,33	0,90	16,3
Greece	2,77	0,65	1,81	20,1
Hungary	2,60	0,38	1,00	17,3
Iceland	2,00	0,62	1,60	0,31
Ireland	2,17	0,90	3,15	37,9
Israel	2,97	1,32	4,25	44,4
Italy	3,85	0,61	1,38	16,8
Japan	1,48	0,50	..	33,7
Korea	2,54	0,73	2,97	28,7
Luxembourg	2,00	0,14	0,37	7,1
Mexico	…	0,12	..	
Netherlands	3,35	1,02	..	29,4
New Zealand	1,35	0,61	1,89	45,1
Norway	2,12	0,92	2,35	42,6
Poland	..	..	..	8,0
Portugal	2,20	0,58	1,69	26,0
Slovak	1,73	0,20	0,65	11,6

Republic				
Slovenia	3,86	0,46	1,25	11,7
Spain	1,89	0,24	0,70	12,9
Sweden	2,21	0,43	1,01	19,4
Switzerland	1,76	0,84	3,11	41,6
Turkey	3,83	1,22	4,23	29,3
UK	2,32	0,58	1,81	24,2
United States	0,72	0,26	0,98	36,1
OECD Europe	2,49	0,55	1,49	22,1
OECD Total	1,61	0,43	1,39	26,2

Source: compiled by author based on (Eurostat, 2016) and (OECD Statistics, 2015)

Annex 2

Calculating external costs and COPERT

External cost model enables to calculate costs of transport within different locations (cities vs countryside) and means of transport (passenger cars, trucks, small vans (*väikekaubik*), busses, electric trains, trains, motorcycles). In some cases (e.g. air pollution, climate change) Estonian specific emission data is usable, in other cases (e.g. noise) OECD Handbook unit values were used.

Data, assumptions and calculations

Social costs in transport are calculated dependent on total mileage data and unit costs within means of transport. Depending whether passenger cars, busses or motorcycles are investigated, this data includes number of vehicles and average mileage in categories of engine type, engine capacity, euro standard and weight. For (electric-)trains mileage is calculated based on real timetables. Future mileage prognosis are based on TTÜ calculations or assumptions of mild or no growth (e.g. motorcycles, trams).

Climate change costs are found based on COPERT data for CO2, CH4 and N20 and mileage data. For trains/trolleys electric energy use data from AS Elektriraudtee is used, according CO2 calculated with EcoSense model in Stockholm Environment Institute. Diesel trains use vales from Handbook 2014, finding monetary costs is based on unit costs from same source. Since climate change is global external costs, no GDP or purchasing power adjustments were made.

For air pollution emissions, such adjustments are made. In addition to various emissions, wear of studded tyres and according road exhaustion resulting in PM10 emission is estimated based on (Aasestad, 2008). Cost for trains are calculated based on Handbook unit costs, for electric transport local and regional environmental costs are found with EcoSense.

External costs for noise are calculated based on Handbook 2014 unit costs, which are differentiated for day/night and countryside/city. Possible overestimation of countryside costs might occur due to low population density in Estonian countryside.

Congestion cost are calculated taking account only Tallinn and Tartu, which however are responsible for most Estonian traffic jams. Costs are calculated based on Stratum modelling, which describe total time cost of all vehicles dependent on traffic flows.

For accidents real data and risk values of accidents are used, assigning different values for different types of injuries.

For up- and downstream processes, soil and water contamination and additional costs in urban areas (time costs for soft traffic and pedestrians caused by traffic) Handbook unit values are used.

Annex 3

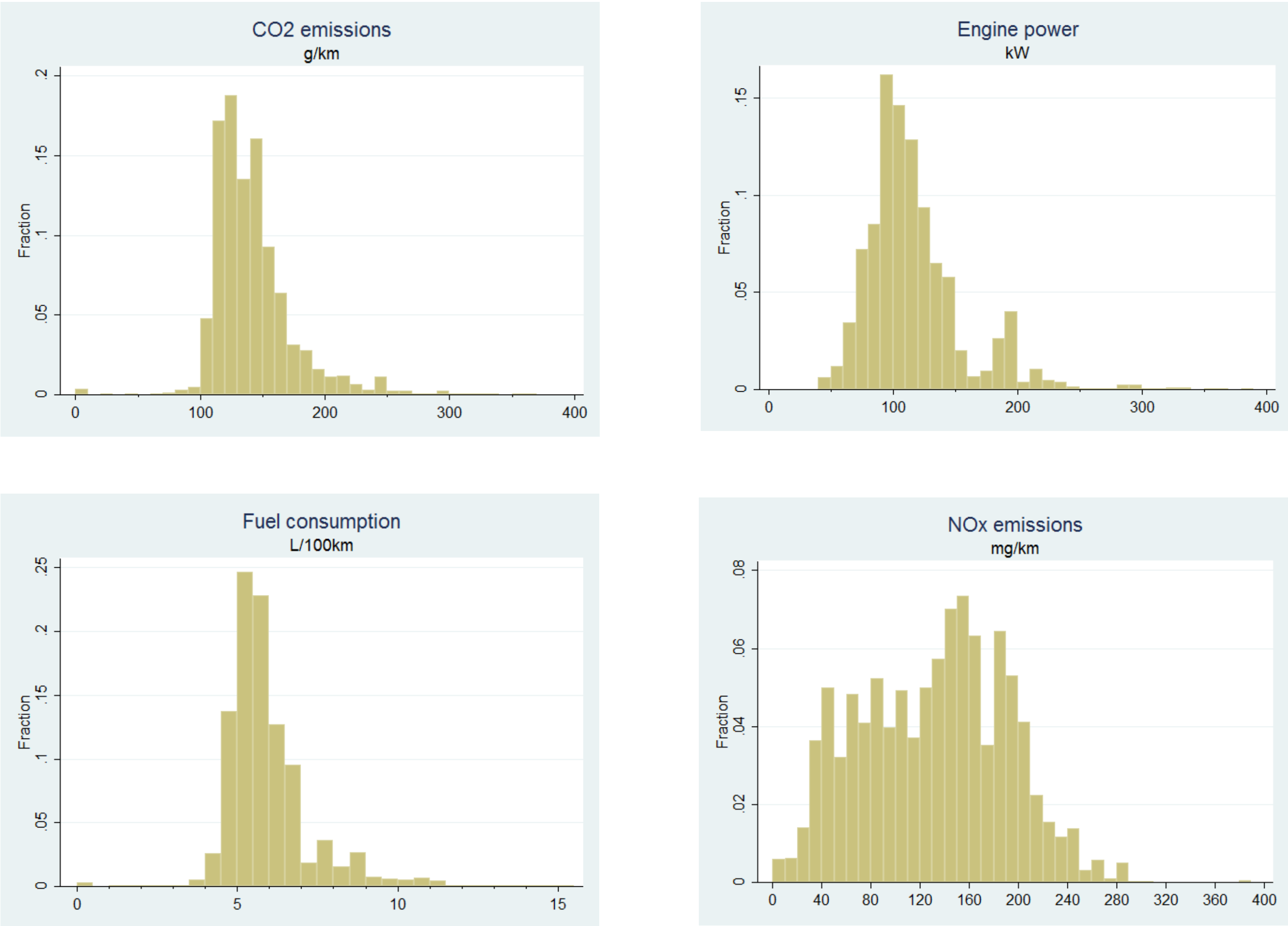


Figure 6: Vehicle park descriptive figures

Annex 4

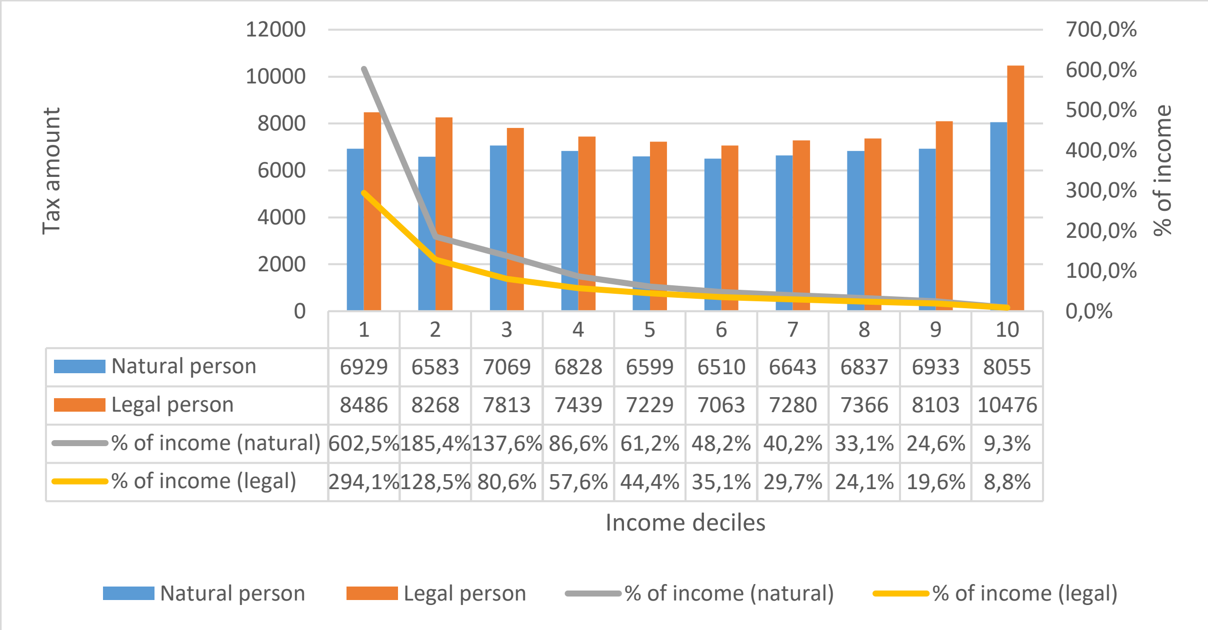
Table 9: Norwegian vehicle tax

Component	***Level of emissions***	***Tax rate***
CO2	<50 g/km	-4906.9 € - 126€*CO2(g/km)
	50 - 105 g/km	-96.4 € * CO2
	106 – 120 g/km	85.6€ * CO2
	121 – 160 g/km	1284.0 € + 95.9€ * CO2
	161 – 250 g/km	18423.1 € + 351.4€ * CO2
	>250 g/km	18423.1 € + 351.4€ * CO2
kW	<70 kW	0€
	70 – 100 kW	26.36€ per kW above 70
	101 – 140 kW	791.1€ + 84.9€ per kW above 100 kW
	>140 kW	3845€ + 210€ per kW above 140 kW
NOx	0+ mg/km	4.96€ * NO2 (mg/km)
Weight	<1150 kg	4.21 $ per kg
	1150 – 1400 kg	4839.2 € + 10.2€ per kg above 1150 kg
	1400 – 1500 kg	7132.9 € + 20.4€ per kg above 1400 kg
	>1500 kg	8968.0 € + 23.7€ per kg above 1500 kg

Source: Compiled based on (OECD Policies, 2017)

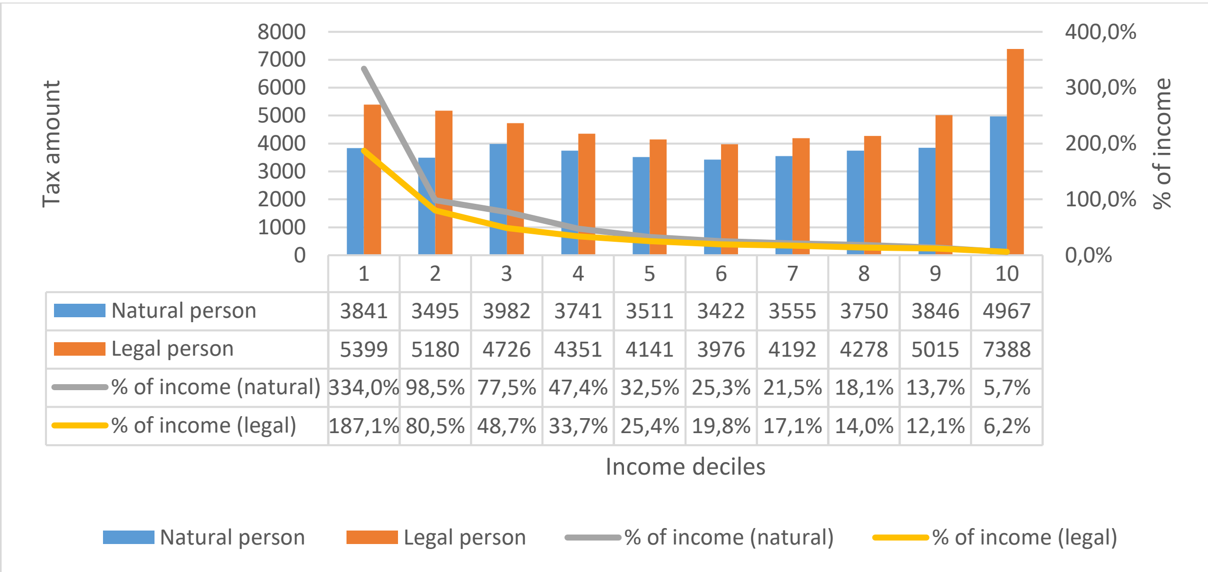
Annex 5

Table 10: Norwegean vehicle tax implemented to Estonia (weight included)



	1	2	3	4	5	6	7	8	9	10
Natural person	6929	6583	7069	6828	6599	6510	6643	6837	6933	8055
Legal person	8486	8268	7813	7439	7229	7063	7280	7366	8103	10476
% of income (natural)	602,5%	185,4%	137,6%	86,6%	61,2%	48,2%	40,2%	33,1%	24,6%	9,3%
% of income (legal)	294,1%	128,5%	80,6%	57,6%	44,4%	35,1%	29,7%	24,1%	19,6%	8,8%

Table 11: Norwegian vehicle tax implemented to Estonia (without weight)



	1	2	3	4	5	6	7	8	9	10
Natural person	3841	3495	3982	3741	3511	3422	3555	3750	3846	4967
Legal person	5399	5180	4726	4351	4141	3976	4192	4278	5015	7388
% of income (natural)	334,0%	98,5%	77,5%	47,4%	32,5%	25,3%	21,5%	18,1%	13,7%	5,7%
% of income (legal)	187,1%	80,5%	48,7%	33,7%	25,4%	19,8%	17,1%	14,0%	12,1%	6,2%

Annex 6

Table 12: Internalizing tax

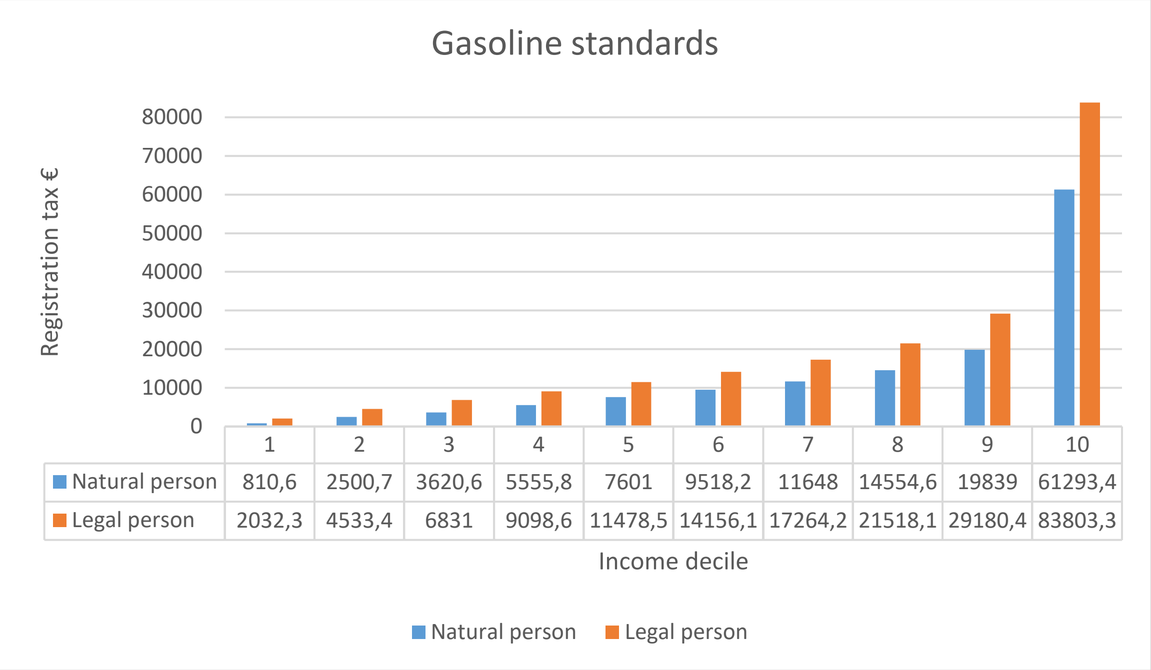
Component	*Level of emission*	*Tax rate €*
CO2	0 – 95 g/km	0
	96 – 130 g/km	150*CO2
	130+ g/km	5250 + 200*CO2
NO2	0 – 60 mg/km	1*NO2
	61 – 80 mg/km	2500
	81 – 150 mg/km	5000
	151 + mg/km	12500

Here CO2 level of 95 g/km is EU restriction after 2021, 130 g/km is target of 2015. NO2 limits are set by Euro standards.

To match 366 millions of passenger car transport, increasing constants of 15 and 20 in table above by tenfold would lead to tax steps of 0, 150*CO2 and 5250 + 200*CO2 totalling 229 mln euros with average carbon tax sum around 11200€. For NO2 emissions, using gasoline tax levels and taxing emission respectively at 0, 2500€, 5000€ and 12500€ for rest would lead to roughly 145 million net revenues with average sum of 7100€.

Hence, on average and on the basis on 20000 registrations, sum of just above 18000€ for registration would mean covering external costs of passenger cars. For natural persons highest sum would be paid by 10^{th} decile (19800€), lowest by 6^{th} (17175€) while Kakwani index of -0.54 confirms strong regressivity.

Annex 7



	1	2	3	4	5	6	7	8	9	10
Natural person	810,6	2500,7	3620,6	5555,8	7601	9518,2	11648	14554,6	19839	61293,4
Legal person	2032,3	4533,4	6831	9098,6	11478,5	14156,1	17264,2	21518,1	29180,4	83803,3

Figure 7: Distributionally flat tax internalizing external costs

Non-exclusive licence to reproduce thesis and make thesis public

I,

Kaupo Koppel,

1. herewith grant the University of Tartu a free permit (non-exclusive licence) to:

1.1. reproduce, for the purpose of preservation and making available to the public, including for addition to the DSpace digital archives until expiry of the term of validity of the copyright, and

1.2. make available to the public via the web environment of the University of Tartu, including via the DSpace digital archives until expiry of the term of validity of the copyright,

"Distributional Effects of Vehicle Tax In the Framework of Transportation Externalities", supervised by Helen Poltimäe.

2. I am aware of the fact that the author retains these rights.

3. I certify that granting the non-exclusive licence does not infringe the intellectual property rights or rights arising from the Personal Data Protection Act.

Tartu, 25.05.2017