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ASSESSING THE EFFECTIVENESS OF MARGINAL COST PRICING IN TRANSPORT - THE HELSINKI CASE

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Abstract: A geographic MEPLAN model based on the principles of economic behaviour was applied to study the marginal cost pricing approach for optimising the use of the transport system in the Helsinki region. As the model can estimate land use relocation the analysis emphasises the long-term impacts. According to the model calculations, marginal cost pricing can increase the overall socio-economic efficiency of the transport system especially by reducing urban sprawl. The welfare gain obtainable can be estimated at 168 - 216 Euros per capita per annum compared with the business-as-usual scenario for year 2020 depending on the optimality of the pricing in the road network. This amounts to 6 to 11 % of the total expenditure on travelling. The real-world model test results of an urban area support the conclusions of the marginal cost pricing theory originally developed in conceptual models.

Key words: marginal cost pricing, modelling, land use and transport interaction, urban sprawl, external costs, congestion

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Tiivistelmä: Taloustieteen periaatteille rakentuvalla liikenteen ja maankäytön vuorovaikutusmallilla tutkittiin, kuinka rajakustannusperiaatetta voitaisiin käyttää Helsingin seudun liikennejärjestelmän käytön optimoimiseen. Koska malli laskee politiikkojen aiheuttamat maankäytön muutokset, tutkimuksessa keskityttiin liikenne-järjestelmän aiheuttamiin pitkän aikavälin kustannusvaikutuksiin. Rajakustannus-hinnoittelu lisäsi liikennejärjestelmän tehokkuutta erityisesti estämällä kaupunkirakenteen hajautumista. Mallilaskelmien mukaan hyvinvointihyödyt verrattuna vuoden 2020 perusennusteeseen olivat 168 - 216 Euroa riippuen tieverkon hinnoittelun optimaalisuu-desta. Summa vastaa 6 - 11 % liikenteeseen käytetyistä tuloista. Tulokset tukevat talousteoreettisiin malleihin perustuvia rajakustannushinnoittelun johtopäätöksiä.

Asiasanat: rajakustannushinnoittelu, mallintaminen, liikenteen ja maankäytön vuorovaikutus, kaupunkirakenteen hajautuminen, ulkoiset kustannukset, ruuhka

Summary

Marginal cost pricing is seldom applied in practical transport policy making even though the theoretical concept is well-known and widely recognised as means to enhance economic efficiency. A multi-disciplinary project AFFORD led by the Government Institute for Economic Research in Finland (VATT) was commissioned by the European 4th Framework Programme to investigate this issue at urban level of transport.

The economic merits of marginal cost pricing have typically been illustrated within a simplified graphical and analytical framework. Many important questions concerning the geographical nature of the transport market and the interactions between various user and operator categories have been left unanswered. AFFORD has aimed to address this problem of missing information by using existing transport models of European cities in order to gain practical knowledge of the possible impacts on efficiency and equity. The goal was to consider how the policy making could be supported by applied models in relation to marginal cost pricing. The results have been documented in Deliverable 2a of the project. This paper reports the Helsinki case study in more detail.

The particular objective of the Helsinki case study was to examine with a geographic transport and land use model MEPLAN how the marginal cost pricing approach could be used to optimise the social welfare of the transport system in the Helsinki region. The model is based on the principles of economic behaviour. The following conclusions are gained in model tests of a complex geographical structure of the transport system and the other detailed spatial features of an urban area economy and land use.

The driving force in the model tests is consumer behaviour which is affected by changing prices in transport to reach a given goal. The goal is simplified here to be the socio-economic cost-benefit assessment of the transport policies. The transport users benefits are compared with the valued externalities in addition to direct costs of transport market. By default the users try to optimise their individual welfare using the knowledge of the prices and other characteristics of the transport system. The transport prices users pay do not reflect all of the marginal social costs (e.g. congestion and pollution the users cause to others) in the expected scenario. Therefore the optimised fares and prices based on the marginal social costs increase for the individual users in order to give them a reason to behave according to the common goals for the society. This way the society on the whole is more efficient although the transport users naturally feel this as a loss (as they would not otherwise change their behaviour).

The results are indicative of the type of the modelling and assessment issues that could be considered when the marginal cost based policy packages are developed. The special feature of the modelling framework applied here is the ability take into account the urban relocation due to changes in transport costs. When the prices are socially optimised the land use patterns concentrate, transport distances go down and large savings in resource costs and externalities will accrue. Thus, the largest impact that marginal cost pricing in transport could have in terms of land use relocation and its feedback to the transport demand is the reversal of the urban sprawl effect.

The results indicate that the theory of the marginal cost pricing originally developed within conceptual models can be applied in the real world. Implementation of the theory

would be an effective way to increase the overall socio-economic efficiency of the transport system in the Helsinki Metropolitan Area. According to the model tests the socio-economic welfare gains are 150 – 300 Euros per capita per annum. This is 6 to 11 % of the total expenditure on travelling and 0.6 to 1.1 % of the average total income.

As a direct impact transport users lose while government gains revenues from the optimal pricing policies when the marginal cost pricing policies are compared with the expected scenario. This lowers the acceptability of the approach and has traditionally rendered the policy politically difficult to implement. However, as the revenues to the government are larger than the overall losses to users it would be possible to redistribute the revenues and savings in a way that no-one would be less well off. The primary purpose of marginal cost pricing is not to increase revenue but to decrease the cost of inefficient use of the transport system. For example, the labour taxes could be lower so that employees would earn more from work rather than paying less for commuting. This nevertheless raises many more questions about the right handling of the equity issues, taxation policies and the connection other wider policies (e.g. full cost recovery) so that the redistribution could not be tested in this time frame within Helsinki case study although the issues are touched elsewhere in the AFFORD project.

The tests included various alternatives for transport pricing measures that could be implemented in practice (second-best policies) in addition to the ideally optimised road network that is only feasible in the model (first-best policy). Well designed second-best policies seem to be able to go a long way towards the benefits related to the ideal first-best. However, careful attention should be paid to examining the impacts of such second-best policies before they can be implemented. Unless the prices are spatially well planned e.g. according to the land use patterns they may be less efficient than simply socially optimised fuel price at least considering the urban point of view. This is likely to be possible with the more advanced charging systems that are emerging for example due to the developments in transport telematics.

According to the modelling results, socially optimal fuel prices are two to three times higher than the prices in the base forecast year 2020. This kind of development in prices may be publicly unacceptable that need to be taken into account before policy advice can be given. The base forecast includes various assumptions about growth, planned investments, prices and valuation of externalities that determine the optimal price. Hard measures was needed in the optimisation tests to offset the expected urban sprawl effect of the increasing GDP and new infrastructure investments. Urban sprawl results usually in congested city centre, pollution and excessive use of resources. Further investments in the bottlenecks to gain acceptability proved inefficient as the investment costs were higher than the benefits. The socio-economic score is defined by a socio-economic assessment that is in line with cost-benefit evaluation of infrastructure investments.

The conclusion of the study is favourable for marginal cost pricing as a policy tool. However, some detailed issues remain to be solved (e.g. valuation of externalities, assumptions in the base forecast and economic assessment of land use effects) before the impacts could be fully analysed with a comprehensive framework used in this exercise.

Contents

1 Introduction

Marginal social cost pricing applied in the transport market considers economic efficiency as the sole criterion of performance as opposed to broader social, political and engineering goals which have also other criterions. Economic efficiency can be maximised by providing optimal incentives to transport infrastructure users to change their behaviour (Milne et al. 2000). It has recently gained more interest in the Finnish transport policy research (Liikenneministeriö 1999) after already a substantial amount of investigation by the European policymaking (e.g. EC Green Paper 1995, EC White Paper 1998).

Although being theoretically well known and widely accepted as a condition to enhance economic efficiency the approach has been proved difficult to apply in practical policy making in the transport sector. A multi-disciplinary project AFFORD led by the Government Institute for Economic Research (VATT) in Finland was commissioned by the European 4th Framework Programme to investigate the operationalisation and implementation issues of marginal cost pricing. (Milne et al. 2000)

Deliverable 1 of the project looked into the issues of operationalisation i.e. how the gap between the theory and the practise could be shortened before it is ready to be decided upon and implemented. One of the major problems identified was the lack of information of the efficiency and equity impacts in actual complex urban situation (Milne et al. 2000). Thus the approach is unlikely to be accepted as a criterion for practical policy measures. Deliverable 2a building on the observations of the Deliverable 1 continued with the questions of implementation. It aimed to address the problem of missing information by making a realistic attempt to use existing transport models to gain practical experience of the likely impacts. This would enable AFFORD project to make suggestions how the policy making could be supported by applied models in relation to marginal cost pricing. (Fridstrøm et al. 2000)

This analysis is based on the modelling work reported in Deliverable 2a of the AFFORD project. A methodology to identify the relevant indicators for assessing the economic feasibility, efficiency and equity for overall performance of a range of marginal cost based pricing measures was developed and tested in Edinburgh, Oslo, Athens and Helsinki. The paper summarises the results of the Helsinki case city study using a geographical modelling application. First, chapter 2 provides the background and the objective for developing a marginal cost based policy tool. Chapter 3 describes the process to define and optimise various pricing policy packages for the Helsinki region. The results of land-use, transport and economic assessment using the framework developed in AFFORD are described in chapters 4 and 5. Lastly the conclusions are drawn and the scope for further research is considered.

2 Background and objectives

2.1 Current practice

Most of the economic merits of marginal cost pricing have been illustrated within simplified graphical and analytical framework. Many of the questions concerning the geographical nature of the transport market and the interactions between various user and operator categories have been left unanswered. (Milne et al. 2000)

A widely used methodology to support current transport policymaking especially by the transport engineering profession is to use applied computer models of the transport systems. They represent a real urban area usually with the geographical detail and where behavioural aspects of the modelled city have been taken into account of. The downside so far has been the lack of support for using the marginal cost principles in the modelling and assessment of policies. The emphasis has been on the traditional policy tools to cover the wider goals than just efficiency. Therefore a close integration of conceptual and applied modelling is needed; on the other hand to facilitate the applied models to enable the assessment marginal cost pricing policies and on the other hand to bridge the knowledge gap between the theory and practise in marginal cost approach. (Milne et al. 2000)

2.2 Defining pricing policy according to marginal costs

In the case of imperfectly functioning markets -- eg due to monopoly power, externalities, or when markets are completely lacking -- intervention by government is needed: the government has to create incentives to the firms to face effective marginal social cost prices and to behave optimally. This is a common situation in the transport markets. The intervention by the government can be accomplished either by means of direct regulation or administrative means or by means of financial measures which includes pricing. It is argued that cost accounting and average cost pricing is in this sector the most common approach which does not promote economic efficiency. Furthermore, the taxation is mainly determined by a general fiscal policy which only aims for the funding of the general societal needs. (Niskanen and Moilanen 1999)

The reason for applying marginal cost prices is how they affect consumer behaviour. At a private optimum each activity is extended to the level where the private cost of the last unit equals the private benefit. Analogously at a social optimum each activity has to be extended to the level where the social cost of the last unit equals the social benefit when the costs are rising and the benefits are falling. Under ideal competitive conditions the effective price faced by any economic agent i.e. consumer or firm equals the marginal social cost so that the agent will adjust his/her behaviour such that the condition for social optimum be satisfied. In competitive markets with profit-maximising firms this condition and the marginal cost pricing principle are satisfied due to the workings of the ”invisible hand.” (Niskanen and Moilanen 1999).

2.3 Helsinki case study objectives

MEPLAN is a geographic modelling system to study land use and transport interaction. It is largely based on the same principles of economic behaviour described above in the transport and land use markets (Echenique 1994). The framework has been applied by the Finnish authorities to Helsinki Region since 1992 (see e.g. Echenique et al. 1995, Liikenneministeriö et al. 1997).

The objective of the Helsinki case study was to examine with this application of a geographic model how the marginal cost pricing approach could be used to increase social welfare in the Helsinki region. The idea was to optimise the overall welfare function as defined by a standard cost-benefit framework of AFFORD including externalities and accidents as well as the time and monetary costs of the transport users and operators (see Fridstrøm et al. 2000). The policy tools to accomplish this goal were mainly the prices using the marginal cost pricing principles as explained above.

Being a part of a European wide research project the emphasis has been on the methodological issues rather than the completeness of the policy definitions or accuracy of the results. The research has nevertheless included realistic model tests and can show at a coarse level the type of effects when marginal cost pricing is applied to an urban environment. The project from the Finnish policy perspective can be seen as preparatory work for introducing marginal cost pricing in the policy toolbox.

3 The assessment process

3.1 Structure of the process

The assessment process has consisted of

(i) the calibrated model that estimates the physical and economic impacts of the pricing measures for the region;

(ii) the assessment framework that defines the cost components and user or operator categories that costs are calculated for;

(iii) definitions of the assessed pricing measures;

(iv) optimisation of the different measures and their combinations i.e. packages by modelling and using the assessment system; and

(v) comparative analysis of the different packages and the expected scenario.

The methodological phases (i) and (ii) briefly mentioned in the chapter 2.3 are not documented here (see instead Fridstrøm et al. 2000). Policy phases (iii) and (iv) are covered in this chapter and analysis phase (v) in the next chapters.

3.2 Theoretical first-best congestion cost pricing

The differentiation of the charging regime in the transport sector can concern various dimensions of behaviour as identified by Milne et al. (2000):

(i) driving style;

(ii) vehicle kilometres driven;

(iii) number of trips done (to accomplish the same amount of economic activity or kilometres);

(iv) time period i.e. according to time when the congestion happens;

(v) different parts of the network;

(vi) the chosen trip origin or destination;

(vii) the vehicle technology used;

(viii) the car ownership or fleet size; and

(ix) the location of the activities.

All of these different dimensions affect the efficiency of the transport sector in using scarce resources or causing externalities in different ways. Ideally the model used to analyse optimal structure of the charging system could cover and optimise all these dimensions in real-world accuracy and detail. However, as all models in practise, the Helsinki model is a simplification of the real world and cannot cover all of these dimensions especially lacking points (i) or (vii) and having insufficient behavioural presentation concerning points (iii) and (viii).

Ideally marginal cost pricing is implemented so that the transport users face all of the relevant costs in real time exactly where they are created in the network. Accordingly their behaviour is optimised for efficiency. This theoretically correct but difficult policy instrument in practice as it would require a pricing system for every stretch of the road network that would vary the price every hour is called 'first-best policy tool'. What can be done in practice is called the second-best package that uses existing or possible new instruments.

The term 'first-best' can refer to different markets and level of definition from peak hour route finding to whole multi-modal transport system with its interaction between other markets like land use and economic activity. The comparison carried out in this exercise between the first-best and second-best concern mainly the costs of congestion on the roads and externalities.

Congestion charges have been optimised in the first-best policy using the most detailed spatial disaggregation as possible in the model structure at an individual link level for each network assignment period. The charge is determined dynamically from the traffic flow using a special volume-cost functions that follow closely the principles of marginal cost pricing on each link separately. This directly optimise the route choice behaviour and indirectly the mode split and other behaviour.

Therefore the simplest first-best package optimises the congestion in the road networks using the marginal cost approach in an ideal way and optimises otherwise the efficiency in line with the second-best package. The congestion on every link is charged according to the real congestion costs and externalities are optimised by changing the vehicle operating costs and fares so that the social welfare according to the objective function is maximised by total cost savings, less time in traffic, and also revenues for public authorities and operators.

3.3 Practical second-best congestion cost pricing

Second-best charging policies define various spatially disaggregated charging systems. Geographical locations of tolls are based on the previous research on toll rings and distance based zonal congestion tolls e.g. in the Metropolitan Area Transport Plan 2020 land use impact study. The difference this time is the optimisation of the overall level of charging to make it 'second-best'.

Externalities have been derived in the assessment framework from the vehicle kilometres and charged with a fixed kilometre fee from person cars. Therefore the charge affects directly the vehicle operating cost in the similar way as fuel tax does as there is no spatial variance (e.g. by trip origins or destinations) present in the price per distance unit. Goods vehicles have not been charged in order to retain clarity in the results.

The second-best tools affect also the location of the activities in the geographic model and the overall social welfare calculated by the objective function. Thus the first-best policy has to include the same distance based policy tools as the second-best and they must be optimised the same way too to retain definitional consistency between first-best and second-best.

3.4 Shadow price of public funds as an efficiency measure

The time savings during the transport are a true resource benefit whereas the road user charges are only a transfer from private consumers to public operators or authorities. They do not constitute a social cost in the relevant economic sense. It may be argued that since public funds are a scarce resource the fact that road pricing provides revenue for the government adds to its efficiency rather than subtract from it. The amount by which a one Euro public revenue adds to the overall efficiency is given by the so-called shadow price of public funds (Fridstrøm et al. 2000). This may be a significant factor for the overall score of the policies and the optimisation of the charges. Although the precise value has not been determined for the Helsinki region the sensitivity of results to it has been tested by optimising and analysing the packages either assuming no value (i.e. zero) or a value of 0.25. In the latter case it is assumed that every Euro to public revenues adds 0.25 Euro in efficiency to the welfare function.

3.5 Optimisation of the individual measures

The level of each type of measure was optimised first individually. The policy tools tested to find the optimal real life (i.e. second-best) combination covered various tolls and charges (including parking) to maximise the social welfare. A series of tests were conducted to find the optimal set of measures to maximise the socio-economic evaluation. The policies were chosen from the set in consideration generally in AFFORD and which were straightforward to implement both with the model and to assess with the used evaluation framework. The measures were as follows:

(i) the level of public transport fares;

(ii) parking charges;

(iii) fuel tax for private cars;

(iv) city centre two-way cordon charges;

(v) outer ring two-way cordon charges;

(vi) a combination of (iv) and (v);

(vii) zone- and distance-based congestion pricing;

(viii) an approximation of marginal social cost pricing in the route assignment for congestion and externalities; and

(ix) a change in road capacity by reducing bottlenecks.

The optimal level of change in fares in the Helsinki Metropolitan Area (which has a one-hour or monthly tickets) was –50 %. The fares were only changed for the (short distance urban) public transport. The previous tests with the model have shown that reducing the fares of the long distance public transport creates a strong decentralisation effect of the non-car owning households. This gives a low score in the socio-economic evaluation.

The optimal parking charge level was found to be three times the ones in the foreseen package. The optimal level for increase in the vehicle operation cost (fuel tax) was found to be 150 %. The various (optimal) road toll measures were compared against each other. The best one was chosen to be included as part of the second-best packages. The variations of tested tolls consisted of combinations of toll rings around the centre and zone based tolls in the whole Metropolitan Area. Distance based charges varied according to the distance from the centre. The “best” (zone and distance based) road toll type turned out to be the one considered also in the Metropolitan Area Transport Plan tests conducted earlier with the same model. The charge per kilometre increased in the proximity of the centre.

3.6 Optimisation of the policy packages

The optimal combination of the individual measures was then searched for. There are a few dimensions to the definition of the policy packages. The naming has followed these to be logical. The main division of the combined policies is according to the policy package definitions by Milne et al. (2000) into a first-best package, second-best packages and an acceptable package. The second-best packages have been furthermore divided into ‘after institutional reform’ and ‘before institutional reform’ according to the estimated needs for legal or administrative changes in the transport system.

Those measures that did not bring any enhancement to the socio-economic score of the combination i.e. parking charges were left out. This was due to the “correlation” of the measures with each other. Also the level of the distance based road toll was found much lower than tested as an individually measure. The optimal simple second-best package after institutional reform included (i) kilometre-based zonal peak congestion charging system, (ii) fuel tax and (iii) public transport fares. The effects of the other tested policy tools functionally overlapped with these and were not as efficient as the chosen tools.

Second-best package after institutional reform was created from the ‘before’ package simply by assuming that the road tolls were not possible with the current institutions as it needs new legislation. Also, as the modelled region includes many cities and rural areas the petrol tax can be looked at both urban and at inter-urban level.

The acceptable policy was modified from the suggested examples in Milne et al. (2000) with the knowledge of initial modelling results for second-best policies. The policy charge motorists by increasing fuel taxes by 0.125 Euro/litre and use the revenues so that one third is directed to tax recycling (i.e. left as a revenue for the government) and one third is invested in capacity expansion of known road traffic bottlenecks. The remaining one third is used to lower fares in public transport. The test was however not then re-defined because of the feed-back effects of the package itself e.g. in relation to traffic forming other bottlenecks.

4 Physical impacts

4.1 Land use effects

The geographic model used in Helsinki can be optimised to cover different settings including all modes and relocation of activities. The majority of effects in the model tests come from the externalities of urban sprawl that cause pollution, accidents and excess use of resources as can be seen in the following paragraphs. This is largely due to the growth of the region, increasing incomes and large supply of transport infrastructure resulting in better accessibility in the reference scenario. The population is expected to grow by one third during the forecast period 1990-2020.

The level of settings when using the marginal cost pricing (i.e. just congestion, with externalities and with multi-modality) affected the overall impact of the measure to the land use patterns (see the following figures). Therefore it seems important which markets are considered when the marginal cost pricing packages are planned.

The marginal cost curves applied in the assignment procedure has a very limited impact on the land use themselves (see figure 1) if the distance-based externalities and resource and operation costs are not charged. The relocation process just adjusts the geographical pattern of transport demand so that the congestion can be avoided.

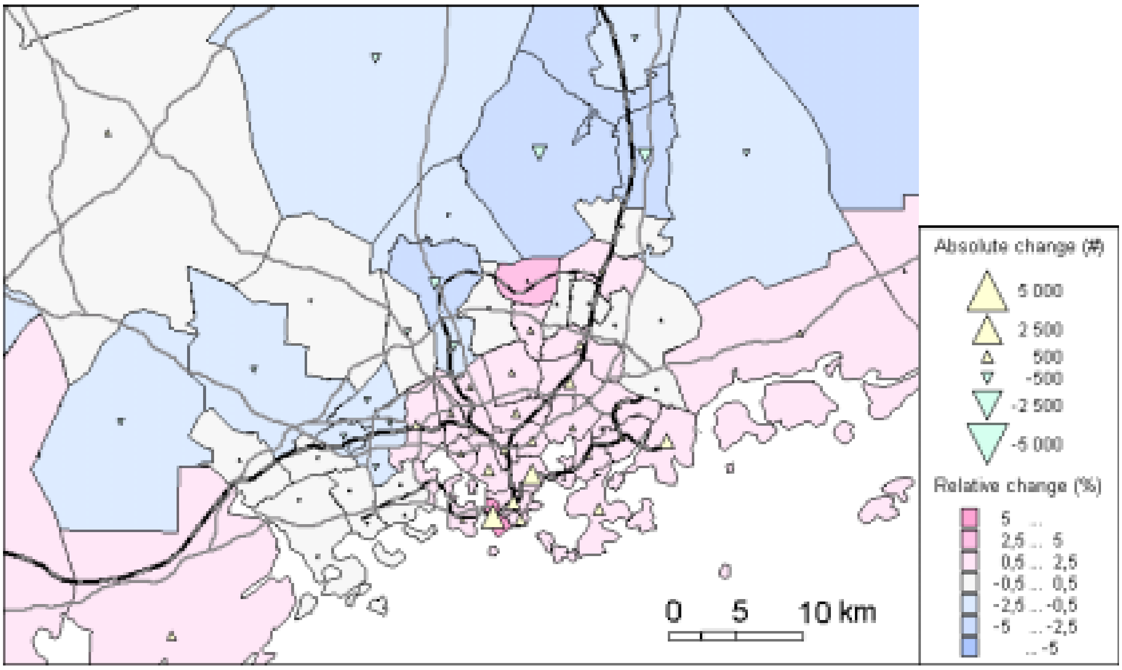

Figure 1: The land use relocation effect of inhabitants due to ideal marginal congestion cost curves without changes in other distance based charges. A sub-zone coloured blue indicates relative reduction of land use activities (with a green triangle pointing down to indicate the absolute figure). Accordingly a red sub-zone (with yellow triangle pointing up) shows an increase in the land use activity.

When the distance based charges are applied more changes in the land use pattern occur. The car-owning households begin to concentrate near the employment centres as the car travel costs increase. This drives the non car-owning households away from the congested land use in the city centres (see figure 2).

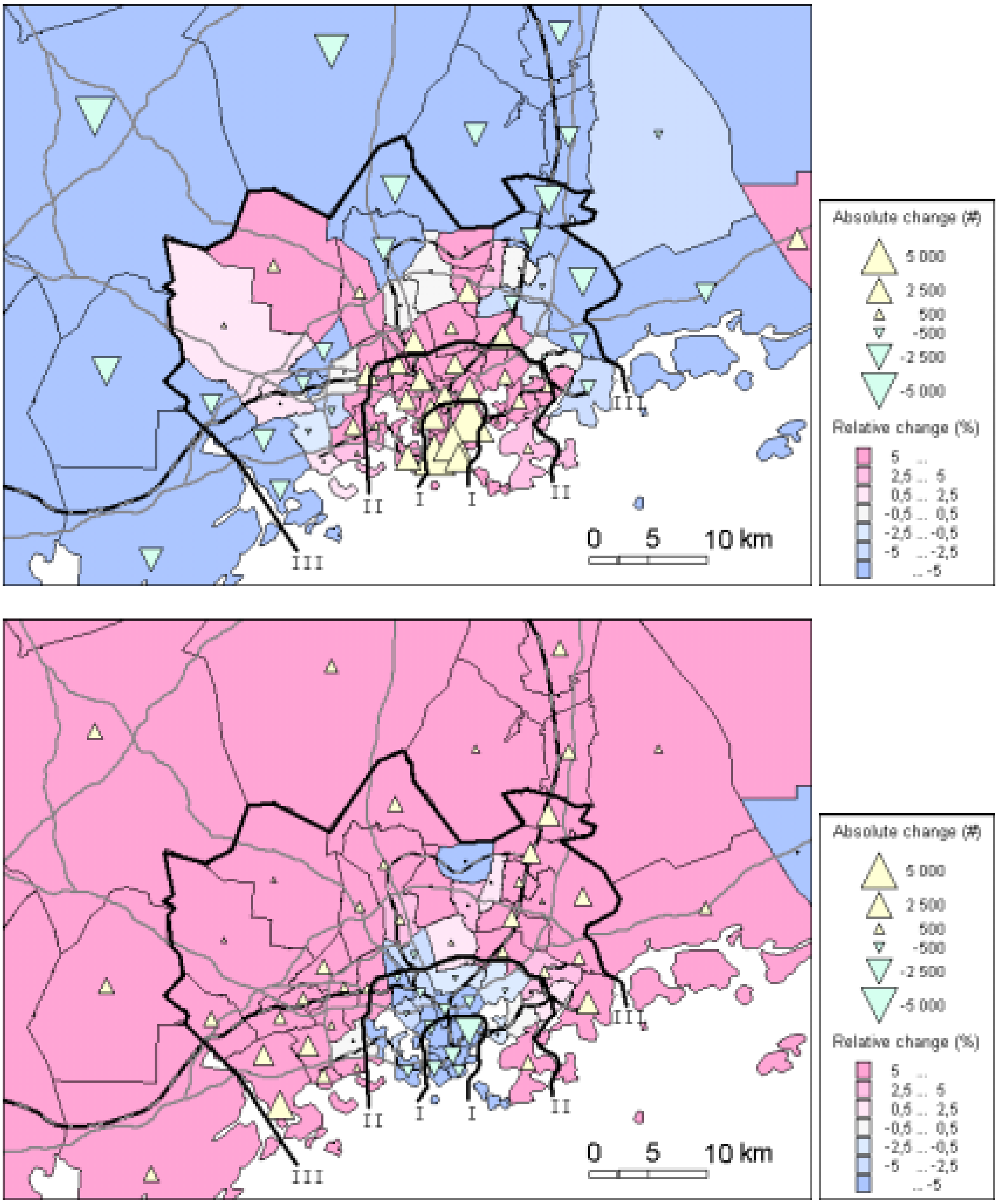

Figure 2: The land use relocation effect by car owning households (up) and non car owning households (down) when the travel costs increase due to petrol tax and a distance based zonal congestion tolls in the metropolitan area marked as concentric rings I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre is set up.

Overall the effect of the petrol tax and congestion charging is as figure 3 shows below. The population as a whole centralise towards city centre where the jobs are. The jobs de-centralise except from the central business district to reduce the work travel distances.

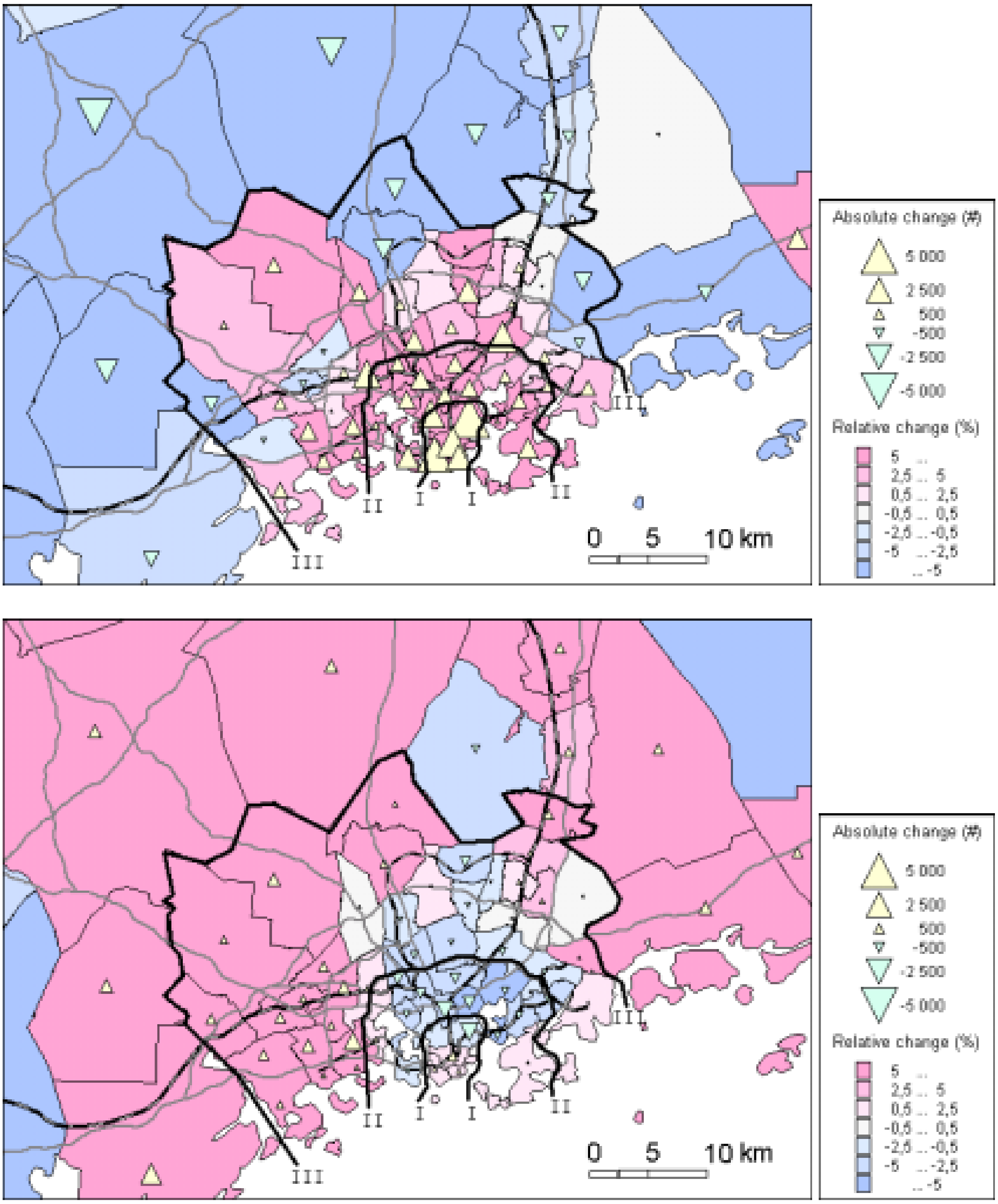

Figure 3: The land use relocation effect by inhabitants (up) and jobs (down) when the travel costs increase due to increase petrol tax and setting up a distance based zonal congestion tolls in the metropolitan area marked as concentric rings I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre.

When the public transport prices are optimised the benefits from reducing the fares come from the positive effects of the relocation process along the public transport corridors (see figure 4). The excess congestion in the land use in the metropolitan area seems to have negative effects on the provision of the urban public transport services. As seen in figure 2 the car owning households drive the non car-owning households away from the metropolitan area where the effective provision of the public transport is.

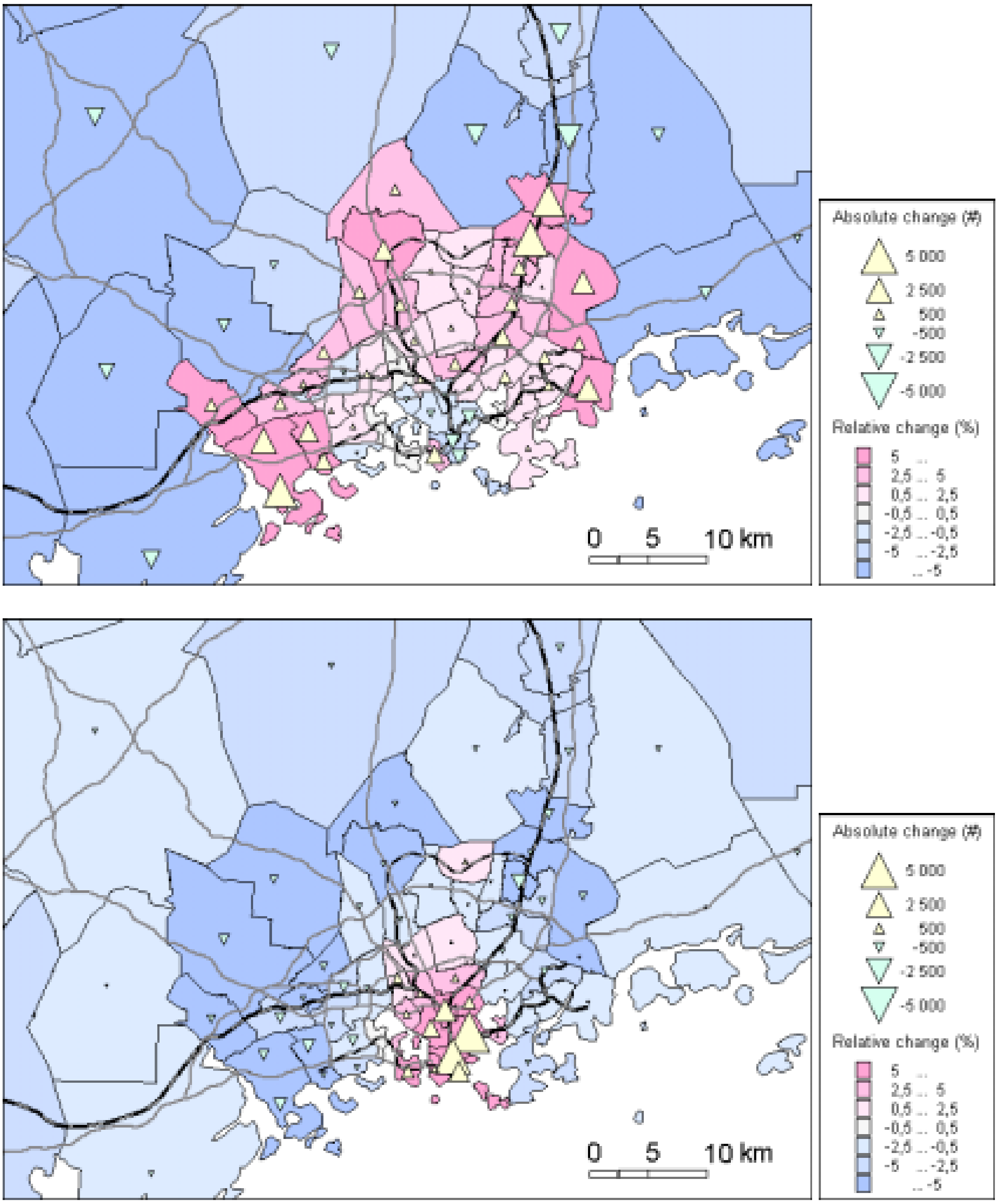

Figure 4: The land use relocation effect by inhabitants (up) and jobs (down) when the public transport fares decrease by 50 per cent in the metropolitan area. Note that the dark dotted lines present the rail services and the grey ones main roads in the area.

As seen in figure 5 the overall effect of the pricing package is a more balanced spread of inhabitants over the metropolitan area (within the outmost zone III) where the low-cost urban public service is located. Therefore the jobs concentrate also to the Helsinki centre which is supported by the geographic structure of the public transport system.

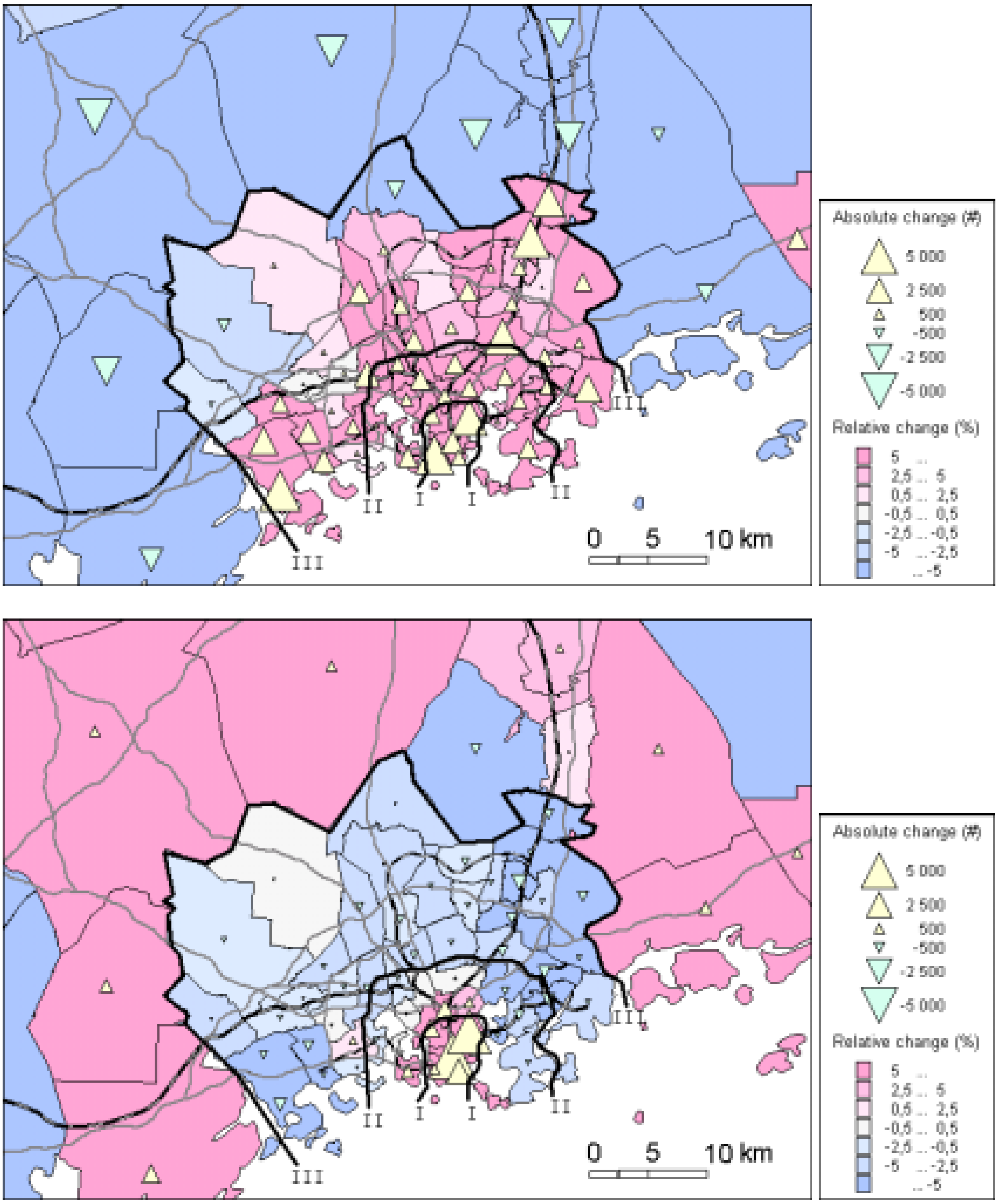

Figure 5: The land use relocation effect by inhabitants (up) and jobs (down) when the travel costs increase due to increase in petrol tax, setting up a distance based zonal congestion tolls in the metropolitan area marked as concentric rings I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre and a fare reduction of 50 per cent in the metropolitan area.

4.2 Travel demand effects

The foreseen package for year 2020 affects the level of the alternative packages with its assumptions. All the tests are derived from it and the comparison is done relative to it. The foreseen package is based on the Metropolitan Area Transport Plan which is a combination of a high growth scenario due to the strong migration and urbanisation happening in Finland. A substantial package of transport infrastructure investments for both road and public transport which are also supported by policies for dense land use patterns along the transport corridors has been planned to support the growth with investments.

The expected urban sprawl has been a reason for an increase in travel costs. Petrol price has been expected to rise 2 % per annum in line with yearly growth in GDP. Public transport fares rise annually 1.3 %. Nevertheless an urban sprawl effect remains in the expected scenario. The increase in incomes, insufficient availability of developable land for housing in the central areas and the large transport investment program has lengthened the average trip lengths by 10 %. The average time per trip has grown even more. The substantial increase in travel costs has not been enough to offset the other driving factors. There seems to be still a lot of room for savings in resource, accident and environmental costs by means of demand management.

As can be seen in figure 6 the increased prices on road and reductions on urban fares in public transport result in large shifts of mode towards public transport. The demand for different types of trips by households in the two model one-hour assignment periods is kept constant. This enables consistent assessment of user benefits in the transport sector by trip types. The elasticity of travel demand is reflected therefore as land use and mode changes. However, the overall reduction in the number of total trips comes from the fact that the observed amount of trips for a day as a whole is less for public transport users than for car users. What is notable in addition to the reduced car travel is that the amount of trips by slow modes reduce even more due to lower public transport fares. If both fuel prices and fares were raised, people would switch more towards biking and walking to avoid higher prices.

Figure 7 illustrates the impact of the correcting effect of pricing distance to the average speeds when no major congestion problems exists. As land use concentrates closer to city centres the street network with lower free flow speeds are used more which lowers the average speeds measured per trip. Also the average speed of public transport system is lower in the urban system than when long distances are travelled with less interchanges between vehicles. The average trips lengths are shown in figure 8. The trip lengths overall reduce on average to 80 per cent of the base case. The increase in car travel costs and reduction in public transport fares make users behave as expected according to the price elasticity in travel demand. This is also reflected to figure 9 where the resulting total mileage is shown.

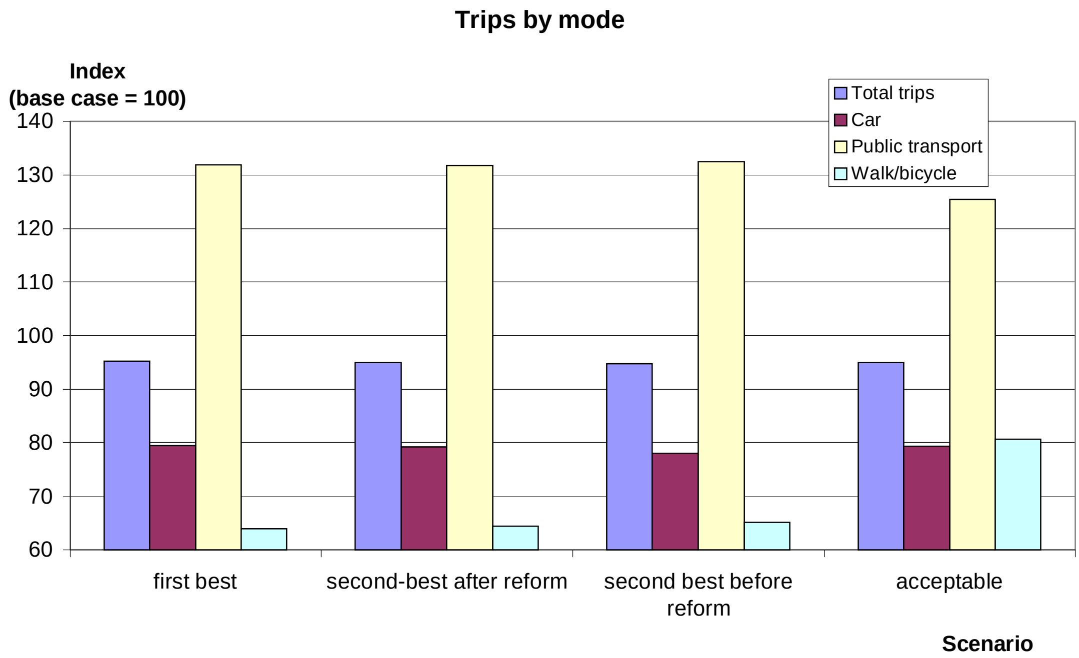

Figure 6: Trip frequencies by mode for Helsinki relative to base case.

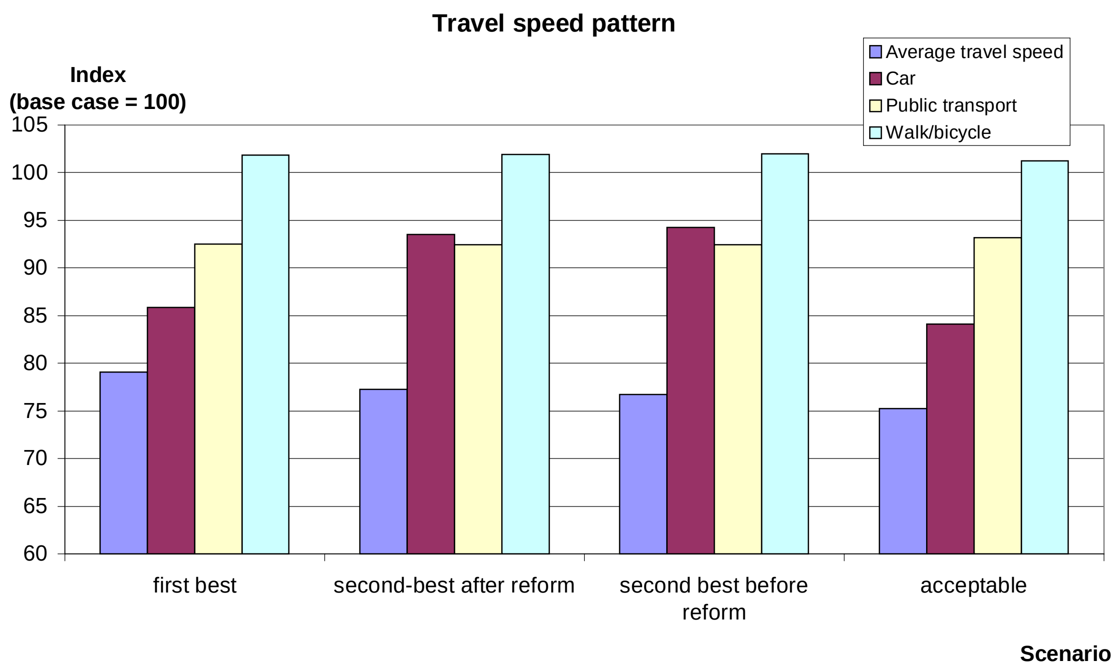

Figure 7: Mean travel speeds by mode relative to base case.

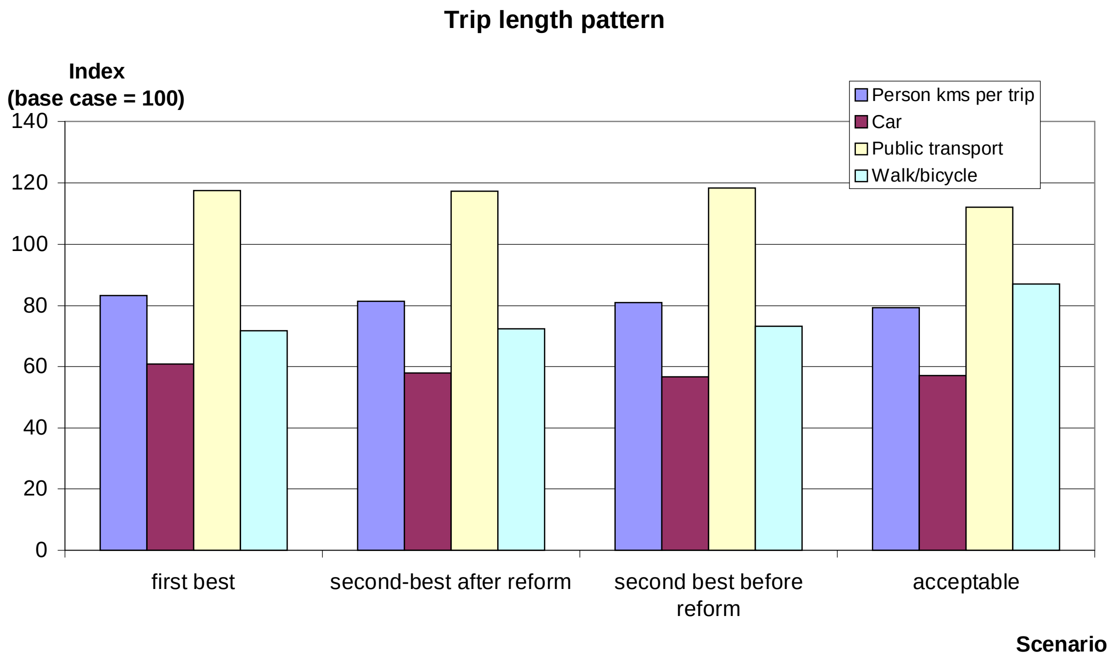

Figure 8: Trip lengths relative to base case.

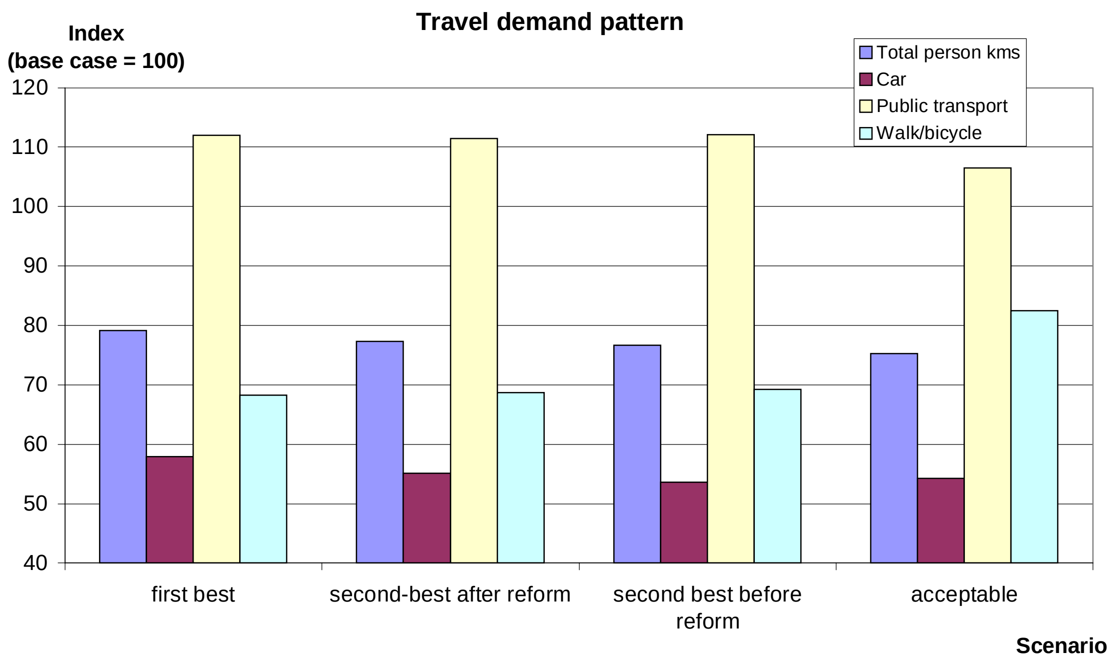

Figure 9: Travel demand patterns relative to base case.

5 Economic effects

5.1 Efficiency gains in the transport sector are possible

Marginal cost based pricing policies can increase efficiency in the transport sector. The welfare gain obtainable from the first-best marginal cost road pricing scheme as defined in chapter 2 has been calculated at 216 Euros per capita per annum. An assumption is made that the marginal cost of public funds is zero (meaning that alternative public revenue is raised without loss of efficiency throughout the economy). The benefits are discounted over a 30-year period including the environmental costs, resource costs and accident costs.

The reference year is 2020 when the average “perceived variable” real cost (including petrol price, parking and public transport fares) of travelling is 1160 Euros per capita per annum in the model reference scenario. The welfare gain is from 6 % to 11 % of the total expenditure on travelling. As total travel expenditure is roughly 10 % of the average income the welfare gain is on average from 0.6 % to 1.1 % of the average total income. Although the impact is not overwhelming for the GDP as a whole the impact would not be negligible. For a comparative example increasing annual GDP growth from 2 % to 2.5 % would result around 0.5 % increase in transport sector welfare gain relative to average salaries due to increased mobility tested with the same assessment system (Pesonen et al. 1999).

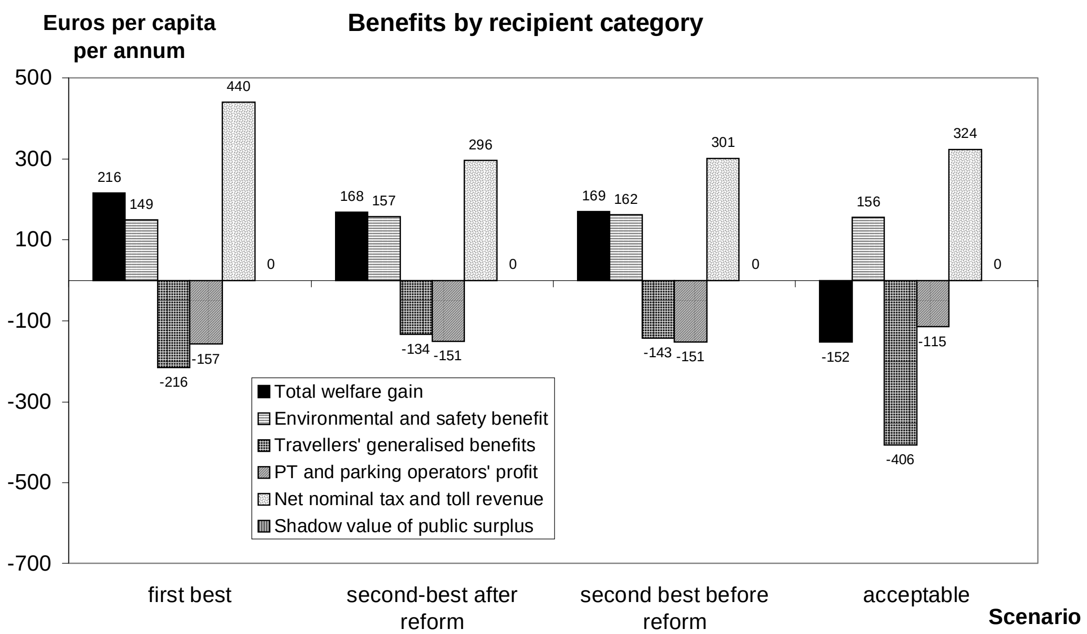

Figure 10: Assessment of the AFFORD policy packages using the geographic model of the Helsinki Region.

5.2 Urban sprawl overweighs congestion problems in the Region

Most of the net benefits would be gained from the savings in external costs (resource, accidents and environmental) as urban sprawl is avoided. Congestion is largely solved by the reference scenario that already includes major investments in the transport infrastructure despite of the problems of expected growth and increased mobility.

This result can lead to a (secondary) conclusion that there are probably over-investments in the transport infrastructure in the Metropolitan Area Transport Plan 2020. The coarse geographical resolution of the model may however affect this conclusion.

5.3 Second-best can go a long way towards optimal efficiency

The second-best solutions are able to gain 168 Euros per capita per annum or 78 per cent of the first-best package. Thus they seem to be able to enhance efficiency with much cruder measures. It must be kept in mind that the measure to avoid excessive distance-based externalities are effectively the same in the both first-best and second-best packages although optimised separately. Therefore difference between first-best and second-best concerns the gain of the ideal congestion charge in addition to the optimisation of the externalities.

Helsinki Region has relatively little problems of congestion compared with average European metropolitan areas. Comparing the first-best and second-best congestion charging done here it seems that there still are potential for savings in congestion costs. A secondary impact is that urban sprawl is handled first which inevitably gathers the economic activities closer to the city centre. This in turn creates higher densities of traffic there which needs proper attention.

5.4 New charging systems need to be spatially planned

Institutional reform was decided to introduce a distance based 4-zone congestion charging in the Metropolitan Area that requires new legislation. The 'before' package was then that the price of petrol would be used instead for altering the distance based costs. Before institutional reform the measure covered the whole area and no regional variation was possible (whereas the first-best policy has a varying price for each section of the road network being a highly spatially disaggregate measure). After the institutional reform the distance-based charge was separated between central business district, inner suburbs, outer suburbs and the region outside the Metropolitan Area but the charging was only used in the peak hour.

It would appear from the results that petrol price is enough as a policy measure and no special arrangements are needed to vary the prices. This conclusion is true only up to a certain point. Both second-best packages had non-optimal features compared with the first-best package. However, the policy package after institutional reform could have been enhanced in several ways whereas the petrol price policy is more or less fixed to its current level. The alternative measures for congestion pricing system was based on simple predefined spatial and temporal structures and not optimised whereas the level of charging was optimised using an iterative process. The zonal distance-based congestion charge did not make large impact after the high fuel tax was set. The fuel tax that covered the whole region (and for the full day) was more effective to reduce urban sprawl than the distance based congestion charge during the peak hour in the Metropolitan Area. This has a tendency to give competitive advantage to peripheral regions over Metropolitan area with higher costs for transport.

Also, as seen in figure 12 the averaged first-best charges proved to be higher in the off-peak period than in the peak period. This result is due to the higher proportion of urban freight traffic that was disturbed by the private cars concentrating in the city centre. Therefore the congestion charging should have been added for the off-peak period to enhance the second-best pricing system after institutional reform. Furthermore, no analysis of the possible problems in the rural areas due to remaining excessive investments have been done. Most of the concentration in land use would be by the migrating population and not by the population located already there in year 2000.

The way the congestion charging system is planned in spatial detail is important. It is also important to consider all possible impacts like off-peak period and freight traffic. The definition of the second-best policy after institutional reform can be seen here is an indication of the required level of spatial variation for peak hour pricing before it is as efficient as simply adjusting petrol price. The upper limit for gains by spatial detail is naturally the first-best package which includes an ideal spatial resolution on link-by-link basis separately for peak and off-peak.

5.5 Acceptability through investing may have efficiency problems

The test using ill defined policy to gain general acceptability by investing in bottlenecks on streets shows that the investments in the network infrastructure are highly spatial measures. The idea to clear existing bottlenecks was not effective as the policy was implemented in a crude way just increasing the capacity in those links that had high saturation level (more than 54 % of the capacity). This just created bottlenecks in other places as the increased capacity in some places attracted more demand on them. Therefore the further (especially rather random) investments in supply are unlikely to make the situation much better any more. Combined with the high user costs due to the fuel tax in addition to the investment costs the overall socio-economic score was bad.

It was decided not to go into deeper or iterative analysis of the spatial optimality of the crude congestion-based investment rule. The result was left intact to demonstrate the interesting fact that simple non-analysed promises to gain public acceptability by investing more are not necessarily cost-effective from the social welfare point of view. Again, this conclusion is largely undermined by the wealth of supply in the base scenario.

5.6 Equity can be handled by revenue surplus due improved efficiency

All of the optimised pricing policies leaves the users worse off on average as measured by the generalised utility when the overall social welfare is optimised. All of the first-best and second-best policy packages showed that as the overall efficiency was improved the loss in total user consumer surplus was less than the government revenues and operator savings. Therefore it would be possible to redistribute the revenues and savings in a way that no-one would be less well off as the theory suggests.

The negative result of the packages for the operators are due to the reduction in public transport fares that decrease revenue. This is however offset by the larger benefits to the users especially when the car travel has been made more expensive and the land use pattern becomes denser with more traffic on the road near the city centres. The share of public transport goes up and the land use concentrates to the public transport corridors. The modelling and assessment of public transport is less detailed than roads. Therefore this result of overall benefits of reducing fares by 50 % in transit should be checked before final conclusions. It must be also noted that the reference scenario had already increased the fares by 68 %. As including the consideration of the cost of funds increases the importance from generating revenues from the transport sector the optimal fare reduction is halved and the loss for operators reduces to one third.

5.7 Effects of shadow cost of public funds

The shadow price of public funds is included in the analysis as a sensitivity analysis as the issues concerning it are still under debate and precise value has not been determined for the Helsinki Region. The sensitivity of results to it has been tested by optimising and analysing the packages either assuming no value (i.e. zero) or a value of 0.25.

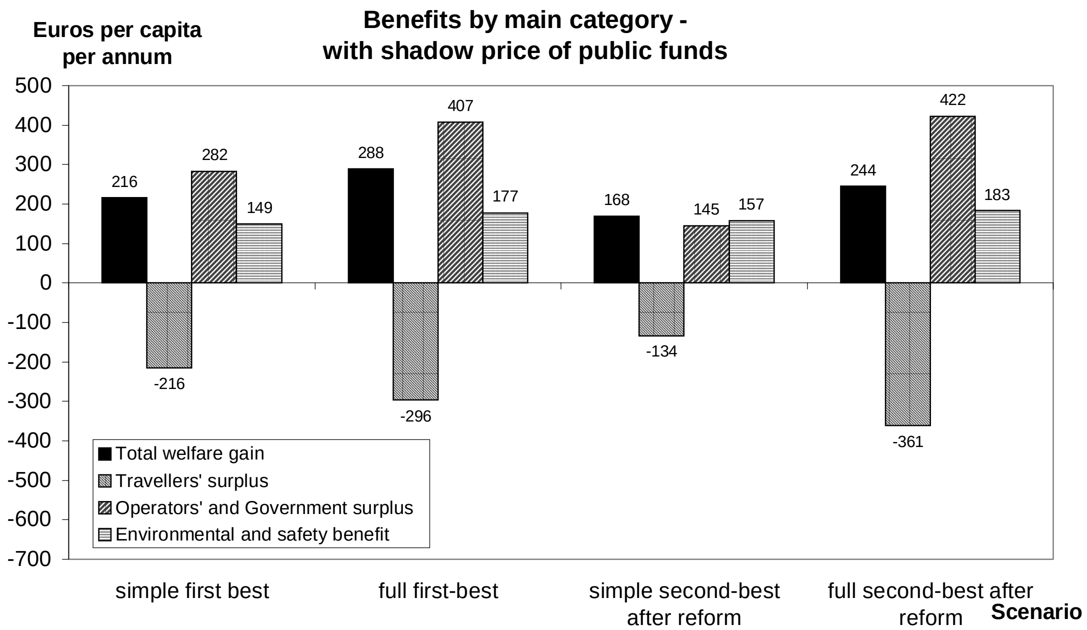

Figure 11: Sensitivity of the AFFORD policy packages to shadow price of public funds using the geographic model of the Helsinki region. "Full" refers to the inclusion of shadow price of public funds (0.25). "Simple" packages do not have shadow price of public funds.

The shadow price of public funds (0.25) applied did not have major impact (21 – 34 % of the overall gain) but affected the optimal prices substantially for the second-best policies in particular (see figure 12). The value of the shadow cost has not been determined to match Finnish conditions and the assessment is therefore only indicative.

In scenario including the assumption on the cost of funds, the second-best policy after institutional reform, increases welfare by 84 Euros per capita in annum and further benefits accrue from the externalities so that the total result is 244 Euros per capita per annum, up from 169 in the 'simple' case. The 'full' second-best case is 77 % of the 'full' first-best case (and should not be compared with the simple first-best).

5.8 Optimal prices

Fuel taxes were the most variant parameter after which the fuel price (including tax) was ranging from 215 to 325 % of the fuel price in the reference scenario (that has already increased it from 1990 level by 86 %). To offset the urban sprawl effect of the increasing GDP and infrastructure investments to mobility needs hard measures in the model to reach optimal efficiency and use of resources and externalities.

The details of the optimal policy tools can be seen in figure 12. The tested price levels are in a different level than in the calibration year 1988 when revealed traveller behaviour has been observed. It is not based on real information how travellers would behave when pricing would be in operation. The emphasis has been in this project to create the framework for analysis and to gain experiences on using model in operationalisation of the pricing policies and not to concentrate on the accuracy of the results. Therefore the resulted prices are only indicative and should be re-checked before policy conclusions.

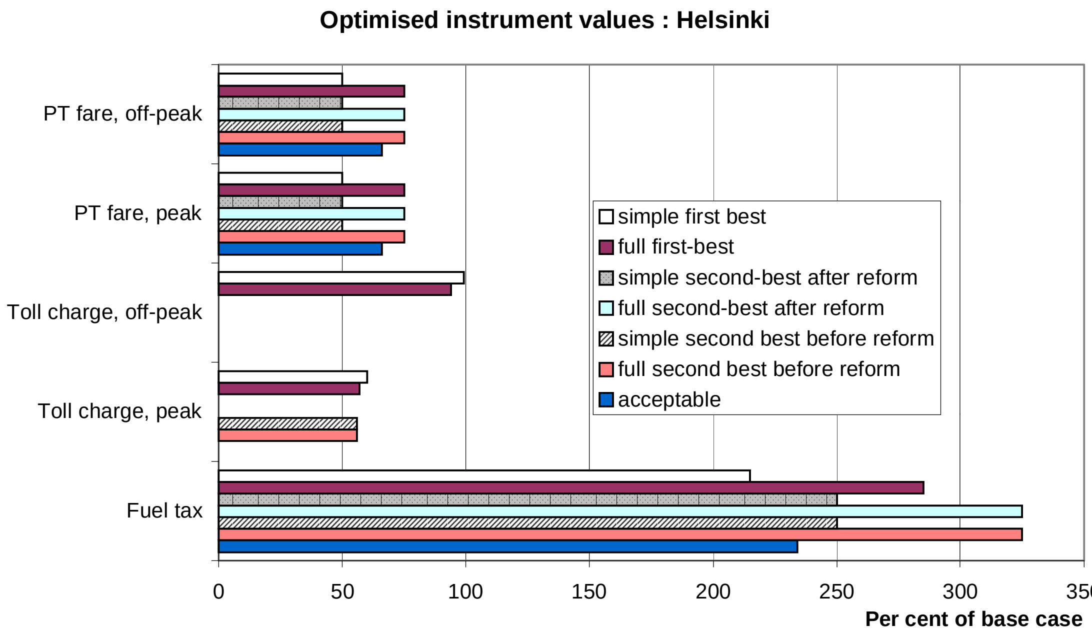

Figure 12: The level of optimised policy instruments in second- and third-best scenarios. "Full" refers to the inclusion of shadow price of public funds (0.25). "Simple" packages do not have shadow price of public funds. The averaged toll charge on links is relative to petrol price.

The optimised higher prices for off-peak (which is actually modelled as inter-peak i.e. day traffic) using the principles of marginal cost pricing for congestion link-by-link seems surprising but can be explained. The higher prices in transport drives the land use to concentrate to centre. However, in the off-peak period the goods traffic has a major share of the demand in the centre as majority of the jobs are there. Goods traffic is based on real costs e.g. wages of drivers and has high value of time and is disturbed by the increased off-peak traffic by person cars. The optimal tolls try to correct this resulting in higher tolls in the city centre for off-peak than for peak.

This phenomenon can explain why the flat rate of petrol tax turns out as effective as the 4-zone peak period kilometre-based system. The lack of congestion in the reference scenario elsewhere than in the city centre does not make a good justification of rough second-best peak-hour system although benefits can be gained especially when petrol price is not adjusted. This result is indicative of the importance of including the goods vehicles in the analysis and looking carefully at the spatial form of the charging system.

The modelling of the public transport services is based on the scheduling of various types of rail and bus services that have different headway and capacity issues in changing conditions of demand. Thus it was not considered possible to automatically optimise the level of services for public transport especially when the car demand was constantly changing due to the optimisation process of the pricing. The level of service was assumed constant (i.e. the generalised time remained constant) throughout the packages. The operation costs and the impact of fare revenues could be calculated roughly based on total hours. Therefore the resolution of the fare reductions was kept rather coarse changing from 50 % to 75 % of the prices in the reference scenario. This analysis however could not include the externalities from public transport into the analysis due to changes in demand.

The AFFORD project included also other pricing instruments that were not included in the packages e.g. vehicle taxes and parking charges. Although analysed individually, they were left out because of various technical issues or the similarities between the instruments in their economic effects. These various issues left open at this stage suggest that more work should be done to enhance the model and the policies before the optimally performing policy package can be found. Although the basic impact of the marginal cost based policies is clear and effective various details change different aspects of the results considerably.

6 Methodological issues

6.1 Assessment framework

The methodology is based on economic theory and therefore the implementation of the testing of the transport pricing policies is straightforward. The economic assessment in the transport sector is possible assuming that the changes in prices are fully fed back to the demand of transport. However, the level of generality in the setting and the structure of the model and the functional forms of the equations make the evaluation and analysis of the results somewhat complicated and laborious. Some more research is also required in the analysis of the welfare impacts of the policies using the household expenditure functions and input-output structures where the costs and benefits are fed back in a much more complex way than is the standard in the traditional cost-benefit (CBA) studies in the transport sector.

The possible congestion problems in the land use sector may remain as a problem if it is not used in the social welfare objective function. The traditional reason to leave land use costs out from the economic evaluation is the danger of double-counting. The framework for including it was not attempted here as no other models could model land use effects. More work should be done with the evaluation of the land use to investigate these effects. A proper investigation of the welfare effects of the relocation should nevertheless be done. This would enable to see second-term impacts of the transport on land values and overall production costs that could be missed looking only the feedback effect on transport demand due to transport pricing.

Equity assessment could not be done for different household groups with the current version of the model and the assessment framework. This was due to the fact that the travellers' utility and therefore benefits was modelled from the transport demand model by trip types and not by household groups in the land use location choice model. In this case the calculation of benefits needs to be developed in the land use model. If household equity impact analysis becomes an issue for policy process (in addition to examine the elasticity leaks to land use sector) the framework should be extended to cover the land use model utility chains. This is a controversial issue involving consideration of double counting among others but would be inevitably needed for more thorough analysis.

Some caution need to be taken also when a partial equilibrium model is used to estimate policy packages with large changes in prices or otherwise than those used to calibrate the model. As the resulting change of price differs significantly from the calibrated situation the question of the validity of the model calibration becomes a question. Whether the resulting reduction in mileage (to gain in resource and externality cost savings) can be actually possible is doubtful. The relocation process in the model is mainly based on transport accessibility (including intermediate consumption costs) and does not consider whole variety of issues in firm location. This kind of level in effect may be simply impossible in reality.

6.2 Modelling issues

The public transport model has been used in a coarse way and no special attention to the issues in the provision of public transport has not been done (e.g. Mohring effect or the pollution by the public transport) except for the rough calculation of the operation costs and subsidies. The average travel times has been assumed to be constant irrespective of demand. This would have required too much effort in this analysis.

The model still lacks a good presentation of car ownership as consumer good although a link between a location choice, transport accessibility and propensity to belong a household car ownership category exists. The other modelling work in the AFFORD project has shown that car ownership and use are inter-linked in a way that may cause rather complex consequences in results as car ownership put travellers in fundamentally different position when the mode choice is done. This however would need careful attention in the way the car ownership is modelled as part of the general consumption of the households. Also it should be examined how the welfare effects would then be calculated. The utility of owning the car would be part of the consumption function rather than transport demand function. This leads us back to the assessment issues.

6.3 More sensitivity analysis of the assumptions is needed

The optimality of the system seems to be highly dependent on the initial spatial structure of the city. The expected scenario adopted from current plans in the area has not provided the best starting point to test marginal cost pricing solutions to ease up congestion and to internalise externalities in the Helsinki Region. The planned transport infrastructure generally is enough to supply all of the needed capacity to the planned demand. Therefore no major congestion exists and the benefits marginal cost pricing for congestion does not show up fully. The more important effects for the welfare evaluation comes in this case from the reductions in the urban sprawl and the corresponding problems. The effect of the assumptions in the base forecast was left for further work.

If the shadow price of public funds (SPPF) is included in the evaluation framework and in the policy optimisation procedure the pricing becomes more attractive. The optimal petrol price rises considerably. However, the real value of the SPPF in Finland should be studied more. The same applies to the handling of the externalities which are determined just by multiplying the relevant mileage by an average coefficient. In reality the costs of externalities depend on the location and type of the road in addition to the vehicle types, congestion and resulting speeds.

6.4 Definitions of the policies

It is clear that various alternatives to the policies tested here still exist that could not be tested in this time frame. The second-best policies appeared to be the same before and after the institutional reform concerning the economic efficiency. The equal welfare gains were mainly due to their similar effectiveness to resolve excessive costs of urban sprawl. Both seemed to have non-optimal features compared with the first-best policy that could be resolved by further adjustments the packages. Therefore the results are still inconclusive concerning the need for institutional reform in road pricing.

The ‘acceptable’ policy failed altogether due to lack of spatial network analysis and was therefore not a good presentation of the optimal ability of the infrastructure planning to enhance the traffic conditions.

Although the conclusions from the analysis are favourable to marginal cost pricing as a policy tool some detailed issues remain to be solved in modelling before the impacts of various implementation could be thoroughly and accurately analysed with a comprehensive framework as used in this exercise. The current results nevertheless show what could happen in the urban structure due to the pricing policies and this also reflects the problems that might not be taken into account in reality in the traditional approach of the transport cost-benefit analysis.

7 Conclusions

The model results are indicative of the type of the relevant modelling and assessment issues that could be considered when the marginal cost based policy packages are operationalised. The pricing test results gained in this exercise seem to be internally logical and consistent. No instability of the model has been found during the tests. For operationalisation the main conclusion is that the development and implementation of the policy package details must be considered and analysed thoroughly before the most successful pricing packages are found and properly justified. This concerns especially the assumptions and spatial aspects of the packages. The following detailed findings vis-à-vis questions identified in Milne et al. (2000) can also be noted:

(i) The Helsinki case shows that applying a long run model (as a land use model with a forecast period in 2020 naturally is) to a policy primarily defined in a short run setting does not change the conclusions drawn in the short run analysis as expected by the theory (see Milne et al. 2000 page vi).

(ii) The right level of settings in the analysis seem to matter. The fundamental question may not be whether marginal cost pricing should be applied but what the impacts are and how big they are. If the changes in prices are large the leaks of the effects to other settings become imminent.

(iii) Various cost and user categories can be modelled and derived but require careful attention if accuracy of the results or the level of prices are vital to acceptability or policy making. This exercise used only simple functional forms for calculating the externalities and did not look in detail of the possible feedback effects.

(iv) Policy packaging seems to efficient way to enhance the efficiency of second-best policies (see below).

(v) When the petrol tax is considered as a means to solve urban problems the inter-urban and rural issues need to be considered also. The strong migration from rural areas closer to urban centres may leave the problem of inefficient use of existing infrastructure in the rural areas.

A summary of conclusions gained from the test results follows. It must be noted that these tests still present only a subset of possible alternatives for second-best pricing policy packages not thoroughly analysed in this exercise. Therefore the accuracy of the figures may not be sufficient enough to draw final conclusions of the right level of prices etc. in the Helsinki Region.

The Helsinki case city tests suggest that the marginal cost pricing implemented closely according to its principles is an effective way to increase the overall socio-economic efficiency of the transport system in the Helsinki Metropolitan Area. The model is designed to follow the same economic principles that are also behind the marginal cost pricing theory and therefore the result is more or less as expected. Nevertheless it has been shown that the marginal cost pricing theory originally developed in the conceptual world is applicable in the complex geographical structure of the transport system. Assessing the economic impacts and the other detailed physical impacts of an urban area modelled has been possible in a more realistic scene and the conclusions are in line with the theoretical ones.

Optimal fuel prices seem to be two to three times higher than the assumed prices in year 2020 (rising in line with the GDP since 1995 according to the definitions of Metropolitan Area Transport Plan modelling work). This may be a worry for the public and political acceptance when major changes are difficult to tolerate although the marginal cost pricing theory emphasises the efficiency gains as a primary goal. These prices have been optimised using the official valuations of the costs of the externalities. What also matters is how the model is calibrated to match the elasticity of the travellers to reduce demand when the price is increased. It may be too early to conclude that these prices would be optimal in reality too. The research project was concentrated in setting up the optimisation and assessment system overall and not so much on the accuracy of the various definitions. The determination of an efficient price would however not pose a difficulty in practise as the prices could be optimised even after implementation when real information on elasticity would be gained.

A major factor for acceptability in addition to efficiency is the equity impacts i.e. how the benefits are spread amongst the various groups affected. The users loose while government gains more revenues in the tests due to higher prices as they do not reflect all of the marginal social costs in the base forecast. A drawback of the economic assessment of the Helsinki tests was the lack of separation between the socio-economic or income groups. What can be said however is that as the revenues to the government are larger than the overall losses to users it would be possible to redistribute the revenues and savings in a way that no-one would be less well off as the theory suggests.

When general distance based pricing tools e.g. petrol tax are applied the land use patterns concentrate, transport distances go down and large benefits are accrued from the distance based costs. Thus the largest impact that marginal cost pricing in transport could have in terms of the land use relocation and its feedback to the transport demand is the reversal of the urban sprawl effect. Urban sprawl happens largely due to the growth of the cities, increasing incomes and the falling commuting costs. Urban sprawl results usually in congestion, pollution and excessive use of resources.

Using marginal cost pricing only for internalising pure congestion costs do not necessarily affect the land use patterns substantially as trip re-routing and small variations in trip origins and destination may be sufficient to avoid congestion costs. However, if marginal cost pricing is used to internalise resource costs and externalities the natural outcome is that average travel distances fall which again results in large savings in total mileage, vehicle operating costs and externalities.

Another opportunity to gain social welfare is the concentration of land use along the public transport corridors where the scale effects of providing efficient rail services are possible. The combined optimisation of public transport fare and the marginal cost pricing had an effect on households to locate along the public transport corridors. The jobs had a strong centralisation effect. This made the average length and time shorter and public transport more attractive as a mode especially for work trips. The reduction in public transport fares in the Metropolitan Area (MA) complements the higher cost of private cars. It decentralises the population along the public transport corridors at the same time keeping the population within the MA. This tendency towards the fringes of the MA eases up the land use congestion in the centre created by the strong centralising effect of the road tolls and fuel taxes on the car owning households. Thus the multi-modal package approach seems to be effective from the relocation point of view.

The MEPLAN modelling framework employed in the Helsinki region is an example of a geographical model application. The special feature of the type of modelling methodology applied here is the ability take into account urban relocation due to changes in the transport costs which is often considered a drawback in the more traditional transport assessment. A comprehensive way to evaluate the changes in the transport sector has been used in this analysis. The methodology could be also enhanced to analyse combined packages involving also land use policies.

The effects of land use relocation could be in long term more fundamental than the change in pure transport mobility to trip demand. Previous studies have also shown that the effect of any individual policies are modest compared with the overall changes due to the urban sprawl in the foreseen scenario. Drastic measures may be needed to avoid the associated problems. Marginal cost pricing has proved an effective policy tool in the tests to prevent socially inefficient urban sprawl.

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