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ECONOMIC AND EQUITY EFFECTS OF MARGINAL COST PRICING IN TRANSPORT

Case studies from three European cities

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Foreword

Studies on infrastructure are one of the central themes in the research programme of VATT. The reason for this is obvious: investments in infrastructure are typically a responsibility of public sector. The discussions concerning costs and benefits of the infrastructure investments are in the core of public economics.

This study is a part of the larger EU financed project called AFFORD. This project is tackling the problems of urban transportation. In large cities all over in the world, as well as in Europe the increasing traffic creates problems of congestion and other environmental effects. These problems are often considered as some of the main urban problems by political decision makers, as this report clearly shows. In the project AFFORD the main research question is whether by introducing road pricing one could alleviate the problems created and improve the efficiency of the use of public funds. The project has been co-ordinated by VATT under the leadership of research director, Dr. Esko Niskanen. There are altogether eleven research European research institutes participating in this project.

In this paper costs and benefits of introducing marginal cost pricing for urban transportation have been examined in three European cities Edinburgh, Helsinki and Oslo. Specific and detailed models are used to analyse these three cases. Both efficiency and equity aspects are considered. Authors find that under appropriate conditions pricing schemes may improve the welfare of the urban population quite clearly. Results are interesting and bring novel aspects to the discussion how to improve the efficiency in the policy of urban transportation.

Helsinki, December 29, 2000

Reino Hjerppe

Director-General

Economic and Equity Effects of Marginal Cost Pricing in Transport

Case studies from three European cities

AFFORD

Deliverable 2A
December 2000

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Abstract: Marginal cost transport pricing – if implemented in European cities – may give rise to substantial welfare benefits for the urban populations. Depending on the local conditions and on the policy instruments used, annual welfare gains may typically amount to 100-400 euros per capita, as measured by the willingness-to-pay within the affected urban population. These welfare gains have been estimated by means of transport models applied to the cities of *Edinburgh*, *Helsinki*, and *Oslo*. Real-world instruments considered include cordon toll rates, parking charges, fuel tax, vehicle tax, distance based charges, and public transport fares and level-of-service. Not all of these instruments are currently available to local urban authorities – some belong at the national level of government. Thus the study distinguishes between second-best policies "under current institutions", and those which are practicable only "after institutional reform". In the latter variant, it is assumed that local authorities are allowed access to certain instruments that are not presently at their disposal, or that national authorities accept to tune the level of certain instruments so as to maximise the welfare of the *urban* population.

Key words: urban transport, marginal cost pricing, transport models, efficiency and equity

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Tiivistelmä: Rajakustannushinnoittelun käyttöönotolla saataisiin aikaan mittavia hyötyjä Euroopan kaupunkien väestölle. Vuosittaiset hyödyt olisivat paikallisista olosuhteista ja käytetyistä politiikkainstrumenteista riippuen 100-400 euroa asukasta kohden maksuhalukkuudella mitattuna. Nämä arviot on saatu liikennemallien sovelluksien tuloksena Edinburghissa, Helsingissä ja Oslossa. Käytännön instrumenteista tarkastelun kohteena ovat kehätullit, pysäköintimaksut, polttoaineverot, ajoneuvoverot, suoriteperusteiset maksut sekä julkisen liikenteen maksut ja palvelun taso. Kaikki nämä instrumentit eivät nykytilanteessa ole paikallisten viranomaisten käytettävissä – jotkut määrätään kansallisella tasolla. Tutkimuksessa tarkastellaan erikseen second best -politiikkoja "nykyisten instituutioiden vallitessa" ja "institutionaalisen reformin jälkeisessä tilanteessa". Jälkimmäisessä tapauksessa oletetaan, että paikallisen tason viranomaiset voivat käyttää instrumentteja, jotka nykytilanteessa eivät ole heidän kontrollissaan, tai että kansallisen tason viranomaiset kaupunkialueiden näkökulmasta optimaalisesti joustavat tiettyjen instrumenttien tasoa.

Asiasanat: kaupunkiliikenne, rajakustannushinnoittelu, liikennemallit, tehokkuus ja oikeudenmukaisuus

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Executive summary

Marginal cost transport pricing – if implemented in European cities – may give rise to substantial welfare benefits for the urban populations.

Depending on the local conditions and on the policy instruments used, annual welfare gains may typically amount to 100-400 Euros per capita, as measured by the willingness-to-pay within the affected urban population.

These welfare gains have been estimated by means of transport models applied to the cities of *Edinburgh*, *Helsinki*, and *Oslo*. While the transport situation as well as the modelling framework differ considerably between these cities, certain common features and patterns do emerge.

First-best and second-best policies

The AFFORD study distinguishes between "first-best" and "second-best" road pricing policy packages. These are referred to by the code names *P1* and *P2*, respectively, or *S1* and *S2* in the case where a non-zero shadow price of public funds is assumed (see Box 1).

Policy scenario	Shadow price of public funds	
	0	0.25
Reference case	*P0*	
Business-as-usual (present situation)	*P01*	
Foreseen strategy	*P02*	
First-best marginal cost pricing	*P1*	*S1*
Narrowly first-best	*P11*	*S11*
Broadly first-best	*P12*	*S12*
Second-best marginal cost pricing	*P2*	*S2*
Second-best under current institutions	*P21*	*S21*
Second-best after institutional reform	*P22*	*S22*
"Acceptable" pricing	*P3*	*S3*
Other, locally defined schemes	*P4*	*S4*

Box 1: Policy scenario code names

In the first-best solution, one imagines that each traveller is charged the true marginal cost of road use, as given by the level of congestion, environmental and accident costs – and of any other external or internal cost – generated by the marginal road user exactly *there* and *then*. This solution presupposes a very sophisticated, real-time revenue collection and information system, in which road user charges vary instantaneously in space and time, i.e. between all road links and for every single minute, depending on the current level of congestion etc.

This ideal road pricing scheme is, of course, only a theoretical construct, infeasible in practice (at least with the present state of technology and legislation). It can, however, be mimicked in a network simulation model, so that one may derive the theoretically optimal level of road user charges and their hypothetical effect on traveller behaviour. We use this theoretical first-best solution as a highly relevant benchmark case, against which the various feasible, second-best solutions – based on real-world policy instruments – can be judged.

Real-world instruments considered in the AFFORD project include cordon toll rates, parking charges, fuel tax, vehicle tax, distance based charges, and public transport fares and level-of-service.

Not all of these instruments are currently available to local urban authorities – some belong at the national level of government. Thus the AFFORD project distinguishes between second-best policies "under current institutions" (*P21, S21*), and those which are practicable only "after institutional reform" (*P22, S22*). In the latter variant, it is assumed that *local* authorities are allowed access to certain instruments that are not presently at their disposal, or that *national* authorities accept to tune the level of certain instruments so as to maximise the welfare of the *urban* population.

Enhanced economic efficiency

The welfare gain from road pricing generally arises as a sum – or difference – between various components. It may be fruitful to distinguish between three main institutional categories: (A) *consumers*, (B) *operators and authorities*, and (C) *overall public welfare* concerns. Under A, one considers travellers as well as non-travellers. Category B encompasses, in addition to the public revenue service, all operators of public transport services (whether or not they are publicly *owned*), as well as operators charged with enforcing parking regulations, cordon toll schemes, etc. The last category (C) encompasses *environmental* and *safety* effects, as well as general *allocative efficiency*, which may or may not be affected by road pricing or by other (alternative) forms of taxation.

The consumer welfare effect for private consumers results as the balance between monetary costs and time benefits. Most road pricing schemes entail a considerable increase in out-of-pocket expenditure for motorists who keep up their demand in the face of a higher unit cost. Other motorists may choose to reduce their demand; these suffer a consumer surplus conditioned by the difference between their willingness-to-pay in the initial situation and the (initial) generalised unit cost of travel.

On the other hand, certain time gains accrue to those travellers who remain on the road (or aboard public transport carriers), as delays are reduced due to diminished demand.

Certain aspects of the first-best solutions in the three cities are shown in Figure 1.

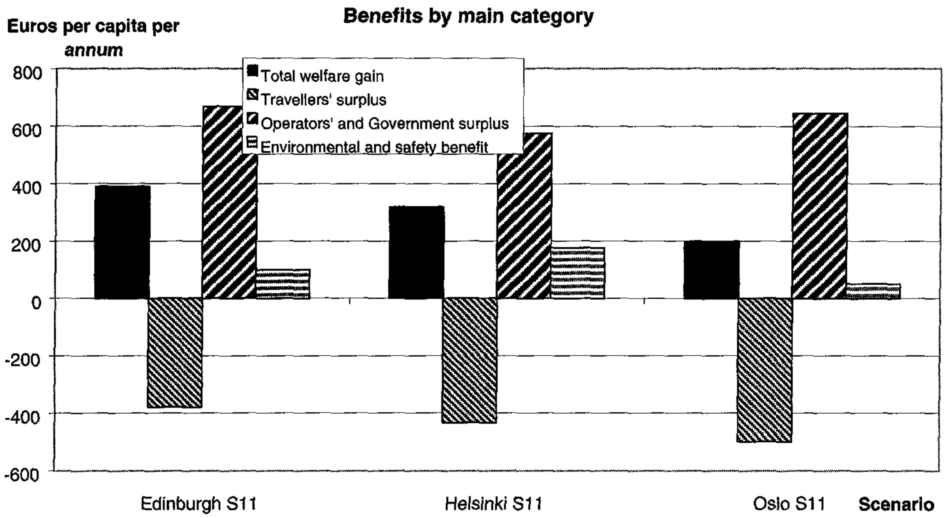

Figure 1: *First-best solutions in three cities, assuming a 0.25 shadow price of public funds.*

Model simulations suggest that the (narrowly) first-best solution (in which one disregards the costs of implementation) would lead to welfare gains of the order of 200 to 400 Euros per capita per annum, as reckoned over a 30-year period. In all cities, the first-best solution would (before revenue recycling) inflict a consumer deficit on the travellers, but provide a surplus for the operators and government, and, in addition, provide certain benefits in terms of environment, safety and (by assumption) general allocative efficiency (Figure 1).

In Figures 2 and 3, we show corresponding graphs for the best practice (optimised) second-best solutions before (*S21*) and after (*S22*) institutional reform, respectively.

The direction of effects is generally the same as in the first-best solution, but the overall welfare gain is considerably smaller, especially in the more restricted scenario "second-best under current institutions" (*S21*).

Most marginal cost pricing schemes seem to inevitably inflict a loss upon private travellers, as these are forced to pay for a service that was previously offered for free. True, as congestion is relieved, time savings accrue, however these savings are usually insufficient – as measured in terms of willingness-to-pay – to offset the monetary cost incurred.

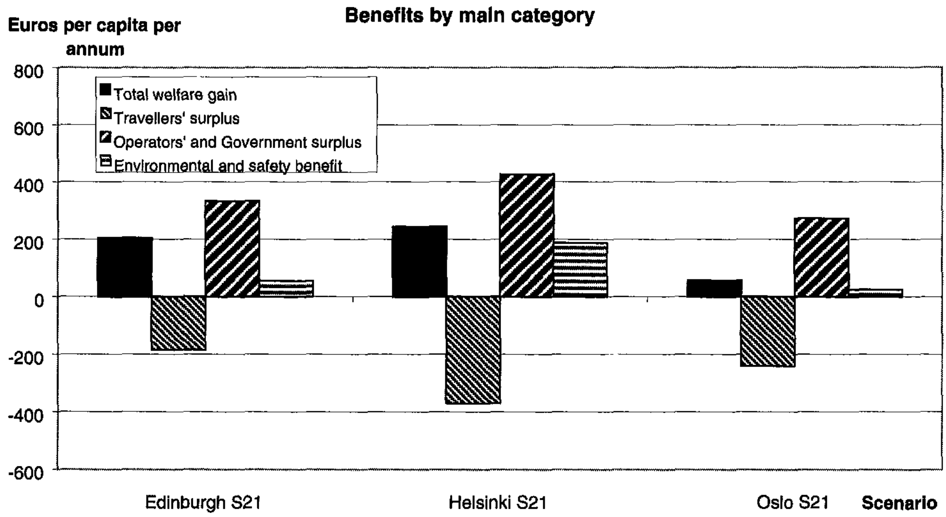

Figure 2: *Best practice second-best solutions under current institutions, assuming a 0.25 shadow price of public funds.*

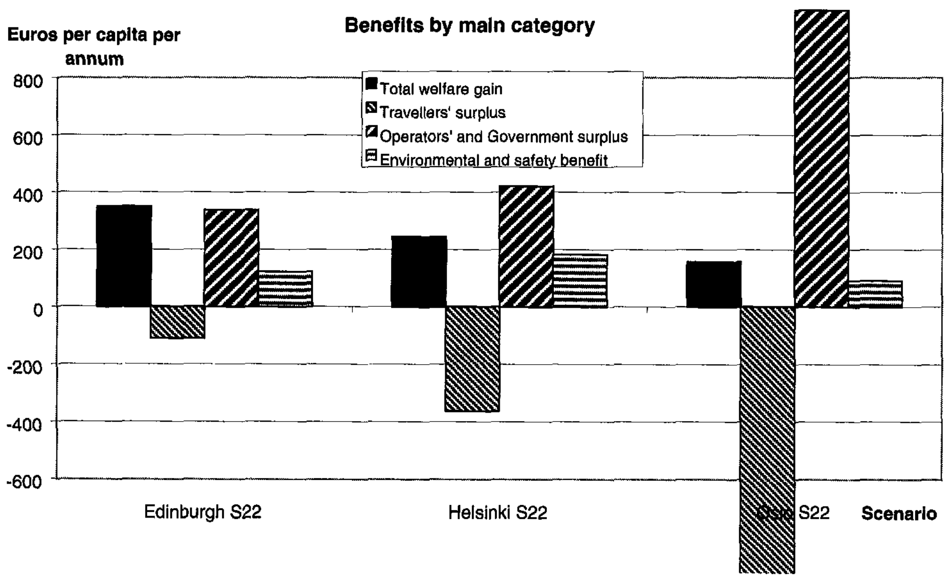

Figure 3: *Best practice second-best solutions after institutional reform, assuming a 0.25 shadow price of public funds.*

At this point, it should be remembered that while the time savings are a true resource benefit, the road user charges – whether they take the form of cordon toll payments, fuel and vehicle taxes, public transport (PT) fares, or parking 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. Indeed, 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*. This issue turns out to be of considerable importance for the evaluation of road pricing measures and will be discussed at greater length below.

Equity effects are moderate

Road pricing schemes have the double consequence (i) of discouraging road use at least at certain times on certain parts of the network, and (ii) of transferring cash from private persons to public funds.

The fact that road pricing – at least in the first place – involves a transfer of cash from private travellers to public institutions, is likely to be a major impediment to its public acceptability. The implementation of efficient road pricing policies typically affects equity in a way that policy makers and/or the general population are likely to disapprove of.

Therefore, to render marginal cost pricing schemes politically and publicly acceptable, it is probably necessary to recycle the revenue generated in such a way as to keep most population subgroups at least equally well off. Such redistribution schemes appear by no means infeasible, but in the process of redistribution large parts of the initial efficiency gain may in important cases (i.e., if there is a non-zero shadow price of public funds) be lost. Thus, marginal cost pricing accentuates the traditional conflict between the goals of economic efficiency and equity.

Equity questions arise at various levels of aggregation. At a coarsest level, an apparent conflict of interest exists – as we have mentioned – between private consumers and the public authorities.

At a second level, diverging interests exist between various segments of the consumer population. Those who do not travel in the initial situation are unaffected by road pricing, and may stand to gain if the revenue generated is recycled in the form of a general tax relief, or if the revenue is used to provide public services for which there is a positive willingness-to-pay.

Moreover, public transport (PT) users are – unlike motorists – generally not hit by measures to curb private car use, yet they may be able to reap a benefit in the form of reduced congestion and enhanced level-of-service. Here, however, the equity aspects are less clear-cut, since private motorists and PT users are not fixed population segments. To the extent that an enhanced PT level-of-service increases PT demand, there is an obvious gain in accessibility accruing to the new PT users, i.e. to previous motorists, bicyclists, pedestrians, or non-travellers.

Thirdly, it may be argued that road pricing schemes are unfair to the less affluent, who may not have the means to pay their way out of the situation and therefore incur a disproportionately large loss in the form of reduced accessibility. Or, if they do find it worthwhile to pay the road price, they do so at a higher rate, in terms of utility, than the more affluent, because their marginal utility of income is higher than the average. They have to spend a larger share of their income in order to maintain the level of accessibility.

Even if one does not take account of differences in the marginal utility of money, but measures in terms of nominal willingness-to-pay (as most cost-benefit analyses do), road pricing schemes may be expected to worsen the (generalised) income distribution, unless one can make the higher income groups pay a higher price.

Studies made by means of the RETRO model for Oslo indicate that, before redistribution, the *Gini* coefficient, which summarises the degree of income inequality within the population, increases (i e, worsens) when road pricing is implemented. But in most cases, these changes to the income distribution appear to be relatively moderate, as measured by the *Gini* coefficient.

If the revenue is redistributed proportionately by personal income, i.e. as a given percentage point relief in the income tax rate, the *Gini* coefficient is – by definition – unaltered from the level attained as a result of road pricing. Such a redistribution scheme does nothing to correct the initial, adverse equity effect as between people within different income brackets. But it does reverse the potentially unpopular transfer of funds from private consumers to the public treasury.

If, on the other hand, the redistribution is done in a more progressive manner, e.g. by recycling the same, absolute amount of money to each adult individual (a "poll transfer" or "flat redistribution"), the *Gini* coefficient not only improves considerably, but even ends up at a much more favourable level than before the road pricing measures were implemented.

Similar analyses made be means of the START model for Edinburgh provide even more optimistic results: the *Gini* coefficient improves even *before* redistribution.

It is, in other words, in principle possible to conceive of a road pricing scheme with revenue redistribution, which enhances economic efficiency as well as equity (as measured by the *Gini* coefficient). It will usually be sufficient to redistribute a certain part of the revenue generated in a progressive manner, in order to keep the less affluent households at least equally well off.

The main reason why road pricing schemes hardly lead to any deterioration in the income distribution is that the more affluent people, exhibiting higher rates of car ownership and use, tend – in general – to incur a higher road pricing expenditure.

The value of public funds

From the above arguments, it may seem that no serious conflict arises between efficiency and equity, as there exist combined road pricing and redistribution schemes by which both purposes can be served. This is, however, less than half the truth.

The AFFORD modelling analyses have been made under two sets of assumptions regarding the shadow price of public funds (and other externalities). In a "simplified" set of scenarios, a *zero* shadow price of funds is assumed. In the "full" optimisation, a shadow price of *0.25* is assumed.

The interpretation of the latter assumption is that *alternative sources of public funds generate an efficiency loss throughout the economy amounting to 0.25 Euros per Euro public revenue raised.*

It is, in other words, assumed that the road pricing revenue is used to step down distortionary taxation somewhere else in the economy, or to extend the supply of a public good for which the willingness-to-pay exceeds the marginal cost of production. In such a case, a "double dividend" accrues: not only do we reduce the costs of congestion, we also improve the overall efficiency of the economy.

Under certain circumstances, the latter effect may be well the more important. In the Oslo case, e.g., a major part of the overall efficiency gain from second-best road pricing is due to the extra value attached to public funds. A bit simplified, one might say that road pricing appears, more than anything else, as a favourable form of taxation. As seen in this perspective, the double role of road pricing (discouraging congestion and raising public revenue) becomes an asset rather than a liability.

In Figure 4, 5, and 6, we compare first- and second-best solutions with and without a (non-zero) cost of funds.

There is no general consensus among economists as to the "true" shadow price of public funds. It will depend on the initial state of the affected economy, on its (more or less distortionary) taxation system, and on how the marginal tax revenue is used. If it is spent in a way that does improve the overall economic efficiency, the shadow value is zero. If the revenue is spent in a way that aggravates an existing allocation problem, the shadow price should be considered negative.

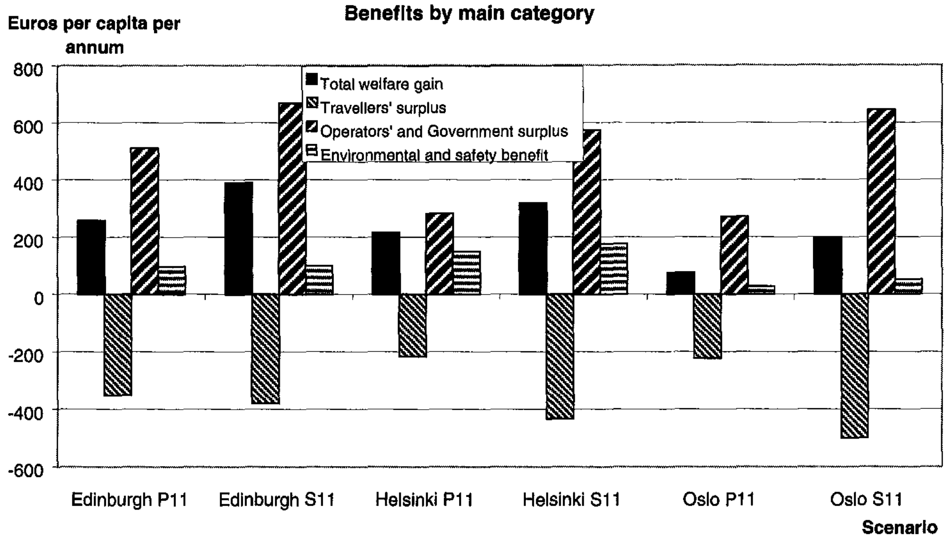

Figure 4: *First-best solutions with (S11) and without (P11) a 0.25 shadow price of public funds.*

Under the assumption that the shadow price of public funds is positive (and of some non-negligible size), the efficiency gain from substituting marginal cost pricing for some distortionary tax could be among the more important benefits obtained. When, on the other hand the shadow price of funds is zero, the overall benefit derived from marginal cost pricing is weakened. Indeed, for the second-best policy after institutional reform in Oslo, it is cut by 90 per cent. In the other cities, the sensitivity with respect to the cost-of-funds assumption is less pronounced.

When it comes to revenue redistribution, the value attached to public funds becomes a rather decisive factor. If the redistribution is done in such a way that distortionary taxation is not reduced, there is no rationale for including the shadow value of public funds in the efficiency measure. In this case, we are faced with a clear-cut trade-off between efficiency and equity: the equity can be improved through redistribution, but only at the expense of certain parts of the efficiency gain.

If, on the other hand, the redistribution does contribute to reduce the incidence of distortionary taxation, at a rate equal to the assumed, average shadow price of public funds, the efficiency measure has been correctly assessed and will not be altered through the redistribution. In this case, the redistribution of income will improve efficiency in other markets, the total efficiency gain throughout the economy being given – precisely – by the shadow value of the public funds being redistributed.

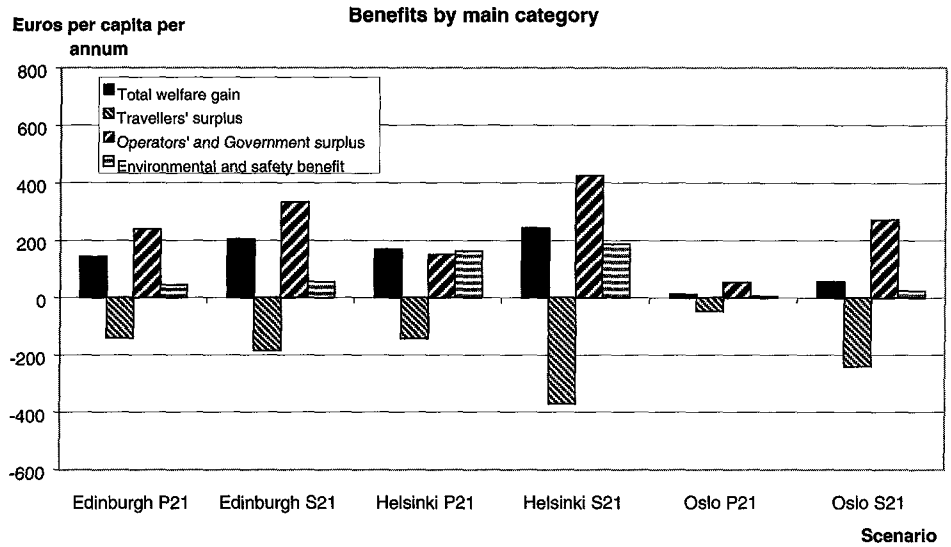

Figure 5: Second-best solutions under current institutions, with (S21) and without (P21) a 0.25 shadow price of public funds.

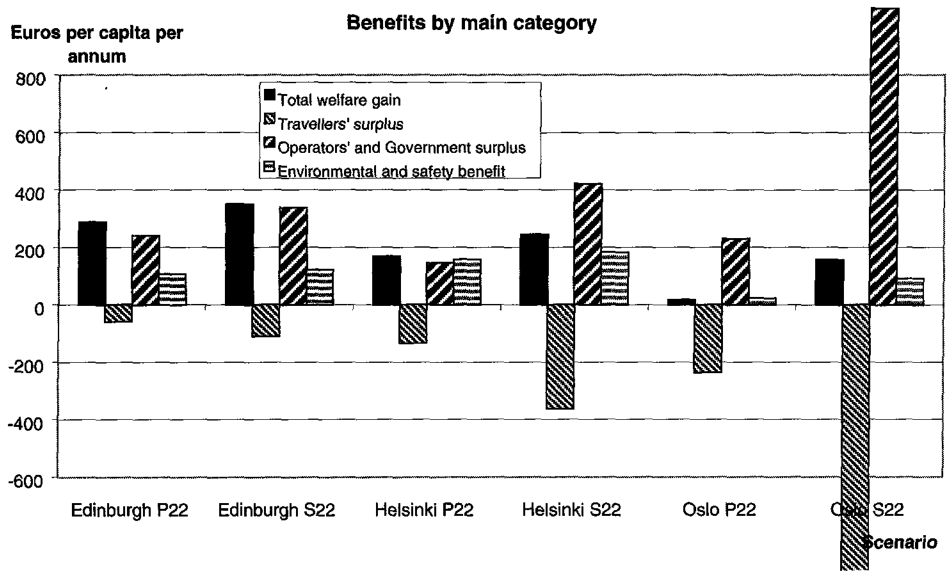

Figure 6: Second-best solutions after institutional reform, with (S22) and without (P22) a 0.25 shadow price of public funds.

To the extent that the marginal tax on labour is distortionary, a redistribution scheme which lowers the marginal tax rate by a given number of percentage points, as in the "proportional" recycling scheme, would seem to qualify as a scheme which does not reduce overall efficiency. Such a tax relief would reduce the tax wedge at all levels of income and hence reduce distortions in the labour market. But – as mentioned above – this redistribution scheme does nothing to correct the income inequality between households.

The "poll transfer" ("flat") redistribution scheme, on the other hand, would give equal amounts to all adult persons, irrespective of initial income, rather than reducing the marginal tax rate. In this case, the efficiency benefit due to additional public funds is most probably lost through redistribution. Since the toll revenue is handed back out to the consumers, without affecting – *on its way* – the marginal tax wedge, there is simply no net public revenue left which can to be used to finance corrections to whatever distortionary taxation schemes may exist.

Optimal, second-best marginal cost pricing may imply stiff charges

The AFFORD modelling simulations generally take the form of optimisation: we calculate the *optimal* combination of instruments, as judged by the goal of overall economic efficiency taking account of externalities. Thus, the "dosage" applied to each instrument is not chosen arbitrarily, but results from a systematic analysis aimed to identify the "best practice second-best solution". Given that the first-best solution is not practicable, what is the best we can do with the instruments that are available in practice?

The optimised values of the various instruments differ considerably between the case study cities. In all cities, however, the best practice second-best road pricing scheme involves some relatively stiff charges by one or more instruments. Optimal cordon toll rates typically range between 2 and 10 Euros per passing, fuel prices may have to be doubled or tripled, and parking charges increase by up to 300 per cent.

Soft road pricing schemes

As a third set of scenarios, the AFFORD modelling teams have studied policy packages (denoted *P3* or *S3*) in which the pricing instruments have been constrained to certain levels deemed to be "acceptable" to the general public. In these packages, only moderate changes in the toll rates, fuel and vehicle taxes, parking charges, and PT fares are assumed.

According to the analyses made for Oslo and Helsinki, these "acceptable" scenarios do very little to improve the welfare of the urban population. Indeed, in both of these cases the gain in efficiency is projected to be *negative*. Put simply, "soft" road pricing schemes, while probably more acceptable to the public, seem to be of little value as measures to curb the social costs of urban transport.

For Edinburgh, however, simulations have been run to study a "smart card" system, by which motorists pay according to distance travelled in certain areas, however in such a way that the maximum and/or minimum charge is limited. This system, which is believed to be relatively acceptable to the population, has been shown to yield very substantial welfare benefits, approaching the maximally obtainable first-best improvement.

Thus, there may seem to be a potential for efficient, softer road pricing schemes based on an intelligent practical use of modern information technology.

Travel demand effects

The general effect of marginal cost road pricing is – not surprisingly – to substantially reduce the number of car trips, in some cases by as much as 30-40 per cent. The effect in terms of car kilometres depends, however, on the exact form of the instruments – cordon toll rings that can be avoided by driving a longer distance may end up generating more vehicle kilometres than before.

Public transport demand increases under marginal cost road pricing, as a result of trips being transferred from the car mode. In certain cases, public transport patronage is also strengthened through transfers from the slow modes (walk/bicycle), as the level-of-service enhancements (increased frequency and speed) serve to reduce the generalised cost of travel by public transport.

Land use effects and their implications

Large changes in the transport prices are apt to have long term repercussions on the patterns of land use. Only the Helsinki model allows for a systematic analysis of these changes and of their feedback effects on travel behaviour and economic efficiency.

The largest secondary impact that pricing in transport could have is the reversal of the urban sprawl effect. Urban sprawl usually results in congestion, pollution and excessive use of resources. When the resource costs and externalities were internalised in the Helsinki model into petrol price or road tolls, the average travel distances fell which again resulted in large savings in total mileage, vehicle operating costs and externalities. The optimisation of the urban public transport prices ended up in lower fares as it was possible to gain social welfare when the concentration of land use along corridors where the economies of scale in providing efficient rail services were.

The overall effect of pricing on relocation to reduce urban sprawl and its associated costs was far more significant in the model runs than the pure effects of marginal cost pricing on congestion cost savings. This naturally depends on the local situation. The effects of land use relocation could nevertheless be in long term more fundamental than the change in pure transport mobility and trip demand.

Accessibility

For Edinburgh, detailed analyses have been made to study the impact of road pricing on spatial accessibility, i.e. on the extent to which residents in the various zones have their travel opportunities diminished or enhanced (in economic terms) as a result of the various policy packages. Reduced accessibility means that the same trips can be made only at a higher generalised cost, or perhaps not at all (i e, only at "prohibitive" costs).

A first-best road pricing policy would entail large reductions in accessibility by car for all zones, with greater reductions for the outer zones.

The effect of tolled cordons is to create boundary effects. A small city centre cordon would hit those who reside within the cordon more than those who reside outside, as the cordon is small enough to allow routing around the charged area. The larger cordon toll based system primarily affects those outside the cordon as the cordon is large enough to allow free movement within the area and to limit the opportunities for re-routing around the cordon.

However a larger cordon with distance based charges would have the opposite effect, since those within the cordon are charged on all trips, while those living outside the cordon can travel to some zones without extra charge.

Fuel taxation would affect all areas but the effect increases with average trip length, i.e. for those living in the outermost zones.

Environmental and safety effects

An important effect of marginal cost pricing in transport is to curb the amount of environmental damage, in the form of air pollution, greenhouse gas emissions, and noise. As a second externality component, accident costs are also reduced, although at this point the net effect is more questionable, since reduced congestion may allow for higher speeds and possibly a larger average accident loss per vehicle kilometre.

The relative amount of environmental and safety benefits varies between the case study cities. In the case of Helsinki, environmental benefits typically constitute a major part of the total welfare gain (up to 95 per cent). In the Oslo case, environmental benefits vary between 15 and 75 per cent, while in Edinburgh their share is more moderate, ranging between 15 and 40 per cent of the total benefit.

Contents

1 Introduction and overview

1.1 Objectives of analysis

European urban areas are marred by the problems of congestion and environmental degradation due to the prevailing levels of car use.

Over the last decade, there has been growing consensus between economists and transport planners that pricing measures need to be considered as a means of controlling road use demand, especially in the most heavily congested European cities. In the words of Goodwin et al (1991),

> " .. demand management would [...] become the centre of transport policy; if supply cannot be matched to demand, demand has to be matched to supply."

Strong arguments have thus been put forward in support of a policy based on *marginal cost road pricing* (Maddison et al 1996, European Commission 1996). Such policy measures – which would force private consumers to pay for a public service that was previously provided "for free" – are, however, notoriously unpopular with the general public and hence also with their elected representatives – the politicians.

There is thus an obvious paradox between economic theory, which suggests that marginal cost pricing is the welfare maximising solution to urban transport problems, and practical experience, which suggests that such pricing measures are unwanted by the affected population and hence hard to implement through democratic processes.

The AFFORD Project (Acceptability of Fiscal and Financial Measures and Organisational Requirements for Demand Management) aims to investigate this paradox and its possible solutions, through a combination of economic analysis, predictive modeling, attitudinal surveys, and an assessment of fiscal and financial measures within a number of case study cities in Europe

This Deliverable from the AFFORD project deals with economic and equity issues and aims to

- identify indicators of performance suitable to the assessment of economic feasibility and efficiency and equity,
- assess the economic feasibility of the specified pricing measures and suggest measures to resolve such problems,
- assess the economic efficiency of the specified pricing measures, by considering impacts separately on the transport market and the general economy,
- assess the equity impacts and issues of the specified pricing measures, and to
- assess the overall performance of the specified marginal cost based pricing measures.

1.2 Three case study cities

Within the AFFORD project, strategic or tactical modelling case studies have been made for three different cities: Edinburgh, Helsinki and Oslo.

The *START strategic model for Edinburgh* is operated by the *Institute of Transport Studies (ITS) of the University of Leeds*. The model simulates traffic flows within an abstract network including 25 zones. Five modes of travel are considered: private car, heavy rail, bus, light rail, and guided bus, of which the last two are new. The market is segmented between six travel purposes (commute, education, visit, business, non-home based, and leisure) and three time periods (two peaks and the rest of the day). In the model simulations, land use patterns, car ownership rates, trip frequency and destination choice are fixed, but the average trip length responds to changes in mode choice and routing. Simulations are made for the forecast year of 2010, based on foreseen changes in land use and mobility up to that horizon.

Supplementary analyses for Edinburgh have been produced through the *ASCOT model* operated by the *University of York*. This model is a detailed 181-zone mode and route choice algorithm, in which land use, car ownership rates, trip frequency and destination choice are fixed. This detailed modelling study is presented in a separate report (Smith and Ghali, 1999).

The *MEPLAN geographic model for Helsinki* is operated by the *LT Consultants Ltd* and the *Government Institute for Economic Research (VATT)* in Finland. The model covers a fairly extended region including the surrounding areas of Helsinki, divided into 81 zones of residence. Road network representation and public transport assignment is done by means of an EMME/2 application including 157 zones. Unlike other models used within the AFFORD project, the Helsinki model predicts changes in land use and their feedback effects on transport patterns and welfare. The model distinguishes between eight socio-economic groups, 15 travel purposes, four modes, and two time periods per day for peak and inter-peak hour assignment. Overall car ownership and trip frequency are inelastic, but respond to changes in land use. Simulations are made for the forecast year of 2020, following substantial foreseen investments in transport infrastructure compared to today's situation.

The *RETRO tactical model for Oslo* is operated by the *Institute of Transport Economics (TOI)* in Norway. The model covers the city of Oslo and the municipalities of the surrounding county of Akershus, exhibiting 49 zones of residence and employment. The RETRO model predicts aggregate car ownership, trip frequency, destination choice, and mode choice within each zone, separately for two time periods (peak and off-peak).

Calculations in the RETRO model are based on the *prototypical sample technique*. In essence, this means that *for each zone* in the network, a set of weights is defined, in such a way that when these weights are applied to the disaggregate units (respondents) of a travel survey, the sample becomes "representative" of the zonal population in the sense of reproducing, at least approximately, the true zonal income distribution, as recorded in official statistics. A total of eight income brackets are defined and used in the calculations.

Network assignment (route choice) is done by means of an EMME/2 application run in an iterative loop with the car ownership/travel demand submodel of RETRO. The EMME/2 network includes a total of 438 zones. Simulations are referred to a benchmark situation as calculated for 1995, and assume that cordon toll charges – if any – are collected at the same toll plazas that are currently in use.

1.3 Outline of report

The remaining sections of this report are organised as follows.

In chapter 2, we explain the principles of efficiency and equity assessment to be applied in this report.

Chapter 3 is an overview of the various policy scenarios calculated in our three case study cities. An effort has been made to define similar or comparable sets of assumptions for the three cities involved. However, due to differences in the local conditions as well as in the modelling tools, certain dissimilarities between case study cities are inevitable.

In Chapter 4, city specific model simulation results are reported.

In Chapter 5 we discuss the equity issue, concentrating on the income distribution analyses made for Oslo and on the spatial accessibility study performed for Edinburgh.

Chapter 6 is devoted to land use effects, assessed by means of the MEPLAN model for Helsinki.

In Chapter 7, the main results obtained for each city are summarised.

For an overview of findings across all case study cities, the reader is referred to the General Executive Summary presented at the beginning of this report.

2 Policy assessment principles

2.1 Efficiency assessment principles

The general methodological framework of the AFFORD modelling exercises is an adaptation of standard cost-benefit analysis.

Cost-benefit accounts are drawn up relative to a business-as-usual ("base case", "do-minimum", reference) scenario, and subdivided between various institutional sectors.

The present value of finance of a policy (PVF) over a 30 years period is defined as the net financial benefit of the policy to government and other providers of transport facilities, both public and private:

(2.1) $$PVF = -I + \sum_{i=1}^{30} \frac{f_i}{(1+r)^i}$$

where I is the present value of the cost of infrastructure investments, compared to the business-as-usual scenario; f_i is the net financial benefit to transport suppliers and government in year i, compared to the business-as-usual scenario, taking into account both revenue and operating cost; and r is the annual discount rate.

The present value of net benefits, B, is given by

(2.2) $$B = \sum_{i=1}^{30} \frac{(f_i + u_i)}{(1+r)^i}$$

where u_i is the added net benefit to transport users (consumer surplus) in year i, compared with the business-as-usual scenario.

The net present value (NPV) may be transformed into a corresponding *annual per capita flow of net benefit* (b, say) simply by dividing B by the size of the population and by the inverse annuity factor:

(2.3) $$b = \frac{B}{N} \Big/ \sum_{i=1}^{30} \frac{1}{(1+r)^i} = \frac{B}{N} \cdot \frac{r}{1-(1+r)^{-30}},$$

where N is the population size. For instance, if the rate of interest is 7 per cent, the annuity factor is 0.0806 = 1/12.409.

In the Helsinki model, the consumer surplus is calculated by means of the nested logit formulation due to Huw Williams (1977). This formulation has a strong and elegant foundation in utility theory and provides correct measures even in the case where demand curves are highly non-linear and the changes are much too large to warrant linear approximations.

In the Edinburgh and Oslo models, on the other hand, consumer surplus changes are calculated by means of the simplifying "rule-of-the-half", i.e. as

$$(2.4)\quad u = \sum_i \sum_j \left(c_1^{ij} - c_0^{ij}\right)\left(x_1^{ij} + x_0^{ij}\right)/2,$$

where c_1^{ij} and c_0^{ij} denote the generalised cost incurred on trips between zone i and zone j in, respectively, the policy scenario (1) and the initial (benchmark) situation (0), while x_1^{ij} and x_0^{ij} denote the corresponding "quantities" demanded, i.e. the amount of travel.

This widely used practice is a linear approximation to the change in consumer surplus. When dealing with strongly non-linear demand relations and large changes in market behaviour, such as a massive shift from private to public transport, the rule-of-the-half may yield rather inaccurate results.

Adding costs and benefits gives the economic efficiency objective function

$$(2.5)\quad EEF = B - I + \lambda \cdot PVF$$

where λ denotes the "shadow price of public funds", i.e. the cost – in terms of economic efficiency – of raising one unit of public revenue through tax schemes other than road pricing. The rationale for assigning an extra value to each unit of public revenue raised is the assumption that the alternative forms of taxation invariably are distortionary – they distort the price signals of the economy by allowing the cost perceived by private decision makers to be different from the marginal social cost. In such a case the resource allocation becomes inefficient, i.e. the total output of goods and services becomes smaller than it could have been, had all individual decision makers been facing the true marginal social cost.

Suppose it were true that motorists in general pay *less* than the marginal social cost of road use, while companies and consumers in general are charged *more* – on account of the labour tax, value added tax, etc – than the real marginal social cost for their use of inputs and consumables. In such a case, it is conceivable that a "*double dividend*" would accrue, if a tax corresponding to the marginal *external* cost were levied on road use, and this revenue were used to reduce the tax wedge affecting, e.g., the use of labour. Such a policy would reduce or eliminate the distortions originating in the road sector as well as in the labour market.

Whether or not such a double dividend is likely to materialise is, however, a contentious matter among economists, as is also the appropriate value of the shadow price of public funds to be applied. In the AFFORD modelling exercises, we shall therefore alternate between the assumptions $\lambda = 0$ and $\lambda = 0.25$.

The AFFORD modelling team is not in a position to judge which one of these assumptions is more realistic. It will depend on the initial state of the affected economy, on its (more or less distortionary) taxation system, and on how the marginal tax revenue is used. If it is spent in a way that does not improve the overall economic efficiency, the shadow value is zero. If the revenue is spent in a way that aggravates an existing allocation problem, the shadow price of public funds should be assumed negative[1].

Adding changes in external costs of accidents, noise and pollution, *EC*, we arrive at the efficiency function with environmental costs[2]

(2.6) $EEFP = EEF + EC$,

which corresponds with one of the efficiency criteria used in the FATIMA project.

The general optimisation principle applied in the AFFORD project is that of maximising the EEFP function (2.6). We compute that combination of policy measures which gives rise to the largest welfare improvement, as measured by EEFP.

In the *subsequent cost-benefit analysis*, we attempt to decompose the components B, I and PVF between various types of agents according to the below Table 2.1.

Table 2.1: Components in the cost-benefit analysis.

	Level of the instruments					
Scenario	Fare	Frequency	Road price	Fuel price	Car tax	Other instruments

Benefit or cost category	Travellers: Work trips	Travellers: Other	Operators: PT	Operators: Parking	Operators: Toll	Government and external	Row sum
Investment			a	b	c	d	
Money savings,road	e	f		g	h	i	
Money savings,PT	j	k	l			m	
Financial benefits							
Time savings, road	n	o					
Time savings, PT	p	q					
Time savings, walk&cycle	r	s					
External cost savings						t	
Total benefit							
EEFP							

The net financial benefit to transport suppliers and government, $\sum_{i=1}^{30} \frac{f_i}{(1+r)^i}$, decomposes into

– *Investments for public transport operators* (frequency dependent costs for public transport operators, which includes a part of the operational costs

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[1] Empirical estimates of the shadow price of public funds range at least from –0.2 to +0.8 – see, e g, Ballard et al (1985), Ballard & Medema (1993), Brendemoen & Vennemo (1996), Dahlby (1998), Hansson (1984), Hansson & Stuart (1985), Holmøy & Strøm (1997), Jorgenson & Yun (1990, 1991), Mayeres (1999), Sandmo (1998), or Vennemo (1991).

[2] As a matter of convention, costs are accounted for as negative benefits, i.e. *EC* is generally a negative term.

[distance dependent costs] plus salary- and social costs and capital cost – code a in table 2.1),

- *Money savings for parking operators* (revenue from parking fee minus the operating cost of parking facilities – code g),
- *Money savings for tolling companies* (revenue from tolling minus the operating costs of the toll scheme – code h),
- *Money savings for government* (revenue from time dependent and distance dependent car taxes – code i),
- *Money savings for public transport operators* (income through fares – code l), and
- *Money savings for government* (subsidies or tax revenues from public transport operators – code m).

The present value of infrastructure investments, *I*, is decomposed into

- *Investments in the parking sector* (operational costs, not modelled – code b in table 2.1),
- *Investments in tolling systems* (code c), and
- *Investments in infrastructure* (not modelled – code d).

For all of these cost components (a, b, c, d, g, h, i, m), a shadow value of public funds – if different from zero – applies, through the multiplication of all nominal cash flows by $1+\lambda$. The only social cost or benefit for which such a shadow price does not apply is the

- *Environmental cost savings* (code t),

also specified in the cost-benefit accounts.

Finally, the monetary and non-monetary benefits accruing to travellers are marked as e, f, j, k, and n through s.

The net user benefits, e.g., decomposes in principle into

- *Monetary benefits* for car drivers and public transport travellers in peak and off-peak periods (items e, f, j, k).

and

- *Time savings* (items n, o, p, q, r, s).

The monetary benefits, which – in the road pricing case – usually are negative, consist of two main subcomponents, (i) the *out-of-pocket expenditure*, i.e. the extra outlay incurred by those individuals who keep up their demand in the face of a higher unit cost, and (ii) the *reduced accessibility*, the loss in consumer surplus due to the movement along the demand curve, as some road users choose to travel less in the face of a higher price.

Time benefits are measured in terms of the travellers' willingness-to-pay for the time savings obtained from reduced congestion.

Such a decomposition between monetary benefits and time benefits is, however, straightforward only in the case where the *generalised cost* (c_k, say) takes the form of a linear combination of monetary and non-monetary items – in essence like this (suppressing the origin/destination superscripts):

(2.7) $c_k = m_k + \theta t_k \quad (k = 0,1)$,

where m_k and t_k are the monetary and non-monetary (i e, time) costs, respectively, in situation k, and θ is the conversion factor between time and money – the "value of time". Thus, the rule-of-the-half can be written

(2.8)
$$\begin{aligned} u &= \frac{1}{2}(c_1 - c_0)(x_1 + x_0) = \frac{1}{2}[m_1 - m_0 + \theta(t_1 - t_0)](x_1 + x_0) \\ &= \frac{1}{2}[m_1 - m_0](x_1 + x_0) + \frac{1}{2}[\theta(t_1 - t_0)](x_1 + x_0), \end{aligned}$$

i.e. as a separable sum of monetary and non-monetary elements. Incidentally, this is one of the large advantages of the rule-of-the-half.

2.2 Equity assessment principles

In the AFFORD model simulations, the impacts on the income distribution are studied by comparison of *Lorenz* curves and *Gini* coefficient values between the respective scenarios.

The Lorenz curve, due to Lorenz (1905)[3], relates the cumulative proportion of income units (x-axis) to the cumulative proportion of income received (y-axis), when units are arranged in ascending order of their income. It takes the form of a straight line through the origin with slope 1 (45-degree angle) if and only if all units in the population receive the same income. In all other cases the curve is a monotonously increasing, upward-bending line located beneath the straight line with a 45-degree angle. The lower the Lorenz curve, the more income is concentrated in the upper income brackets, and the less "equitable" is the distribution.

Formally, let x be an income variable with cumulative distribution function F and expected value

(2.9) $E(x) = \mu$.

The Lorenz curve is defined by

(2.10) $L(u) = \frac{1}{\mu}\int_0^u F^{-1}(t)dt \qquad (0 \le u \le 1)$,

where

[3] For a more up-to-date treatment, see, e g, Kakwani (1977, 1980, 1987), Atkinson (1970), or Sen (1973).

(2.11) $F^{-1}(t) = inf[x : F(x) \geq t]$.

To fix ideas, we show – as an example – the Lorenz curve for Oslo-Akershus in the benchmark scenario (Figure 2.1). Income levels are grouped into 8 brackets, generally NOK 50 000 per annum wide. The lowest bracket runs from zero to NOK 99, while the uppermost bracket includes incomes from NOK 300 000 upwards[4].

As shown by the Lorenz curve, the lowest 40 per cent of the adult population earn only 10 per cent of the total income.

Note, however, that this picture is conditioned by the fact that we use *individual* rather than *household* income. Many persons with low or zero income (students, housewives, etc) live in families with a fairly large household income. An analysis based on household income would most probably provide a less alarming picture of income inequality.

Thus, in the equity analyses based in the Oslo model, for which disaggregate data are available on household income as well as on individual income, we prefer to draw the Lorenz curves in terms of *household income per consumption unit*, defined as follows. Each household member is assigned a weight, equal to 1 for the household head (or the "first" adult person in the household, 0.7 for any additional adult, and 0.5 for children up to 17. With small variations, these weights are in line with international (OECD) recommendations for household consumer surveys. The number of consumption units is given by the sum of the weights assigned to all members of the household.

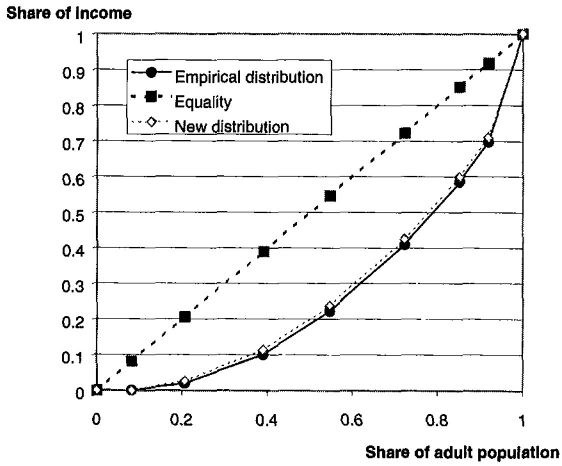

Figure 2.1: Lorenz curves for the adult population in Oslo-Akershus 1992. "New distribution" = NOK 10 000 annual increment for all.

[4] 1 Euro = appr NOK 8.50

When two distinct populations exhibit Lorenz curves such that one is uniformly located above the other, the former distribution (corresponding to the upper curve) is unambiguously more equitable.

However, if the two Lorenz curves intersect, one inevitably needs to "trade" one segment of the income scale against another, in order to conclude which distribution is "more equitable".

One way to summarise the information contained in the Lorenz curve is by way of the *Gini* coefficient, due to Gini (1912)[5], which is defined by

$$(2.12)\quad G = 2\int_0^1 [u - L(u)]du = 1 - 2\int_0^1 L(u)du,$$

i.e. as *twice the area between the 45-degree straight line and the Lorenz curve.* The higher the *Gini*-coefficient, the larger is the "gap" between the actual and the maximally equitable distribution, and the less "equitable" is – in a sense – the distribution at hand.

The *Gini* coefficient is bounded between zero and one: $0 \le G \le 1$.

In Figure 2.1, we also show – for purposes of illustration – the impact of a hypothetical NOK 10 000 increase in annual income for all individuals (except those with zero income), as measured in terms of the Lorenz curve. One notes that the area between the Lorenz curve and the straight line has been slightly diminished – indicating a certain improvement in the income distribution.

The diagram in Figure 2.1 can be made more easily readable by rotating the curves 45 degrees clockwise (Figure 2.2).

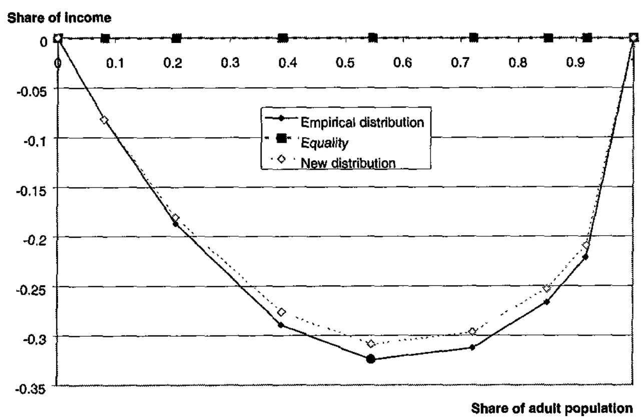

Figure 2.2: Rotated Lorenz curves for the adult population in Oslo-Akershus 1992. "New distribution" = NOK 10 000 annual increment for all.

[5] See also Dagum (1987) and references therein.

Here, the "perfect equality" Lorenz curve takes the form of a straight line along the horizontal axis.

In most cases, the interest is not in comparing some empirical distribution to an ideal "perfect equality", but rather to compare two plausible, real-world situations. To this end, a diagram in which the "new" distribution is compared to an "old" ("empirical") would bring out the differences even more clearly, as in Figure 2.3.

Here, the old "empirical distribution" Lorenz curve takes the form of a straight line along the horizontal axis.

In the sequel, we shall apply this method of graphical illustration to show the equity impacts of the respective scenarios and of various way of recycling the toll and tax revenue to the population.

We shall do this by first adding to the income of each bracket the monetary savings obtained by car drivers (e+f in Table 2.1), then – in this order – the money savings accruing to public transport users (j+k), the time savings of car drivers (n+o), the time savings of other travellers (p+q+r+s), and finally the toll and tax revenue redistributed to the tax payers according to some more or less progressive scheme.

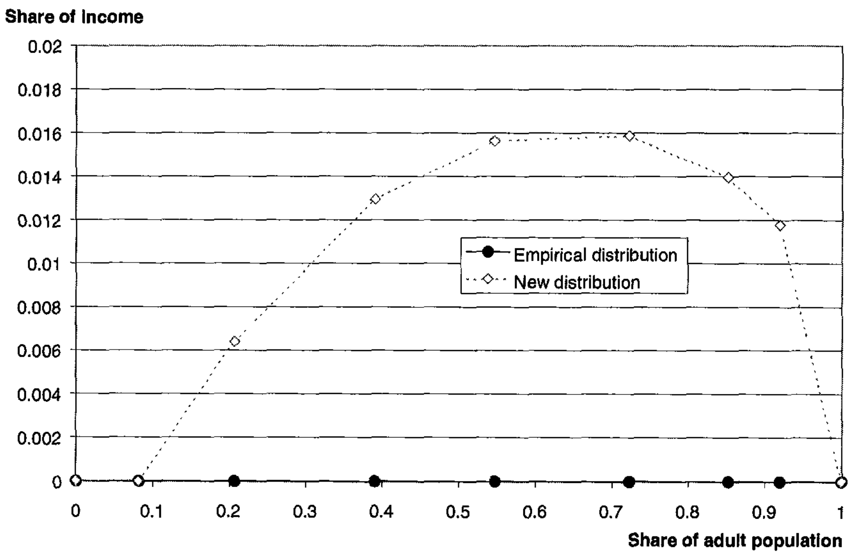

Figure 2.3: Lorenz curve differentials between the empirical distribution for Oslo-Akershus 1992 and a "new distribution" given by a NOK 10 000 annual increment for everyone.

In so doing, we make the simplifying assumption that this redistribution has only negligible feedback effects on behavioural choice. In a rigorous analysis, one would have to take into account that large income transfers will affect consumer behaviour, notably in the labour market, and to a considerable extent also the choices made in the transport sector, such as car ownership and use. Such an analysis would, however, require a full-fledged general equilibrium model of the urban economy, something which has been beyond the scope of the AFFORD project.

In general, the income increments and transfers simulated in our analyses are small compared to the initial levels of income. Thus the assumption of negligible feedback is probably not too far-fetched.

It may be argued that it makes little sense to add together nominal gross income and some measure of consumer surplus, which includes all sorts of non-monetary benefits and utility components, such as time gains. In so doing, we implicitly define a kind of "*partial generalised income*", made up by the initial, nominal income and the consumer surplus *changes* generated by our policy. This is, of course, a simplified measure of welfare, in that the consumer surplus generated in the reference scenario is not included in the initial (generalised) income measure. We are therefore not able to say anything about the *relative* changes in welfare affecting the various income groups. However, as long as we restrict attention to *differential* effects on generalised income, the argument may be considered valid, if not at the ratio level of measurement, so at least on an interval scale.

3 Policy packages

3.1 The reference scenario (P0)

In order to assess any type of policy or situation, the analyst or planner would have to define a reference scenario or "base case", to which the various policy scenarios can be compared.

We shall refer to the reference scenario by the code *P0*.

In the AFFORD model simulations, the reference scenarios are of two kinds, termed

P01: *Business-as-usual* ("do minimum"), or

P02: *Foreseen strategy.*

The business-as-usual (*P01*) scenario is meant to reflect the current situation as of some recent point in time, assuming that no road pricing measures have been introduced. This is the kind of base scenario that has been defined for Oslo, in which simulations are made as of 1995, however with the assumption – in the base case – of zero cordon toll rates. Thus the base case is different from the actual 1995 situation, in which the toll for driving through the cordon *inbound* was appr 1 Euro for private motorist travelling on a maximally large discount coupon. It should be noted, though, that on account of the important road infrastructure investments made during the 1990s, financed in part by the cordon toll ring, the level of congestion in the base case is fairly moderate as evaluated on an urban European scale. This obviously serves to limit the amount of benefits which can reasonably be expected from congestion pricing.

In the Edinburgh and Helsinki model simulations, however, foreseen strategies (*P02*) are defined as of the years 2010 and 2020, respectively. These base case scenarios anticipate large increases in private car use in response to income and population growth. The Edinburgh model simulations therefore presuppose congestion levels far in excess of the present situation. Hence, one might expect a relatively large benefit to be attainable from marginal cost pricing.

In the case of Helsinki, very important public transport and road infrastructure investments are foreseen over the next two decades. These will obviously have the effect of relieving congestion and/or facilitate considerable traffic growth, resulting in a reference scenario resembling that of Oslo, in the sense of exhibiting moderate congestion levels but large environmental costs.

3.2 The first-best policy (P1/S1)

The AFFORD study distinguishes between "first-best" and "second-best" road pricing policy packages. These are referred to by the code names *P1* and *P2*, respectively, when a zero shadow price of public funds is assumed in the case, and by *S1* and *S2* when a shadow price of 0.25 is applied to the optimisation. In the latter case, it is assumed that the opportunity cost of raising a one Euro revenue for the public treasury is 0.25 Euros in terms of lost allocative efficiency[6].

By definition, the first-best pricing policy is the unconstrained welfare optimum, in which one imagines that each traveller is charged the true marginal social cost of road use, as given by the level of congestion, environmental and accident costs – and of any other external or internal cost, such as vehicle operating costs and time costs – generated by the marginal road user exactly *there* and *then.*

Depending on the perspective, two interpretations are possible. To make clear which one of these we have in mind, we shall distinguish notationally between

P11/S11: Narrowly first-best marginal cost pricing, and

P12/S12: Broadly first-best marginal cost pricing.

The *narrowly first-best* policy assumes that all pricing instruments reflect the principle of marginal cost pricing, and that charging itself is costless. The *broadly first-best* package represents optimisation of social welfare while taking account of the costs of regulation. If the equipment necessary for charging fully flexible and differentiated prices is too expensive, it could mean that it is broadly first-best to apply second-best taxes (see below).

By equating the marginal social cost to the marginal private cost, the first-best pricing policy induces all individual decision makers to make the socially most profitable choice, whenever they maximise their own utility or profit. As shown in AFFORD Deliverable 1 (Milne et al 2000), first-best marginal cost pricing is thus able to provide the correct incentives for long-term as well as short-term decision-making, not only in regard to route and mode choice, but also in relation to road capacity provision, technology choice, spatial behaviour, and sustainability.

This first-best pricing solution, however, presupposes a very sophisticated, real-time revenue collection and information system, in which road user charges vary instantaneously in space and time, i.e. between all road links and for every single minute, depending on the current level of congestion etc. This ideal road pricing scheme is, unfortunately, only a theoretical construct, infeasible in practice (at least with the present state of technology and legislation).

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[6] The size of this opportunity cost is contentious – see, e g, Brendemoen and Vennemo (1996) or Mayeres (1999), and references therein. This is why we, as a sensitivity test, perform most policy scenario optimisations under both assumptions.

It can, however, be mimicked in a network simulation model, so that one may derive the theoretically optimal level of road user charges and their hypothetical effect on traveller behaviour. The rationale behind this procedure is as follows.

Let $c(x)$ denote the generalised (private) unit cost of road use at traffic volume x on a given road link. By assumption,

(2.13) $$\frac{dc}{dx} \equiv c'(x) > 0,$$

i e, the unit cost increases with the traffic volume.

The aggregate private cost is given by the unit cost times the volume of road use, i.e. by

(2.14) $$C(x) = x \cdot c(x),$$

and the marginal social cost of traffic (excluding other externalities than congestion[7]) is therefore given by

(2.15) $$\frac{dC}{dx} = c(x) + x \cdot c'(x).$$

If, in addition, there are externalities occurring at a rate depending on the traffic volume (such as gas and particle emissions), one might want to add a term $D(x)$ (say)[8] to the aggregate cost function, yielding an aggregate social cost given by

$$A(x) = C(x) + D(x)$$

and a total social marginal cost given by

(2.16) $$\frac{dA}{dx} = c(x) + x \cdot c'(x) + D'(x),$$

where

$$D'(x) = \frac{dD(x)}{dx}$$

summarises all the marginal external costs other than those due to congestion.

In a network assignment model, an equilibrium solution is usually found by minimising the cost of each individual traveller going from point i to j (say), as summed over all road links comprising the journey. This may be viewed as a reasonable approximation to the decision problem facing the traveller in practice, who takes account of his own (generalised) travel cost $c(x)$, but not the marginal social cost included in (2.15) or (2.16).

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[7] In principle, one might envisage other volume-dependent externalities, such as accident risk, included as well.

[8] The quantity $D(x)$, when summed over all road links, corresponds to $EC - \lambda \cdot PVF$ in the notation of Section 1.3.

This equilibrium solution therefore corresponds to a user optimum not accounting for externalities. The externality is given by the difference between $c(x)$ and the marginal social cost given by, say, equation (2.16), i.e. by

$$(2.17)\quad e(x)=\frac{dA}{dx}-c(x)=x\cdot c'(x)+D'(x).$$

This magnitude corresponds to the theoretically optimal road charge.

To mimic a situation in which such a charge has been imposed, one might simply run a network assignment task in which, *rather than* $c(x)$, *we use the marginal social cost function (2.15 or 2.16) as our volume-delay relationship.* The equilibrium solution thus generated will be interpretable as the *system optimum under marginal cost road pricing*, i.e. as the solution after the imposition of an optimal road charge.

Thus, although it is hard to imagine schemes by which true marginal cost pricing could be imposed on the road users in practice, it is – in principle – perfectly possible to describe such a situation with the help of a network assignment model.

We use this theoretical first-best solution as an interesting benchmark case, against which the various feasible, *second-best* solutions – based on real-world policy instruments – can be judged. How far in the direction of the ideal, first-best solution are we able to move, when constrained by the pricing instruments actually available to planners and politicians?

Policy scenario	Shadow price of public funds	
	0	0.25
Reference case	*P0*	
Business-as-usual (present situation)	*P01*	
Foreseen strategy	*P02*	
First-best marginal cost pricing	*P1*	*S1*
Narrowly first-best	*P11*	*S11*
Broadly first-best	*P12*	*S12*
Second-best marginal cost pricing	*P2*	*S2*
Second-best under current institutions	*P21*	*S21*
Second-best after institutional reform	*P22*	*S22*
"Acceptable" pricing	*P3*	*S3*
Other, locally defined schemes	*P4*	*S4*

Box 1: Policy scenario code names.

3.3 Second-best policies (P2/S2)

As we move on to the description of second-best scenarios, the array of relevant policy packages becomes rather more complex.

In general, by a second-best policy package we shall understand the *optimal ("best practice") combination of policy instruments under the constraints represented by technology, geography, legislation, and institutional barriers.*

These constraints may, of course, be defined in various ways, depending on the temporal and spatial horizon. As a first ordering of second-best scenarios, we shall distinguish between

P21/S21: Second-best under current institutions, and

P22/S22: Second-best after institutional reform.

The *P21/S21* policy package is, by assumption, enforceable given the instruments presently available to the city authorities. The *P22/S22* package, on the other hand, cannot be implemented at the city level without foregoing legislative or institutional changes, as this policy presupposes the use of instruments that are not currently under the jurisdiction of local governments.

Given the way that these two scenarios have been defined, their "technical content" in terms of available instruments may vary from one city to another. For instance, in Oslo there is already a cordon toll ring in place, and the implementation of higher, lower or time differentiated toll rates is considered to be within the limits of the current institutions. A local fuel tax, on the other hand, would require a special legal provision, since excise taxes cannot presently be levied by any authority other than the central government. In Helsinki, the converse is true: a toll ring would require special legal provisions, and hence belongs in strategy *P22/S22*, while a fuel tax is considered to be within the authorities of the modelled urban region, and can be included in policy package *P21/S21*.

The detailed content of each sub-package (*P21/S21* or *P22/S22*) will, therefore, for this and other reasons, depend on the local conditions. It will – in our model simulation exercise – inevitably also reflect the analytic opportunities offered by the various modelling frameworks. As indicated in section 1.2 above, the various models differ in terms of what kind of policy instruments they are able to deal with in a meaningful way.

3.3.1 Edinburgh

In the START model for *Edinburgh*, the following policy instruments are considered within the *P21/S21* (Second-best under current institutions) strategy:

1. city centre cordon toll
2. outer cordon toll

3. parking charges
4. fuel tax
5. smart card system allowing distance based charges within a specified cordon

The fuel tax is modelled as a distance based charge, meaning that no account is taken of the fact that fuel consumption per kilometre may vary depending on speed etc, nor of the fact that vehicles may differ in terms of fuel economy. In the short term, a fuel tax is unlikely to yield very different behavioural responses from a distance based charge. In the long term, however, a fuel tax would provide an incentive to prefer fuel efficient vehicles. To the extent that this incentive affects the composition of the vehicle pool, it will serve to gradually reduce the fuel tax base and hence also the revenue collected.

The Edinburgh "smart card" measure is a hypothetical device which would allow distance based charging to apply – if desirable – only within certain areas, and where a set of minimal and maximal rates could be specified.

After institutional reform (*P22/S22*), some additional instruments are deemed available:

6. public transport fares
7. public transport frequency
8. outer ring road cordon distance based charge

Since public transportation is currently deregulated in Edinburgh, for a public policy maker to regain control of the fare and frequency instruments, an institutional reform would be required.

As a general rule, the scenarios calculated for Edinburgh make use of a 0.25 shadow price of public funds. Certain scenarios are, however, recalculated under the assumption of a zero shadow price, somehow providing sensitivity tests with respect to this assumption.

Optimisation for Edinburgh is done with respect to only one road pricing instrument at a time. This procedure generates a large array of comparable scenarios, of which only a few will be dealt with in this report. We shall be concentrating on the following solutions:

S21: second-best strategy applying only an outer cordon toll (instrument 2) in addition to parking charges, the latter being constrained to a maximally 300 % increase

P21: as *S21*, but assuming a zero shadow price of public funds.

S22: unconstrained second-best strategy based on fuel tax (instrument 4)

P22: as *S22*, but assuming a zero shadow price of public funds.

3.3.2 Helsinki

In the MEPLAN model for *Helsinki*, the following instruments are considered "under current institutions" (*P21/S21*):

1. public transport fares
2. parking charges
3. fuel tax

After institutional reform (*P22/S22*), the following instruments are added:

4. city centre cordon charges
5. outer ring cordon charges
6. zone- and distance based congestion pricing

All Helsinki scenarios are derived under two alternative assumptions regarding the shadow price of public funds (0 or 0.25).

3.3.3 Oslo

In the RETRO model for Oslo, the instruments available under current institutions (*P21/S21*), are these:

1. cordon toll rates
2. parking charges.

In the Oslo model, public transport *fares* are not used as an instrument. Public transport *frequency* is, however, allowed to adjust to changes in demand, so as to keep congestion in the public transport system at an approximately constant level.

After institutional reform (*P22/S22*), it is envisaged that the following policy instruments would also become practicable:

3. fuel tax
4. vehicle tax.

The vehicle tax may take the form of an annual ownership tax or a tax on first-hand vehicle acquisition (car purchase tax).

The use of the fuel and vehicle tax instruments, however, raises some tricky analytical problems. Car ownership is, in the RETRO model, not an exogenous variable. According to the model's simultaneous, discrete-continuous *car ownership and use submodel* (see Ramjerdi and Rand 1992, de Jong 1990), changes in the *fuel price* affect not only the annual distance driven per vehicle, but also – in the medium and long run – the number of vehicles owned, i.e. the size of the car stock. More trivially, the cost of *owning* a car obviously also affects aggregate vehicle ownership and hence also the total annual number of car kilometres driven within the study area.

But since our study area is limited to the city of Oslo and the surrounding county, while cars are frequently also used for longer distance trips (indeed, some families may decide to own a car precisely in order to use it for such purposes), it is not straightforward to identify the relevant consumer surplus (or deficit) derived from an increased (or decreased) private car ownership among the Oslo resident population. Our modelling framework does not keep track of trips made outside the borders of the greater Oslo urban area, and hence cannot calculate their utility.

For maximum transparency in view of these conceptual difficulties, the *P22/S22* policy package for Oslo has been subdivided into three subscenarios:

P22/S22: Short term second-best after institutional reform

P22b/S22b: Medium term second-best after institutional reform

P22c/P22c: Medium term second-best after extended institutional reform.

The *P22/S22* variant is one in which, although the *price of fuel* changes, we do not allow car ownership rates to respond. This situation may be interpreted as the short term impact of the second-best policy, since it will take time for the consumers to acquire or get rid of larger capital assets such as a motor vehicle.

In the *P22b/S22b* variant, on the other hand, we assume that consumers have been allowed the time to adjust their vehicle ownership to a new equilibrium, responding to a change in the price of fuel.

In neither of these cases, however, do we assume *vehicle tax* rates to be available as local policy instruments. This instrument is considered available only in the *P22c/S22c* scenario, which presupposes "extended institutional reform", introducing local jurisdiction over annual car ownership taxes[9].

3.4 "Acceptable" policies (P3/S3)

In the face of growing problems of congestion and environmental degradation, first-best and second-best policy packages are likely to involve some rather stiff charges of one kind or another. The AFFORD project starts from the paradox that such first- or second-best policies are notoriously rejected by the communities they are designed to serve.

As a third general type of scenarios, therefore, AFFORD modelling teams have studied a set of policy packages (*P3/S3*) termed "*acceptable*". These are policy options which, according the modellers' judgement, and considering the local

[9] Both forms of taxation – a local fuel tax and a local vehicle tax – obviously represent challenging practical problems of enforcement, if massive tax evasion is to be avoided. The local fuel tax in effect in the city of Tromsø (northern Norway) is practicable only because the nearest tax-exempt gas station is located more than 70 kilometres outside the city centre.

conditions and experience, are more likely to gain the public and political support necessary for implementation.

To some extent, the acceptable policy packages are designed so as to correspond to the "acceptable" strategy presented to the respondents of the AFFORD attitudinal mail survey (see AFFORD Deliverable 2C, by Schade et al, 1999; Schade and Schlag, 2000). This provides us with insight, not only into the public acceptability of such measures, but also into their impact on economic welfare and equity.

3.4.1 Edinburgh

In Edinburgh, "acceptable" scenarios were constructed by putting a ceiling on the charges arising from the *P22/S22* optimisation.

Parking charges were limited to a 300% increase in real terms and that the maximum road pricing charge for any origin-destination zone pair be 5 Euros. This gave rise to the following scenario:

S3: "acceptable" strategy based on fuel tax (instrument 4), but constrained in such a way that the charge would never exceed 5 Euros for any trip regardless of length.

In addition, the Edinburgh model has been used to simulate a "futuristic" road charging system based on the smart card (instrument 5). We shall denote these scenarios by

S4: "acceptable" strategy involving maximally 300 % increase in parking charges, fare reductions and frequency enhancements for public transport, and a "smart card" scheme for constrained distance based charges (minimum 1, maximum 4 Euros per trip)

S4a: as *S4*, but assuming a 50 per cent increase in public transport fares and a 75 per cent increase in frequency.

3.4.2 Helsinki

In Helsinki, the assumptions made in the "acceptable" scenario (*P3/S3*) were adapted from the description in the attitudinal questionnaire for cities without a toll cordon, as follows:

- no parking charge increase
- a fuel tax increase of 0.125 Euro/litre,

with revenues spent as follows:

- one third to invest in capacity expansion of known bottlenecks
- one third of revenues to lower fares (–33%) in public transport
- one third left as a revenue for the government.

3.4.3 Oslo

The assumptions made in the "acceptable" scenario for Oslo (*P3/S3*) correspond, roughly speaking, to the description in the attitudinal questionnaire:

- a cordon toll rate of 1 Euro at all times
- parking charges increased by 0.25 Euros
- a fuel tax increase of 0.125 Euros

with revenues spent as follows:

- one third to lower the vehicle ownership tax
- one third to lower public transport fares.

The last item mentioned in the questionnaire – "one third to invest in capacity expansion of known traffic bottlenecks and/or to improve parking facilities" – was considered fulfilled already, as the major road improvements in Oslo in later years have to a large extent been financed by toll revenue.

One notes that this policy package is in fact rather softer than the policy currently in place in Oslo, which involves a cordon toll rate of about 1.5 Euros per single ticket and a rate of 1 Euro per passing only on the maximally large discount coupons.

4 The efficiency of marginal cost road pricing

In this chapter, we provide summary accounts of the economic efficiency results obtained for each case study city.

4.1 Edinburgh results

Box 4.1 summarises Edinburgh policy scenarios.

Policy scenario	Shadow price of public funds	
	0	0.25
Reference case		
Foreseen strategy (2010)	*P02*	
First-best marginal cost pricing		
Narrowly first best	*P11*	*S11*
Second-best marginal cost pricing		
Second-best under current institutions: outer cordon toll	*P21*	*S21*
Second-best after institutional reform: fuel tax	*P22*	*S22*
"Acceptable" pricing		*S3*
"Smart card" system with enhanced public transport		*S4a*

Box 4.1: Edinburgh policy scenarios.

4.1.1 Costs and benefits

The main results for Edinburgh are summarised in Figure 4.1. The first-best solution with a 0.25 shadow price of public funds (*S11*) yields an overall welfare improvement valued at 390 Euros per capita per annum. This benefit, however, emerges as a balance between three rather different components: travellers incur a welfare loss of 378 Euros, while operators and government earn a surplus valued[10] at 669 Euros per capita per annum, tipping the balance in favour of an overall welfare *improvement.* On top of that, certain environmental and safety benefits accrue, worth 100 Euros per capita per annum over 30 years.

[10] Recall that a one Euro public revenue is valued at 1.25 Euros.

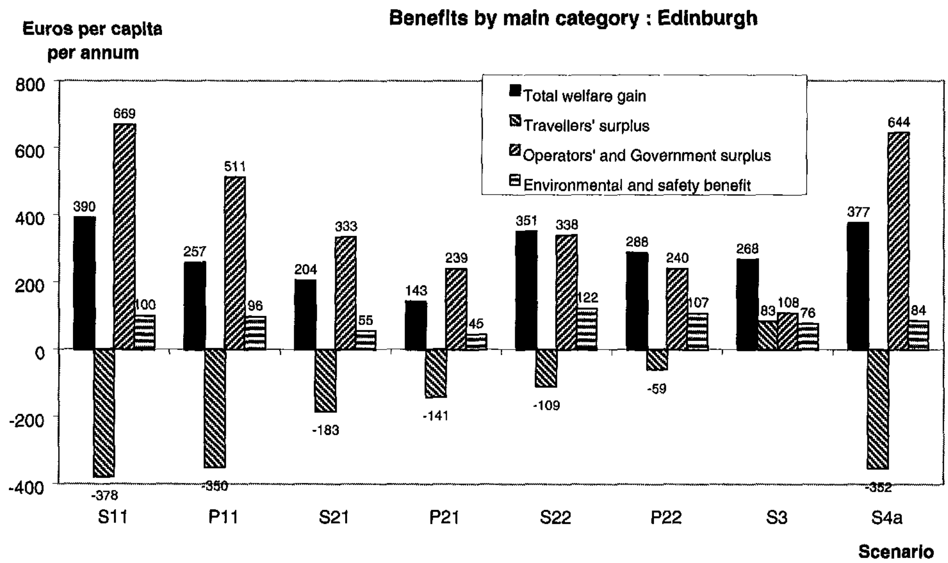

Figure 4.1: Edinburgh: Benefits by main category.

Part of this surplus is due to the extra value (0.25) assigned to a Euro public revenue. In the *P11* scenario, where this value is set to zero, in the optimisation as well as in the subsequent cost-benefit accounts, the total welfare improvement is 35 per cent smaller, viz 257 Euros per capita per annum.

Turning to second-best solutions, we find smaller welfare improvements than in the first-best scenario, but larger improvements based on the fuel tax instrument (*P22/S22*) than by means of an outer cordon toll ring (*P21/S21*). The *S21* scenario, where only a outer toll cordon and a constrained parking charge is used, is able to reproduce only about half the total benefit inherent in the first-best solution. But the *P22* scenario provides an annual welfare gain amounting to 351 Euros per head – a full 90 per cent of the first-best optimum. The *S4a* scenario, in which a smart card is used to keep charges within acceptable limits, while PT fares and frequency are stepped up, even reaches 97 per efficiency compared to the first-best scenario (377 Euros per capita per annum).

In six out of seven scenarios shown in Figure 4.1, the travellers themselves incur a loss, at least "in the first place"[11].

However, when this negative private benefit is decomposed, between monetary benefits and time benefits, it becomes evident that even the travellers' surplus is a balance between two items of opposite sign. The time benefit is positive in all

[11] We shall revert to the question of what happens "in the second place", i.e. if the operators' and Government surplus is somehow redistributed to private consumers.

scenarios, while the monetary "benefit" – composed by extra out-of-pocket expenditure and reduced accessibility – is everywhere negative (Figure 4.2). Only the *S3* scenario leads to a positive private user benefit – an indication that the label "acceptable" may not, in this case, be too misleading.

From the point of view of resource economics, the picture shown so far is, however, grossly misleading, in that it does not distinguish between (i) true economic costs (*resource costs*) and (ii) cash flow *transfers* between different sectors of the economy. The toll, tax, parking and public transport expenditure incurred by private travellers are not resource costs, they are only transfers to the government or public transport operators. These cash flows obviously have their counterparts in form of revenue flows on the part of the recipients.

To assess the resource economic content of the various scenarios, we therefore want to make the assumption that all transfers are made to cancel each other out. Assuming that the net public revenue flow (tax, toll, parking, and public transport operators' surplus) is somehow (and costlessly) redistributed to the private consumers, we can draw the picture shown in Figure 4.3, where we compare the differential *resource costs and benefits*[12] characterising the first-best and second-best scenarios. One notes that, if one assumes full revenue redistribution, all policy packages would imply a certain welfare improvement for the private sector as a whole, because the time benefits far exceed the monetary resource costs. The latter consist of (i) increased resource utilisation among transport operators, (ii) increased resource utilisation among private travellers, and (iii) welfare loss due to reduced accessibility.

Figure 4.3 also provides insights into the composition of resource benefits. Time benefits are the largest component in all scenarios. Environmental and safety benefits alternate with the shadow value of public revenue in representing the second largest item.

To identify the costs and benefits pertaining specifically to private consumers, we show, in Figure 4.4, how these fare after full tax and toll redistribution, i.e. assuming that parking charges, road user charges, and fuel tax revenue – but not the public operators' surplus – have been recycled to private consumers.

The overall consumer surplus is positive in all scenarios, although in many cases the time benefits are bought at the cost of a certain monetary expenditure or reduced accessibility (both of which are included in the change in "consumers' monetary benefits").

[12] In this report, we shall understand by *resource costs* (or *benefits*) all (non-pecuniary) utility and resource effects, *including time savings or losses*. That is, we let all transfers cancel each other out, but count all consumables and inputs in the individual utility and production functions. The *shadow value of public revenue* is a resource benefit in that, by assumption, it corresponds to an efficiency improvement for the general economy.

In Figure 4.5, we summarise results for Edinburgh across the various scenarios, subdividing benefits between main recipient sectors.

While the time benefits are fairly stable across the various policy packages studied, the monetary benefits vary greatly, as do their counterpart – the tax and toll revenue.

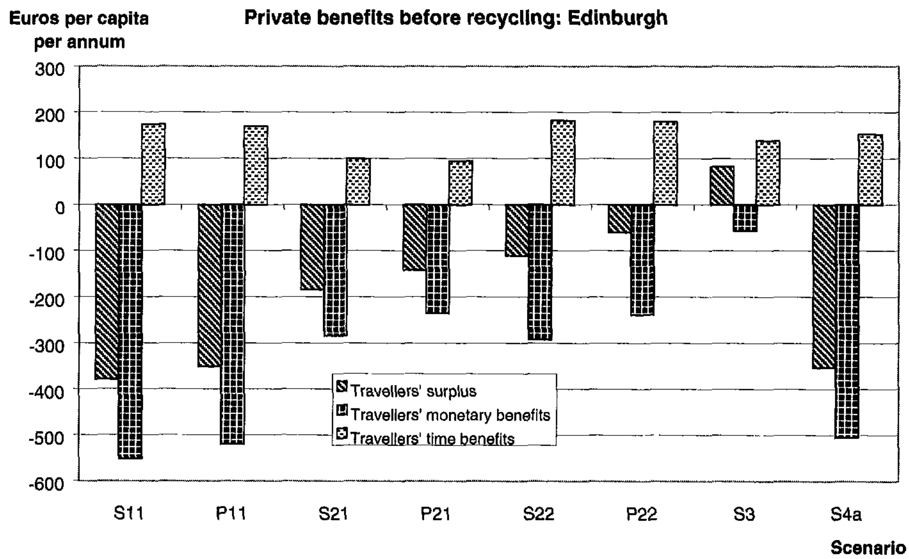

Figure 4.2: Edinburgh. Private costs and benefits before revenue redistribution.

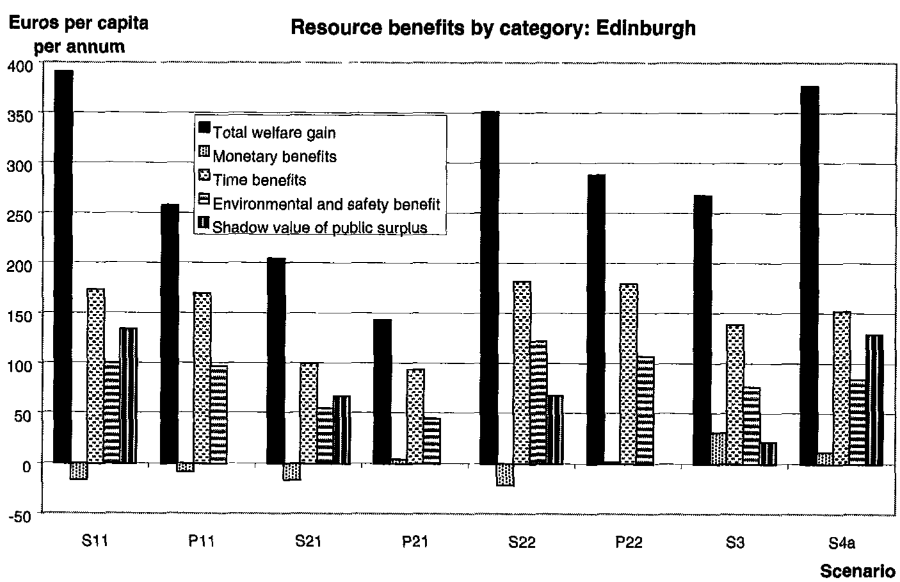

Figure 4.3: Edinburgh. Resource benefits by category.

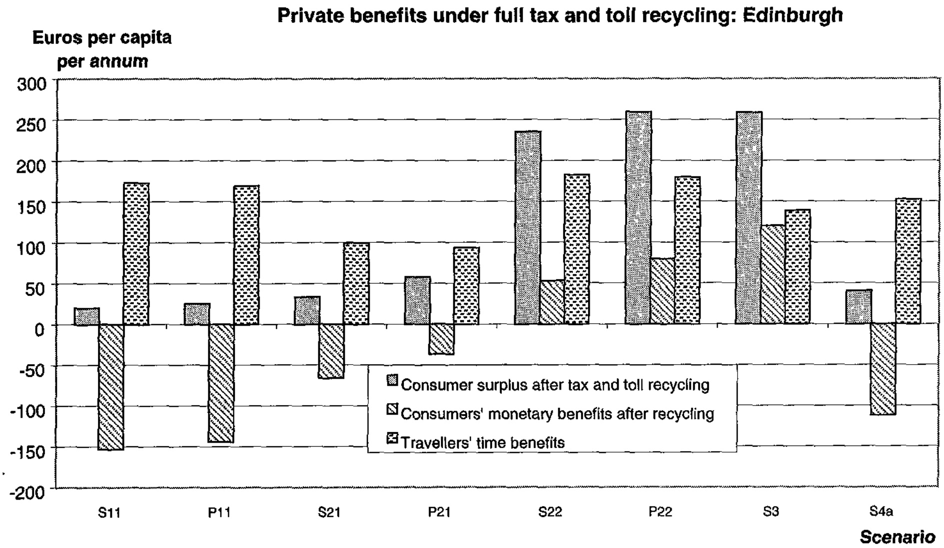

Figure 4.4: Edinburgh: Consumer benefits after recycling of parking charges, toll, and tax.

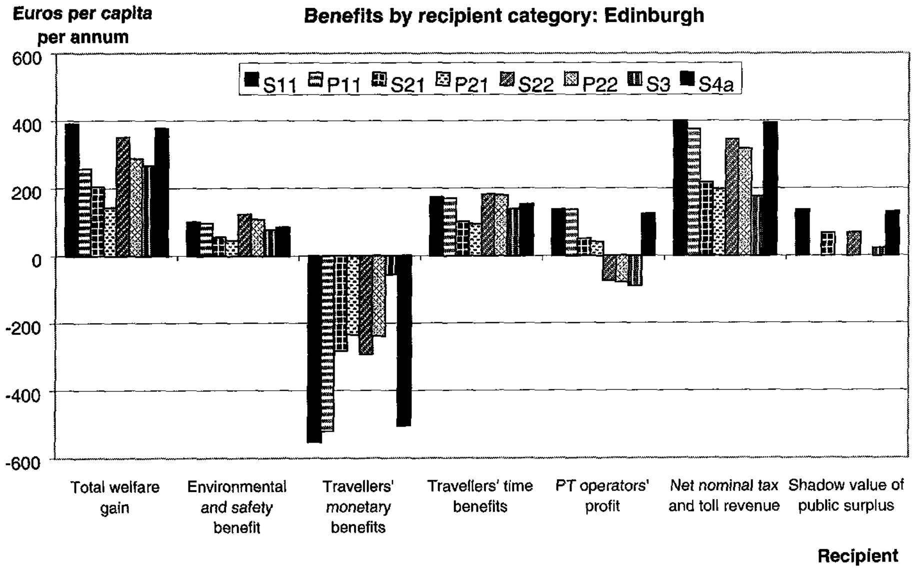

Figure 4.5: Edinburgh. Benefits by main recipient sector, across scenarios.

4.1.2 Travel behaviour effects

How does marginal cost road pricing affect travel behaviour? Some key indicators are shown in Figures 4.6 to 4.8.

All policy packages considered in Edinburgh lead to a massive transfer of trips from private cars to public transport. In most cases the overall travel demand also goes down (Figure 4.6).

In some cases, however, the average trip length for private motorists increases, in response to cordon toll rings which induce travellers to follow a longer route or choose a farther destination (scenarios *P21*/*S21* of Figure 4.7).

The product of trip frequency and trip length is the total travel demand in terms of person kilometres. From an environmental perspective, this is perhaps the most interesting indicator. One notes that, according to the Edinburgh case study, marginal cost road pricing can be very efficient in reducing the amount of travel by car. In the *S22* scenario, private motoring is more than halved, while public transport is almost doubled.

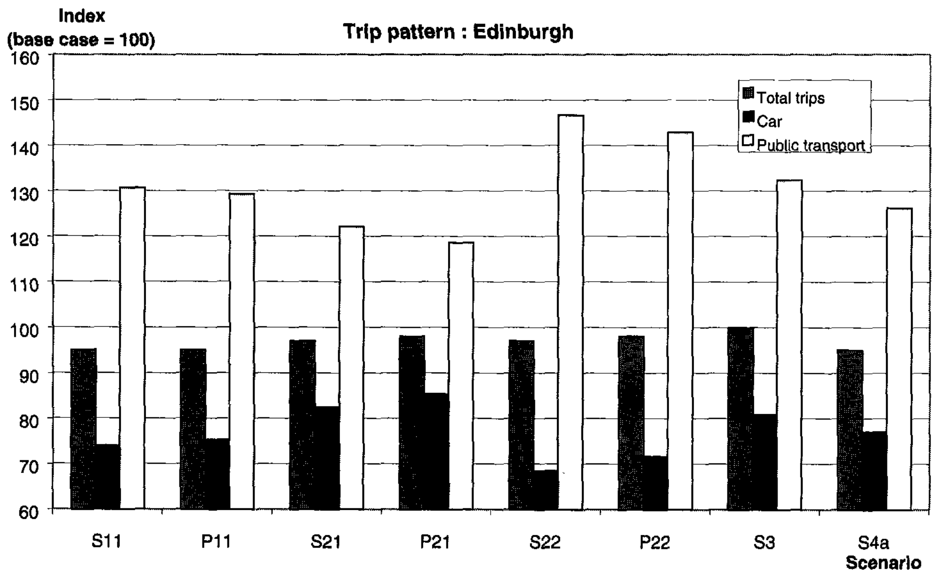

Figure 4.6: Edinburgh. Impact of marginal cost pricing on trip frequency by mode.

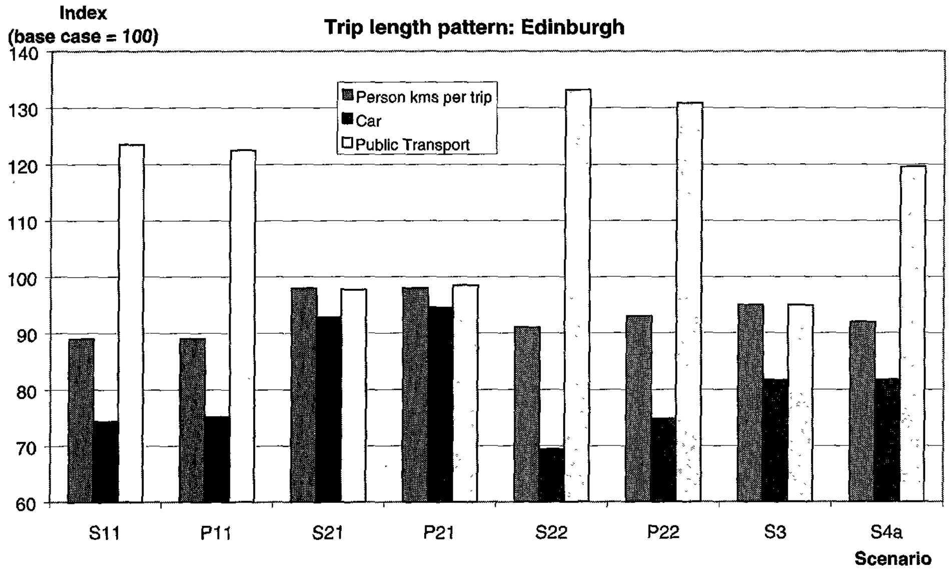

Figure 4.7: Edinburgh. Impact of marginal cost pricing on average trip length by mode.

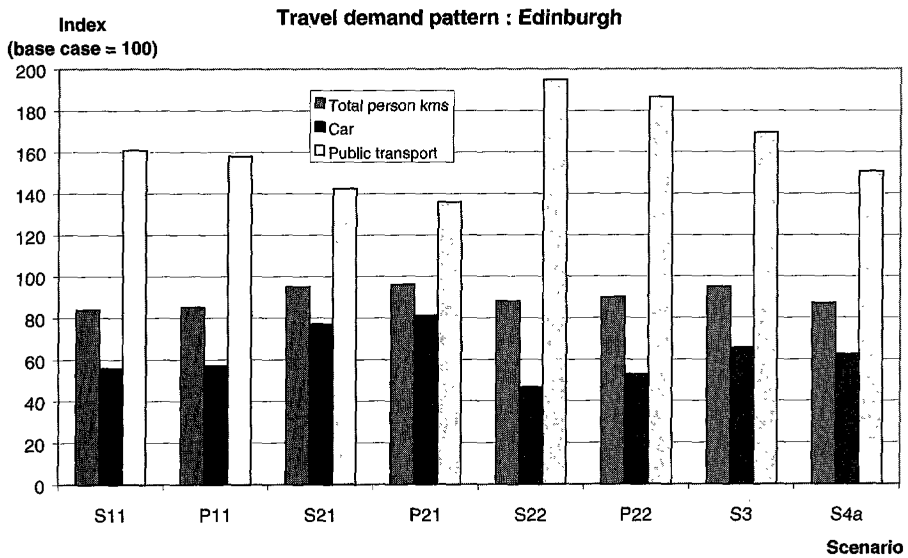

Figure 4.8: Edinburgh. Impact of marginal cost pricing on person kilometres travelled, by mode.

4.2 Helsinki results

Box 4.2 Summarises Helsinki policy scenarios.

Policy scenario	Shadow price of public funds	
	0	0.25
Reference case		
Foreseen strategy (2020)	*P02*	
First-best marginal cost pricing		
Narrowly fiist-best	*P11*	*S11*
Second-best marginal cost pricing		
Second-best under current institutions	*P21*	*S21*
Second-best after institutional reform	*P22*	*S22*
"Acceptable" pricing		*S3*

Box 4.2: Helsinki policy scenarios.

4.2.1 Costs and benefits

In Figure 4.9, we show main results for Helsinki. Under the assumption that (alternative) public revenue is raised without loss of efficiency throughout the economy, the welfare gain obtainable from an ideal, first-best marginal cost road pricing scheme has been calculated at 216 Euros per capita per annum over a 30-year period including the environmental costs, resource costs and accident costs. The best practice second-best solution under current institutions is able to gain 169 Euros per capita per annum or 78 per cent of the first-best package.

If it is true that public funds have a non-zero shadow price, the welfare improvement attainable through marginal cost road pricing is enhanced. In the "full" second-best scenario before institutional reform, the overall welfare gain is 45 per cent higher than in the "simplified" second-best scenario (243 versus 168 Euros per capita per annum – compare scenarios *S21* and *P21*).

Thus, the inclusion of cost of funds increases welfare as measured by our *EEFP* objective function but reinforces the polarising effect of leaving the transport users worse off and collecting more revenue for the government. The impacts on externalities are more or less the same.

The institutional reform (*S22* and *P22*, allowing for congestion charging) is not effective compared to current institutions (*S21*/*P21*, having only fuel tax). This is due mainly to two conditions. Firstly, the total welfare gain is coming from the reduction in the urban sprawl and not from the pure congestion. The reference scenario already includes major investment in the transport infrastructure that solves the problems of growth and increased mobility. Secondly, the re-optimised fuel tax can more or less cover the welfare benefits of the congestion charging system that is rougher than the first-best system. Therefore the way the congestion charging system is planned in spatial detail is important.

Figure 4.9 also includes the "acceptable" scenario *S3*. Further (non-planned) investments into infrastructure are not beneficial, as the reference scenario has not left any major problems to be solved by further investments.

In Figure 4.10, we report benefits from all main scenarios, decomposed by main recipients.

A striking feature of the Helsinki scenarios is the importance of environmental benefits. In general, these are almost as large as the overall total benefit. In other words, the second-best marginal cost pricing policies in Helsinki would produce relatively small welfare gains, were it not for the environmental benefit measured with a fixed cost saving per pollutant ton from transport as defined by the standard assessment method used in Finland.

With few exceptions, the most welfare improving second-best policies are those which squeeze out considerable amounts of money from private travellers, yielding considerable government revenue.

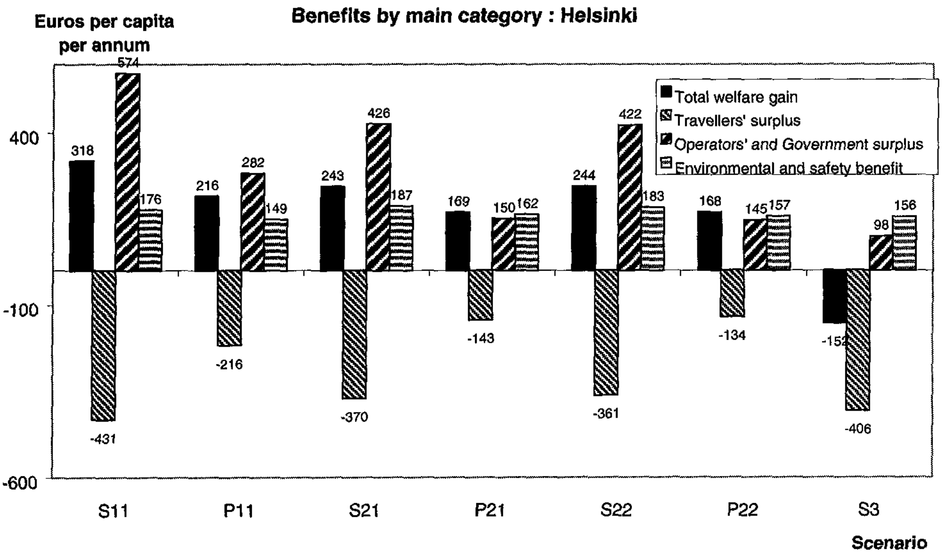

Figure 4.9: Helsinki: Benefits by main category. Second-best solutions with or without cost of funds.

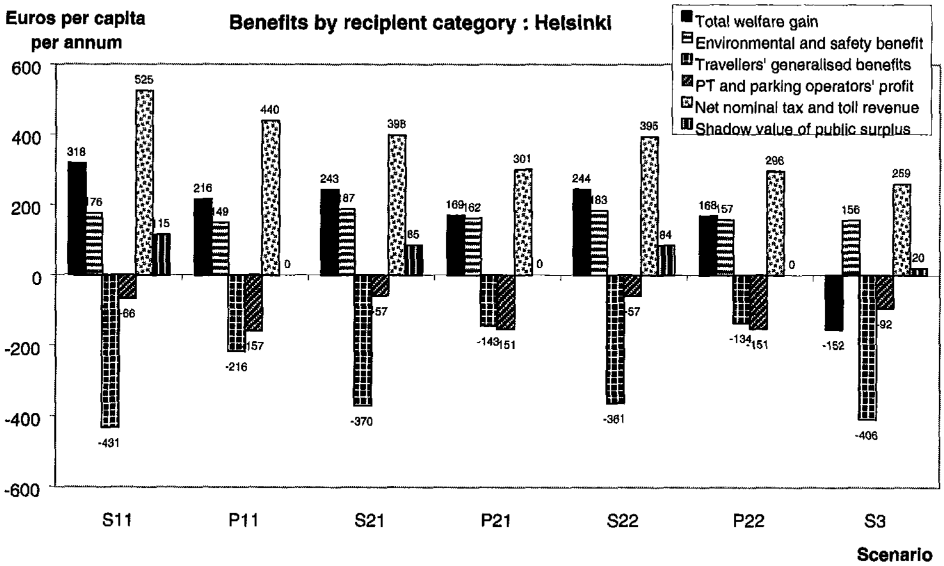

Figure 4.10: Helsinki: Benefits by main recipient sector.

4.2.2 Travel behaviour effects

The impact of second-best pricing on travel behaviour is shown in Figures 4.11 to 4.13, which correspond to Figures 4.6 to 4.8 for Edinburgh. As in Edinburgh, the pricing policy packages are apt to curb private car use by as much as 50 per cent, however without producing – in Helsinki – correspondingly large increases in public transport demand. It appears that in Helsinki, the effect of stiff marginal cost pricing will be to curb overall mobility more than to shift demand into public transport modes.

When a non-zero shadow price of public funds is used in the optimisation, higher public transport fares result, since extra value is assigned to profits in the public transport companies. Thus, by comparing scenario *S22* to *P22*, or *S21* to *P21*, we get an indication of the effect of changes in public transport fares. Interestingly, lower fares appear to attract bicyclists and pedestrians at least as much as car drivers. When both fuel prices and fares are raised in response to a non-zero shadow price of public funds, people switch towards biking and walking, rather than to private cars, in order to avoid the higher prices.

Figure 4.14 illustrates the impact of marginal cost pricing on average travel speeds, when no major congestion problems exist and long term land use effects are taken into account, as in the Helsinki model. As land use concentrates closer to the city centre, the street network with lower free flow speeds receive more traffic. This has the effect of lowering the average speed as 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.

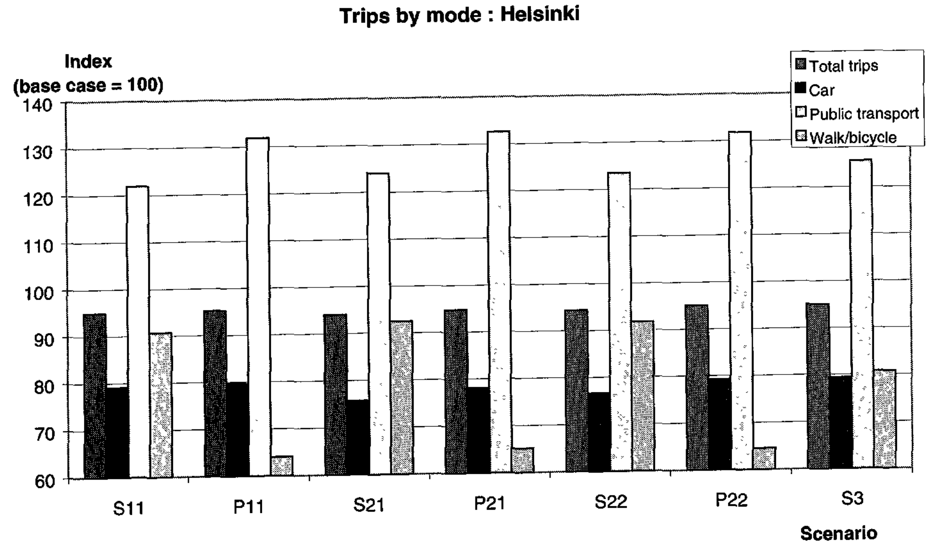

Figure 4.11: Helsinki: Impact of marginal cost pricing on trip frequency by mode.

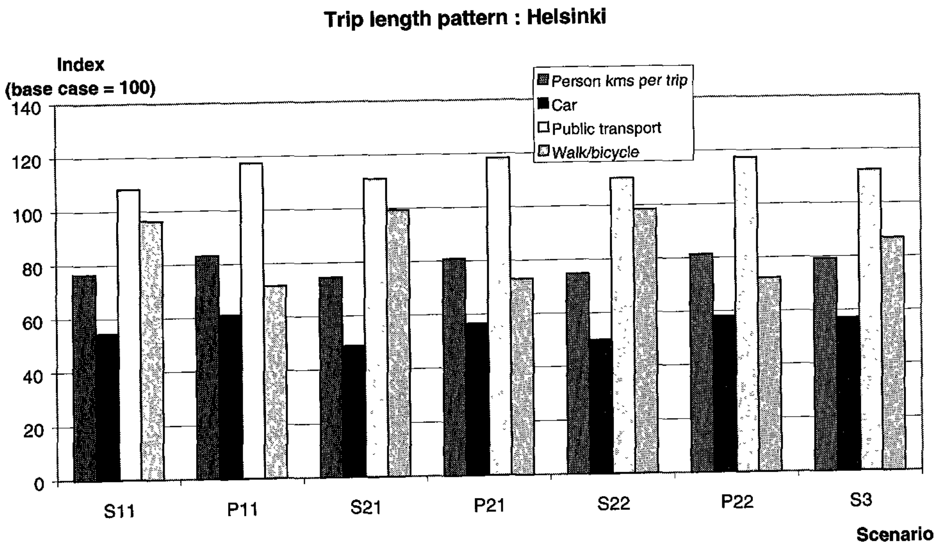

Figure 4.12: Helsinki: Impact of marginal cost pricing on average trip length by mode.

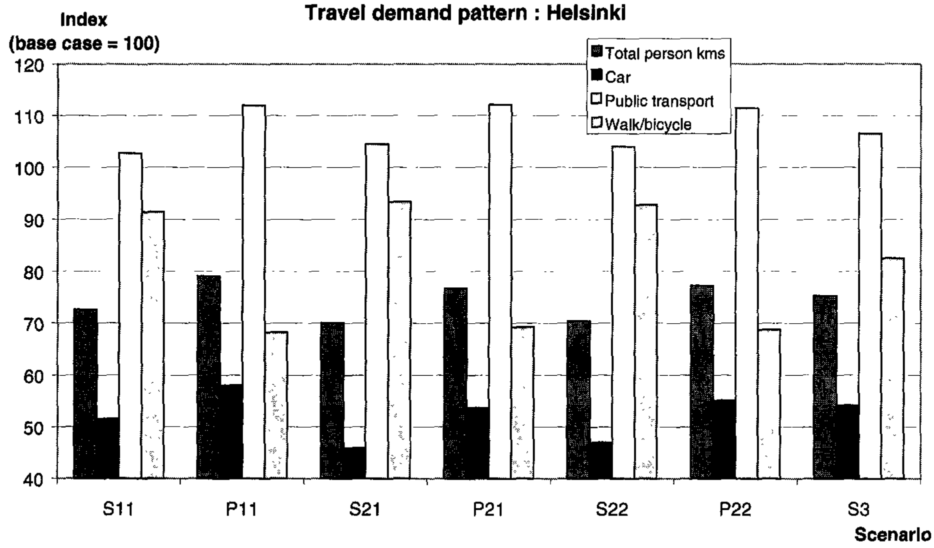

Figure 4.13: Helsinki: Impact of marginal cost pricing on person kilometres travelled, by mode.

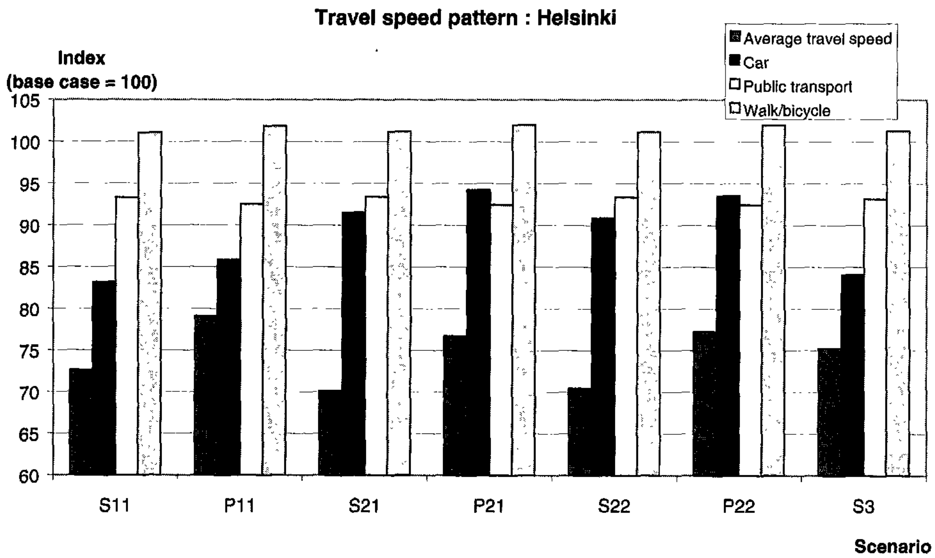

Figure 4.14: Helsinki: Impact of marginal cost pricing on travelling speed, by mode.

4.3 Oslo results

Box 4.3 summarises Oslo policy scenarios.

Policy scenario	Shadow price of public funds	
	0	0.25
Reference case		
Business-as-usual (1995)	*P01*	
First-best marginal cost pricing		
Narrowly first best	*P11*	*S11*
Second-best marginal cost pricing		
Second-best under current institutions	*P21*	*S21*
Short term second-best after institutional reform	*P22*	*S22*
Medium term second best after institutional reform	*P22b*	*S22b*
Medium term second best after extended institutional reform	*P22c*	*S22c*
"Acceptable" pricing		*S3*

Box 4.3: Oslo policy scenarios.

4.3.1 Costs and benefits

Under the assumption that the marginal cost of public funds is zero, meaning that (alternative) public revenue can be (and – indeed – *is*) raised without loss of efficiency throughout the economy, the welfare gain obtainable from an ideal, first-best marginal cost road pricing scheme in Oslo has been calculated at *75 Euros per capita per annum* over a 30-year period (*P11* in Figure 4.15).

Under the alternative assumption of a 0.25 shadow price of public funds, the overall benefit more than doubles, reaching 199 Euros per capita per annum (*S11*).

The second-best solution under current institutions (*P21*) for Oslo invokes the use of (i) cordon toll rates (peak and off-peak) and (ii) parking charges. It turns out that, if one assumes away the cost of funds, these instruments are rather inefficient compared to the ideal first-best policy. The overall welfare improvement in the *P21* scenario amounts to a mere *12 Euros per capita per annum*, or 16 per cent of the theoretically optimal ("first-best") gain under zero cost of funds.

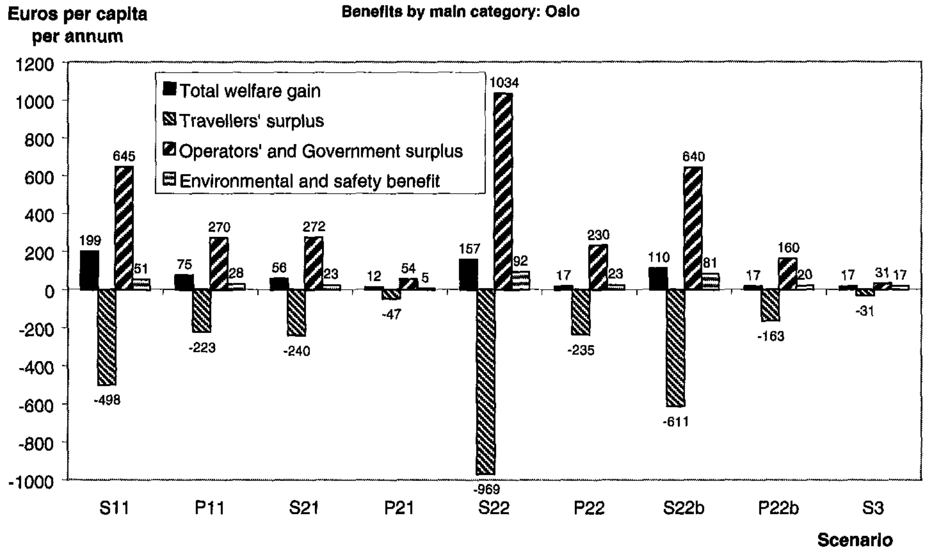

Figure 4.15: Oslo. Benefits by main category.

This rather discouraging result must, however, be interpreted with caution. We cannot rule out certain methodological explanations, such as the fact that our model specifies only two, rather crude travel time periods ("peak" and "off-peak") and does not allow for substitution between them. Nor can we exclude the possibility that these results are strongly tainted by the particular traffic conditions in Oslo, notably by the location of the cordon toll ring, which is such as to maximise revenue rather than to restrain the traffic, and by the fact the toll revenue has facilitated massive improvement in the road network, to a point where congestion is kept at a fairly moderate level.

When a 0.25 shadow price of public funds is assumed, the second-best policy under current institutions (*S21*) achieves a 56 Euro per capita annual benefit, or 28 per cent of the first-best solution.

Turning to the *S22*/*P22* scenarios (short term second-best after institutional reform), in which the fuel tax is allowed as a third policy instrument, welfare gains increase noticeably, especially under non-zero cost of funds (*S22*), in which case the benefit is seen to almost triple from the *S21* scenario. The *P22* scenario, on the other hand, represents a mere 50 per cent improvement from *P21*, achieving no more than 23 per cent of the first-best benefit (*P11*).

The *S3* ("acceptable") policy package for Oslo scenario makes little difference. An overall annual benefit of 17 Euros per head is generated – less than 10 per cent of the first best solution – mainly because of the environmental and safety benefit, which also amounts to 17 Euros per capita per annum. The travellers' deficit and the public surplus cancel each other out exactly.

As in Edinburgh and Helsinki, almost all scenarios are characterised by a negative travellers' surplus before revenue recycling. Assuming, however, that the net public revenue flow (tax, toll, parking, and public transport operators' surplus) is somehow (and costlessly) redistributed to the private consumers, even the second-best solution would imply a certain welfare improvement for the travellers. In Figure 4.16, we compare the differential *resource costs and benefits* characterising the first-best and second-best scenarios. In this picture, we have let the money transfers between the private and the public sector cancel each other out, so that we are left with only true (non-pecuniary) utility and resource effects.

One notes that, in all scenarios, the total welfare improvement decomposes into a *negative* monetary benefit and a *positive* time benefit.

Marginal cost road pricing has the double effect of *discouraging congestion* and *raising public revenue*. To the extent that public funds are a scarce resource, the latter effect may be well the more important as seen in an economic efficiency perspective. This is at least the case in a less heavily congested city like Oslo.

This would, however, depend on how the road pricing revenue is used. If it is used to step down distortionary taxation somewhere else in the economy, or to extend the supply of a public good for which the willingness-to-pay exceeds the marginal cost of production, then a "double dividend" accrues. If, on the other, the revenue is redistributed to the private sector in a way that does not improve the incentive structure faced by economic agents, there is no extra dividend to be accounted for.

The use of a non-zero cost of public funds implicitly assumes that a double dividend somehow does arise.

A bit simplified, one might say that in Oslo, second-best marginal cost pricing is socially profitable first and foremost because it is – we assume – an attractive form of taxation. If, on the other hand, the marginal opportunity cost of public funds is *not* larger than zero, the benefit of marginal cost pricing is very substantially reduced.

Indeed, in the second-best scenarios *S22* and *S22b*, the benefit derived form the shadow value of public funds is larger than the overall benefit of the policy (Figure 4.16).

This point is further illustrated by a comparison between the *S22b* and *S22* scenario, and between *P22b* and *P22*.

The *S22* scenario makes use of the fuel tax instrument, however without allowing households to reduce car ownership in response to rising costs of fuel. Thus, in this scenario, the pricing policy is, in a sense, "twisting the arm" of private households, squeezing out considerable tax revenue. The optimal fuel tax in this scenario comes out at +166 per cent, i.e. 2.66 times the current level. Parking charges are up by 40 and 20 per cent, and toll rates by 200 and 120 per cent, in peak and off-peak periods, respectively.

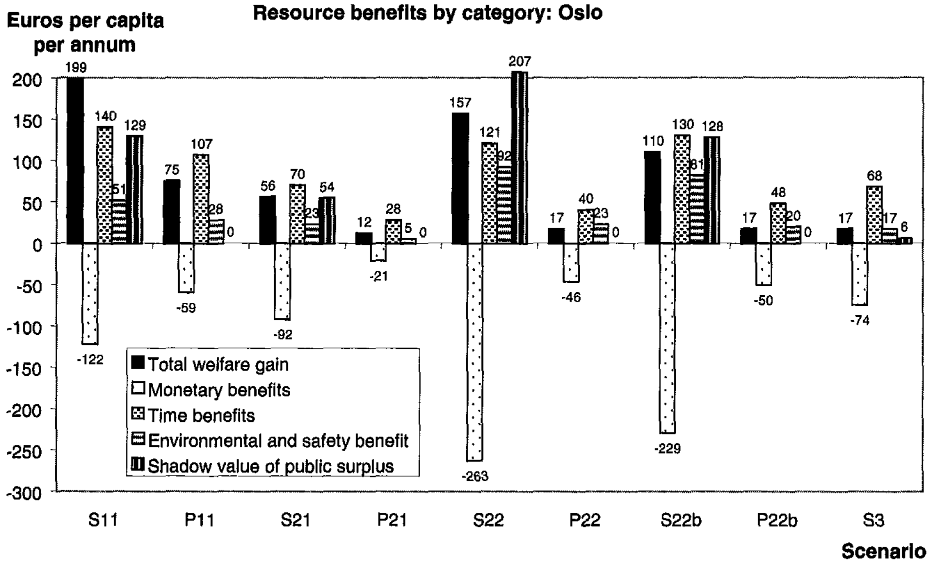

Figure 4.16: Oslo. Resource benefits by category

In *S22b/P22b*, we allow car owners the time to get rid of their cars, in cases where the total annual cost of ownership and use exceeds the utility derived from it. When the price of fuel goes up, a number of households may want to choose a consumption bundle including less car ownership and use.

When the cost of public funds is larger then zero, such an opportunity to evade the fuel tax clearly reduces the social profitability of marginal cost pricing (compare *S22b* to *S22*). Under the zero cost of funds, however, it does not matter much for the optimal solution whether the households are allowed to change their consumption of cars (compare *P22b* to *P22*).

In Figure 4.17, we show private benefits (monetary and time benefits as well as their balance) after full public revenue recycling. One notes that when a particular (shadow) value is attached to public revenue *per se*, the socially optimal policy involves fairly heavy losses to private consumers, even after revenue recycling (*S22* and *S22b*). When no such extra value is assigned to public money, however, there is no point in squeezing out extra revenue from private consumers, and the optimal road charge is set at a level which leaves consumers just about equally well off after second-best pricing, given full revenue recycling.

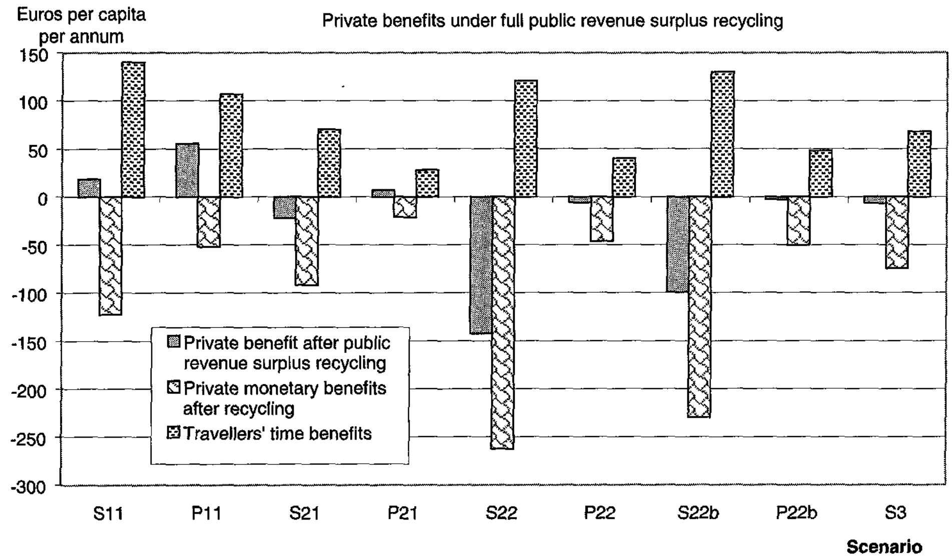

Figure 4.17: Oslo: Private benefits after full revenue recycling.

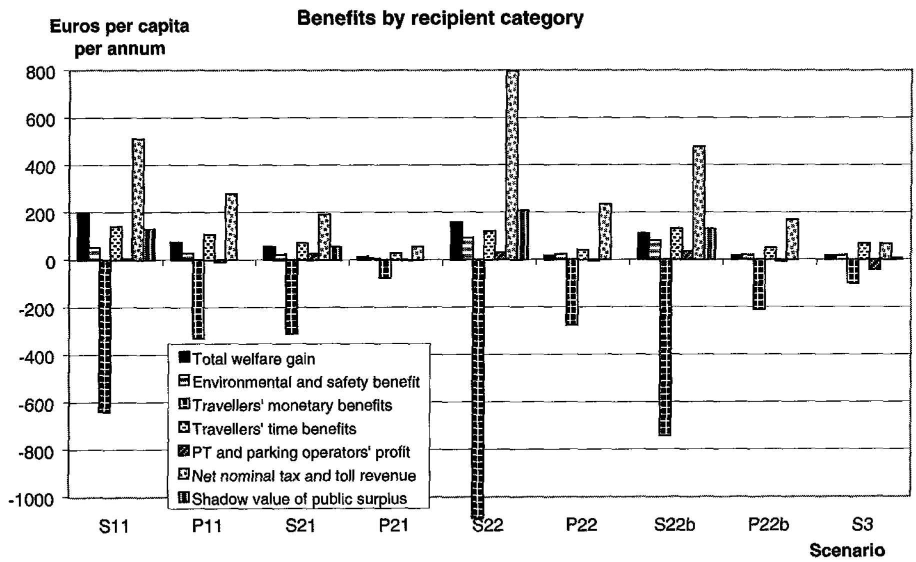

Figure 4.18: Oslo. Benefits by recipient category.

As noted in section 3.3.3 above, the Oslo model also offers the opportunity to study the effect of optimising the *vehicle* tax, in addition the toll, fuel tax and parking charge instruments. This is the content of the *S22c/P22c* scenario - "medium term second-best after extended institutional reform". Thus, in Figure 4.19, we compare second-best scenarios with and without the use of the vehicle tax instrument. Recall that *S22b/P22b* ("medium term second-best after institutional reform") differs from *S22/P22* ("short term second-best after institutional reform") in that car ownership rates are allowed to change in response an increase in the fuel price, and that *S22c/P22c* differs from *S22b/P22b* in that the vehicle tax instrument is invoked as well. Needless to say, also the *S22c/P22c* scenario allows for variable car ownership.

The *S22c/P22c* scenario must, however, be interpreted with great caution, since it is not at all obvious how one should account for the utility of car ownership *per se*. The RETRO model for Oslo takes account of the utility derived from trips made inside the Oslo region only. But a large number of car trips are also made over longer distances. Thus, increased car ownership gives rise to an additional utility component not taken account of in the regional network model. In the cost-benefit analysis, an *ad hoc* procedure, based on the empirically observable split between short distance and long distance travel by car, is used to calculate this utility component and add it on to the consumer surplus measure derived from the regional network model.

This essentially means that in the *S22c/P22c* scenario a rather different objective function is optimised compared to the first-best scenario. Results are therefore not directly comparable with the first-best solution.

Yet, it is interesting to note the vehicle tax instrument seems to add substantially to the obtainable overall welfare gain and even to the time benefits accruing to travellers, although he cost is heavy in terms of overall traveller accessibility and cash expenditure. This is true even if the shadow price of public funds is set to zero.

Somewhat simplified, these results probably reflect the fact that car use in general is closely connected to car ownership, so that an effective way to combat excessive private motoring would be to curb car ownership.

In Figure 4.18, we show costs and benefits decomposed between recipient categories.

In the *S22c* scenario, vehicle tax rates are up by 330 per cent, while the fuel tax increases by only 60 per cent, compared to 102 and 166 in the *S22b* and *S22* scenarios, respectively (Figure 4.20). When the marginal cost of public funds is zero (*P22c*), an even larger diversion of the tax burden, from car use to car ownership, appears optimal: here the vehicle tax is up by 426 per cent, while the fuel tax goes *down* by 19 per cent.

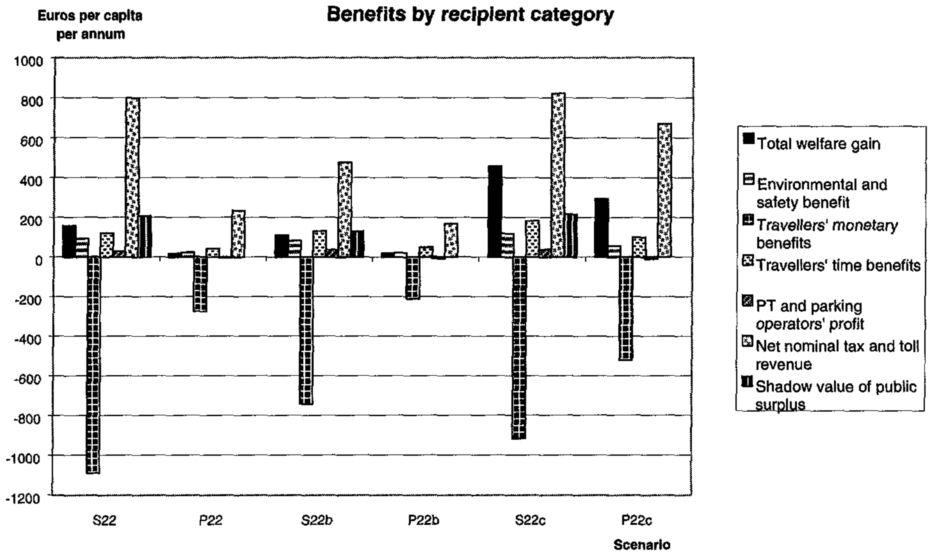

Figure 4.19: Oslo. Second-best scenarios after institutional reform.

It should be noted, though, that vehicle tax increases of this order of magnitude, from the very high level already present in Norway, are entirely unrealistic and politically unthinkable, as they imply a more than 50 per cent cut in aggregate private car ownership.

Thus, the main point of the *S22c/P22c* scenario is to illustrate the following. Although, at first sight, the fuel tax may seem like a clearly more appropriate marginal cost instrument, since – at least under given technology – the charge increases roughly in proportion to the distance driven by each individual driver or vehicle, such a conclusion becomes less obvious in a wider (longer term) perspective. Here, the very rate at which the marginal member of the population decides to own and operate a car becomes highly relevant, since car ownership and use are strongly interrelated elements of behaviour. Therefore, the use of vehicle taxation as a second-best marginal cost pricing instrument is not nearly as inadequate is it may seem from a simplistic, short term line of reasoning, in which one fails to take into account the close *de facto* interrelationship between vehicle ownership and use.

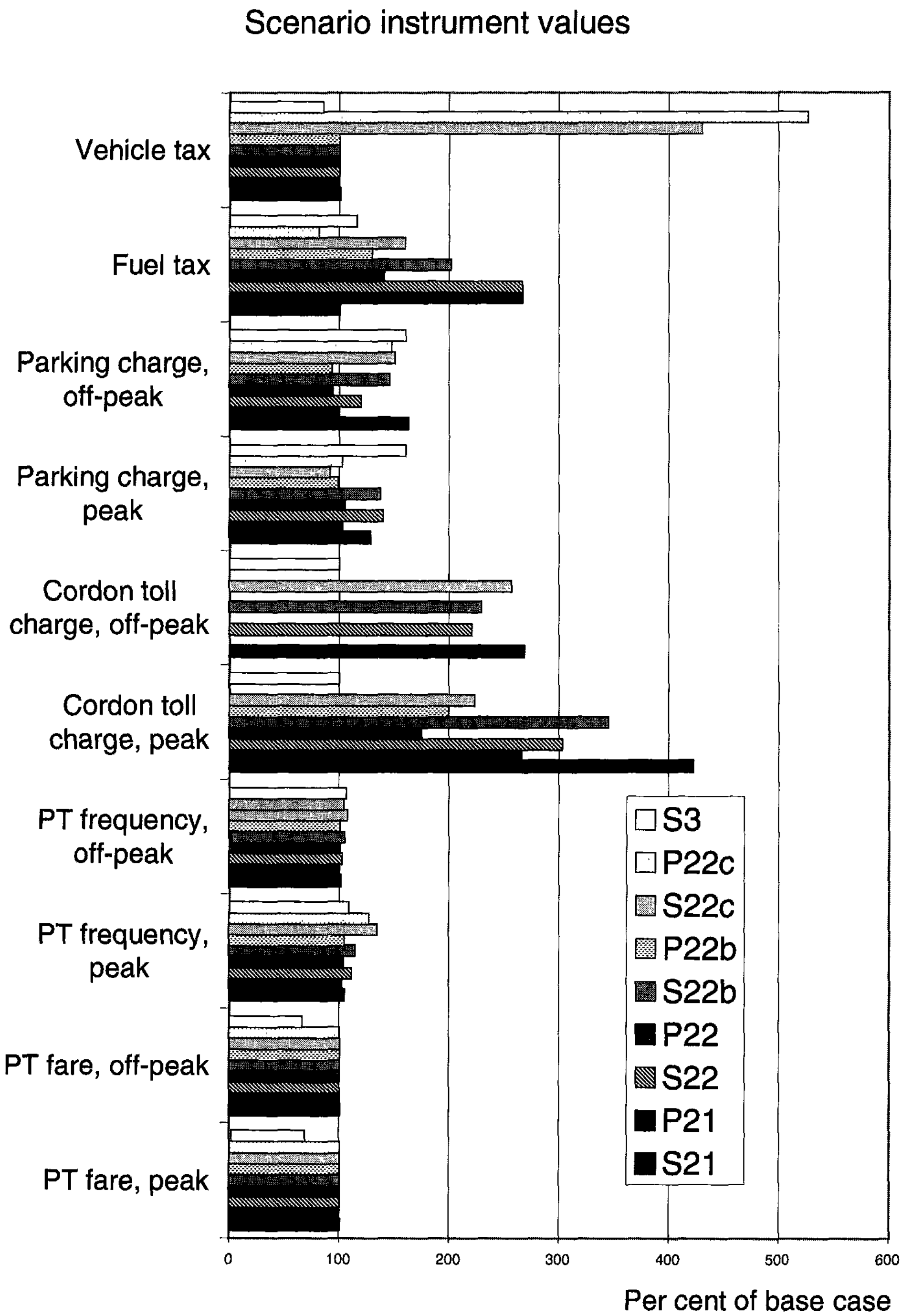

Figure 4.20: Oslo. Policy instrument values under alternative scenarios.

4.3.2 Travel behaviour effects

The effects of marginal cost pricing on travel demand in Oslo are shown in Figures 4.21 through 4.23.

Most scenarios show a moderate transfer of trips form private cars to public transport. Only the unrealistic *S22c/P22c* package, by which most people get rid of their cars, achieves a massive change of mode (Figure 4.21).

Car trips generally become shorter, while public transport trips get longer (Figure 4.22).

Overall travel demand, as measured in vehicle kilometres, is down by up to 10 per cent in the second-best scenarios, while travel by car may drop as much as 20-25 per cent (Figure 4.23).

An interesting picture emerges when one computes the average speed of travel, overall and by mode (Figure 4.24). Although the speed increases within every mode as congestion is relieved, the overall mean speed goes down, on account of the shift from private cars to public transport, walking and bicycling.

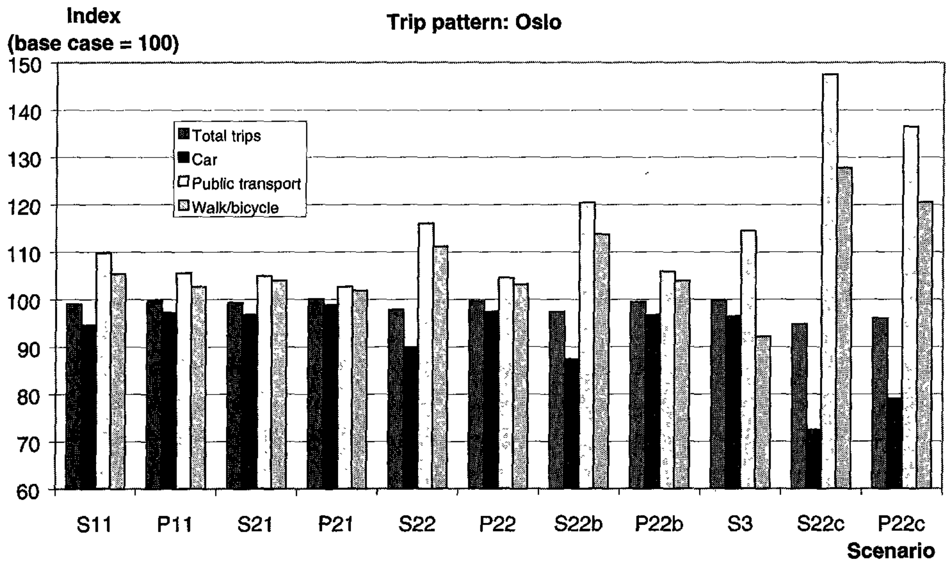

Figure 4.21: Oslo. Impact of marginal cost pricing on trip frequency by mode.

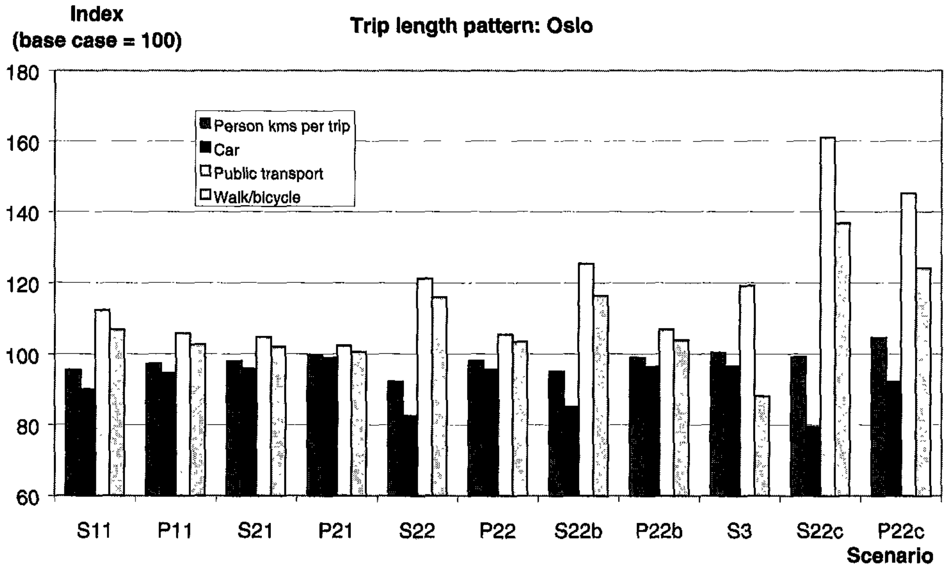

Figure 4.22: Oslo. Impact of marginal cost pricing on average trip length by mode.

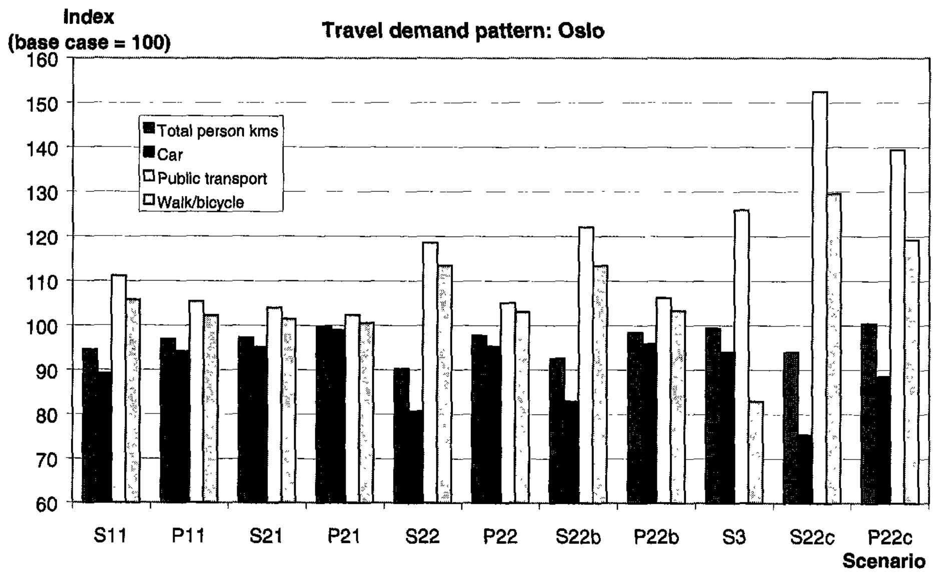

Figure 4.23: Oslo. Impact of marginal cost pricing on person kilometres travelled, by mode.

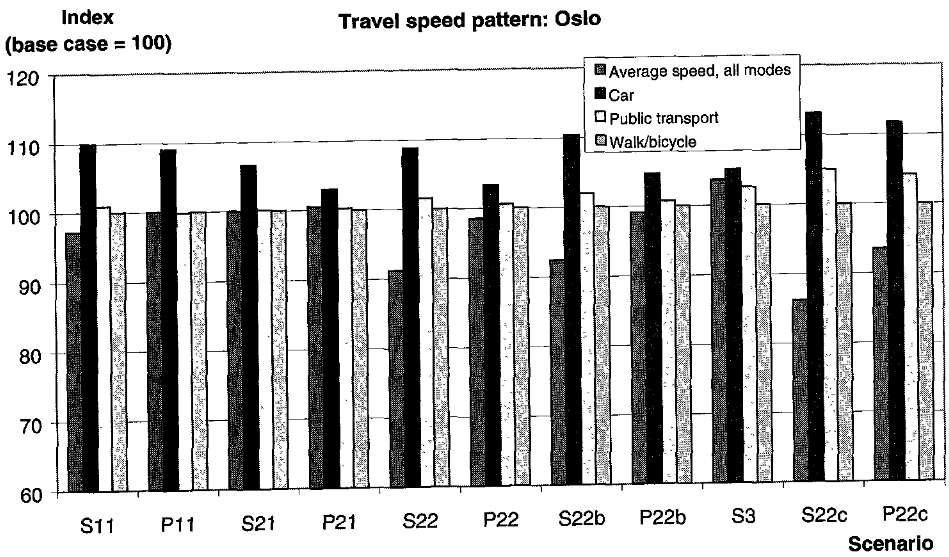

Figure 4.24: Oslo. Impact of marginal cost pricing on travel speed by mode.

5 The equity of marginal cost road pricing

The distributional aspects of marginal cost pricing are essential ones. Road pricing inevitably affects different population groups differently, when it comes to out-of-pocket expenditure as well as in terms of accessibility and time savings. Moreover, a most critical aspect appears to be the fact that road pricing inherently involves a cash flow from private consumers to a public authority or operator.

Thus the fact – demonstrated in the previous chapter – that road pricing may represent a very efficient form of taxation is hardly an asset in the eyes of the general public. It may seem that the acceptability of road pricing hinges crucially on whether the road pricing revenue can be used in a way that mitigates the hardship imposed in the first place.

Another common objection to the implementation of road pricing is that it will affect different residential zones in unfair ways, reducing the accessibility of some while possibly enhancing the travel opportunities of others.

We shall deal with the income (re)distribution and accessibility issues one at a time. The income distribution analysis will be based primarily on the Oslo case study, while the accessibility analysis relies on results for Edinburgh.

5.1 Income distribution effects

5.1.1 The S11 scenario for Oslo (first-best with cost of funds)

A first impression of the equity impact of scenario *S11* for Oslo is given in Figure 5.1. Income brackets are defined in terms of *household income per consumption unit* (see section 2.2), and the brackets are delimited in such a way that each group covers approximately one eighth of the adult population. That is, bracket 1 runs from zero income to the 12.5 income percentile, bracket 2 from the 12.5 to the 25th percentile, and so on.

Under the assumption that the public revenue from road pricing is not redistributed to private consumers, but kept by the public authority, all income groups suffer a welfare loss as measured by the change in consumer surplus.

In Figure 5.2, where the differential effects on "partial generalised income" (see last paragraph of section 2.2) are shown, this is brought out more clearly. Here, we have also added a last column representing the added net income accruing to all income groups if the revenue from road pricing is redistributed to the households in amounts proportional to each household initial income, i.e. as a *constant percentage point tax relief to all income earners.*

One notes that the monetary welfare loss incurred during the peak hour period, in terms of road charge expenditure and reduced amounts of travel, are larger in the higher income brackets (first column in Figure 5.2 – "Money savings peak added" – corresponding to items e and j of Table 2.1). The more affluent people are to a larger extent hit by peak hour road pricing. The off-peak charges, however, are much more evenly distributed between income groups, so that when all monetary costs are summed up (as in the second column of Figure 5.2 – "All money savings added" – corresponding to items e and j *plus* items f and k of Table 2.1), the differences between income segments become less pronounced. Indeed, the third income bracket ends up incurring almost as large a monetary cost as the uppermost bracket.

In the third column if Figure 5.2 ("Road time savings peak also added"), we compound the monetary savings of column two *and* the peak hour time savings for motorist (item n of Table 2.1) for most income groups. As might be expected, these time savings are generally larger among the more affluent.

In the fourth column ("All time and money savings added"), the entire consumer surplus change is included. By and large, the upper income brackets are seen to incur a larger welfare loss (prior to revenue recycling) due to first-best marginal cost pricing than do the lower income groups, at least in terms of absolute willingness-to-pay.

Note, however, that our analyses do not take account of differences in the marginal utility of money. Since the marginal utility of money is generally higher among the less affluent, it may be argued that our efficiency and equity analyses, based as they are on a willingness-to-pay criterion, tend to be inherently biased against the interests of the poor – confer the recent debate between Brekke (1997, 1998), Johansson (1998) and Drèze (1999).

When the (differential) revenue and profit collected by the public treasury and operators are redistributed to the households in amounts proportional to each household's initial income, i.e. as a given percentage point income tax relief, the upper income brackets are seen to reap a net welfare gain, while the opposite is true of the low income groups.

These equity effects are also clearly visible in terms of Lorenz curve differentials, as shown in Figure 5.3, which is tailored to the standard introduced by Figure 2.3 above. The monetary welfare loss incurred by peak hour travellers has an only moderately adverse distributional effect, the *Gini* coefficient going from 0.19014 to 0.19105, while a much larger, adverse effect is due to off-peak travelling. The time gains, on the other hand, tend to reduce the adverse equity effect, shifting the Lorenz curve upwards compared to the situation before time benefits have been taken into account, and the changing *Gini* coefficient from 0.19502 to 0.19405.

Note that, by definition, a proportional redistribution of revenue does not change the Lorenz curve or the *Gini* coefficient. Thus Figure 5.3 also represents the situation after proportional redistribution, as shown in Figure 5.2.

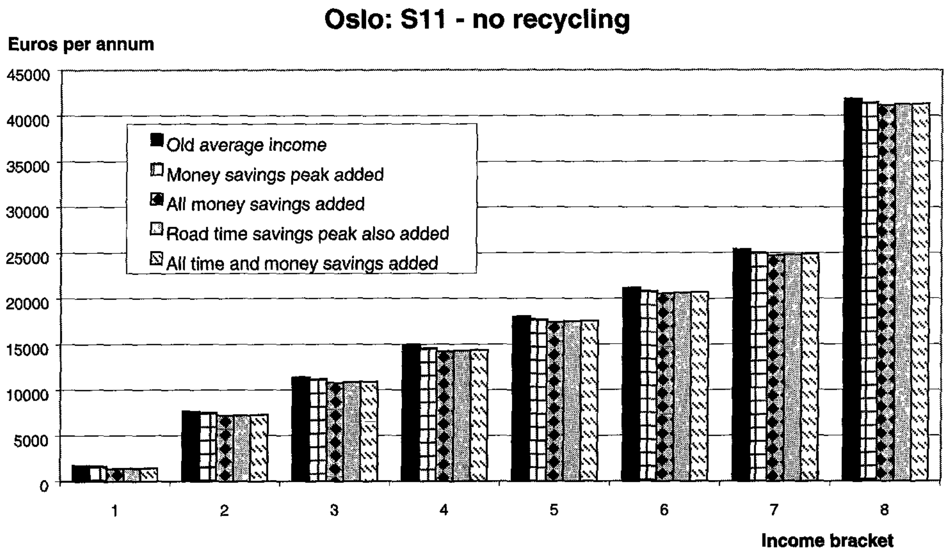

Figure 5.1: *Oslo. Effects of "first-best" marginal cost pricing by household income per consumption unit, assuming no recycling of revenue.*

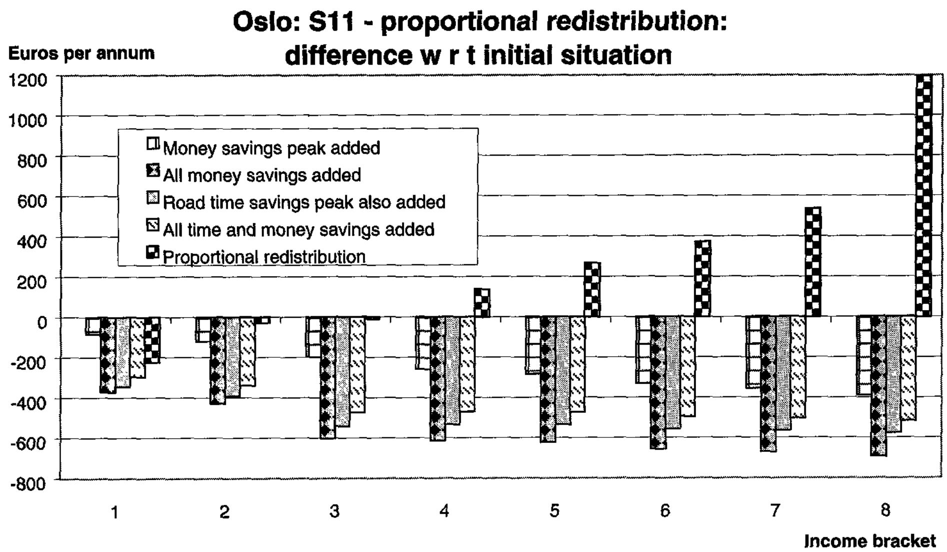

Figure 5.2: *Oslo. Differential effects of "first-best" marginal cost pricing by household income per consumption unit, assuming proportional recycling of revenue.*

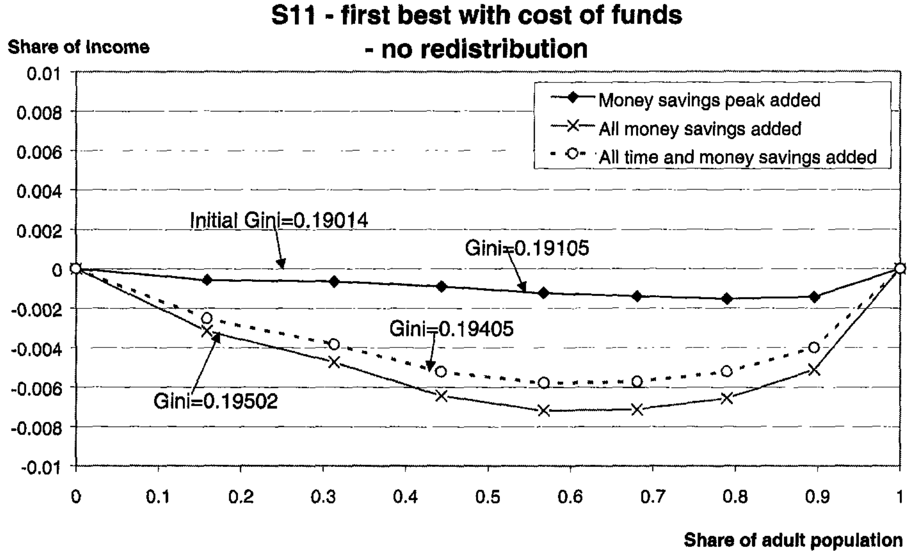

Figure 5.3: *Oslo. Lorenz curve differentials for the S11 scenario (first-best with cost of funds) assuming* ***no*** *or* ***proportional*** *redistribution of revenue.*

In Figures 5.4 and 5.5, however, we show the results of an alternative redistribution scheme, in which all individuals receive the same nominal amount of money, large enough (after tax) to exactly deplete the revenue generated by the road pricing policy. We shall refer to this redistribution scheme as a "*poll transfer*" or "*flat*" recycling.

With this kind of redistribution, all income groups receive a net welfare gain, and the lower income groups receive the largest gain, in relative as well as in absolute terms. This is indicated by a very clear improvement in the *Gini* index, which changes from 0.19405 to 0.18574 after flat redistribution of revenue. Thus, in terms of the *Gini* index, the poll transfer leads to an improvement in the income distribution which is more than twice as large as the deterioration due to marginal cost pricing (0.19405 – 0.19014), and about 9 times larger than the effect of the monetary consumer deficit (= 0.19105 –0.19014).

Put otherwise, it would be sufficient to redistribute only a certain share of the revenue, in order to keep all income groups at least equally well off and the income distribution at least as even as before (in terms of the *Gini* coefficient).

One might, however, question the coherence of an analysis which assumes flat revenue redistribution to the households, and at the same time includes a (non-zero) a shadow value of public funds in the efficiency measure. Several interpretations are possible here.

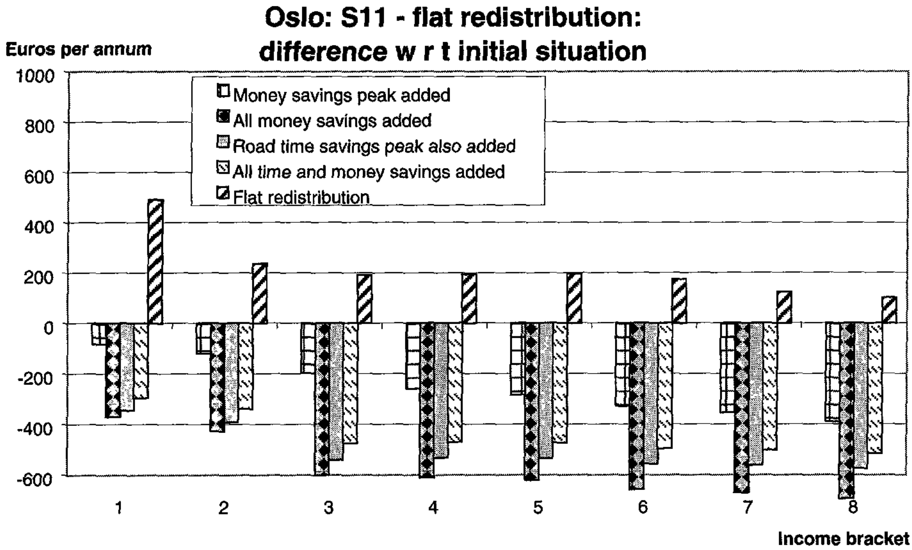

*Figure 5.4: Differential effects of "first-best" marginal cost pricing by household income per consumption unit, assuming **flat** redistribution of revenue.*

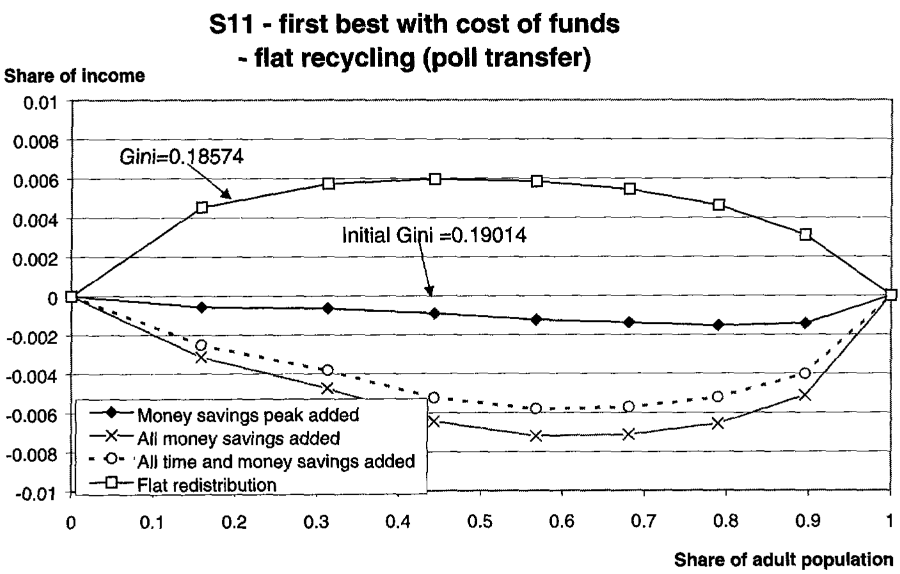

*Figure 5.5: Lorenz curve differentials for the S11 scenario (suboptimal first-best) assuming **progressive** redistribution of revenue.*

If the redistribution is done in such a way that distortionary taxation is not reduced, there is no rationale for including the shadow value of public funds in the efficiency measure. In this case, we are faced with a clear-cut trade-off between efficiency and equity: the equity can be improved through redistribution, but only at the expense of more than half the efficiency gain obtained from the *S11* marginal cost pricing strategy.

If, on the other hand, the redistribution does contribute to reduce the incidence of distortionary taxation, at a rate equal to the assumed, average shadow price of public funds, the efficiency measure has been correctly calculated and will not be altered through the redistribution. In this case, the redistribution of income will improve efficiency in other markets, the total efficiency gain throughout the economy being given – precisely – by the shadow value of the public funds being redistributed.

This relates to the argument given towards the end of Section 2.2 above, on the feedback effects generated from the rest of the economy. One might say that, by *not* correcting the efficiency measure for the recycling of revenue, we include in our policy assessment a summary measure of the efficiency gains obtainable from shifting the tax burden from distortionary taxation to road user charges.

To the extent that the marginal tax on labour is distortionary, a redistribution scheme which lowers the *marginal* tax rate by a given number of percentage points, as in a "proportional" recycling scheme, would seem to qualify as a scheme which does not reduce overall efficiency. But this redistribution scheme does nothing to correct the income distribution.

The "flat" redistribution scheme, on the other hand, would give equal amounts to all income brackets and hence not affect the *marginal* tax rate at all. This scheme certainly improves the income distribution, but hardly the allocative efficiency of the general economy. Indeed, it is quite possible that such a scheme might even *worsen* efficiency, to the extent, e.g., that the poll transfer serves to reduce the supply of labour. In such a case, the relevant shadow price of public revenue would be negative.

The trade-off between equity and efficiency thus seems to come back on us. It may seem that "good" (effective) redistribution schemes are bound to take something away from efficiency.

It is fair to say, however, that – judging by the results obtained by the RETRO model for Oslo – the equity impact of first-best marginal cost pricing is relatively modest. It could, in principle, be neutralised through the redistribution of (part of) the public revenue generated.

5.1.2 The S21/P21 scenario for Oslo (second-best under current institutions)

The equity impacts of another scenario for Oslo – the second-best under current institutions (*S21/P21*) – are illustrated in Figures 5.6 through 5.9.

To ensure coherence between the assumptions made, respectively, in the efficiency calculus and in the equity analysis, we shall – in the sequel – adopt the following convention. *Proportional redistribution* schemes are linked to the scenarios assuming a non-zero shadow price of public funds, while the *poll transfer* schemes are applied only to the solutions based on a zero shadow price of funds.

Thus, in Figure 5.6 we show the differential effects of second-best pricing given a 0.25 shadow price of public funds and a proportional recycling scheme. This policy package, too, keeps the upper income groups at least equally well off, while the low income groups lose. The changes in welfare are generally smaller than under first-best pricing (confer Figure 5.2).

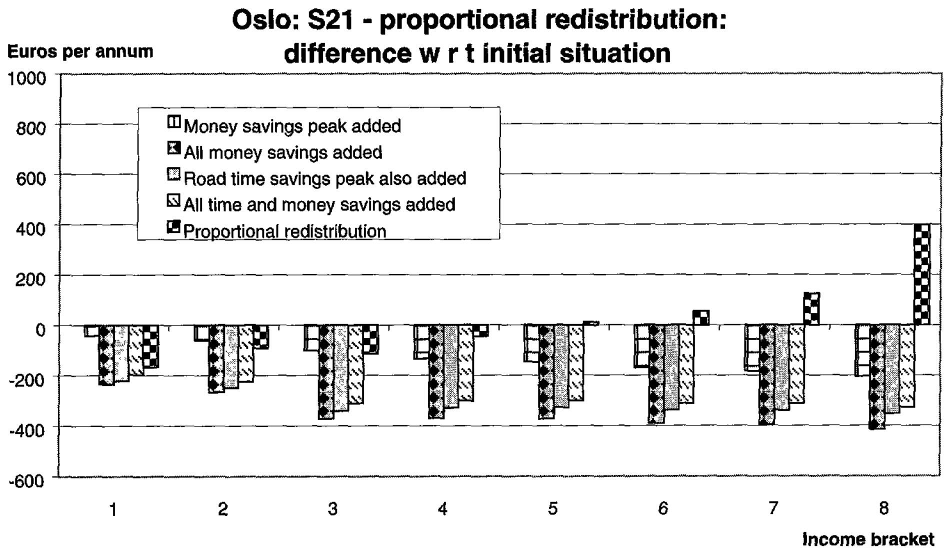

*Figure 5.6: Oslo. Differential effects of best practice second-best pricing under current institutions, by household income per consumption unit, assuming a **0.25** shadow price of public funds and **proportional** recycling of revenue.*

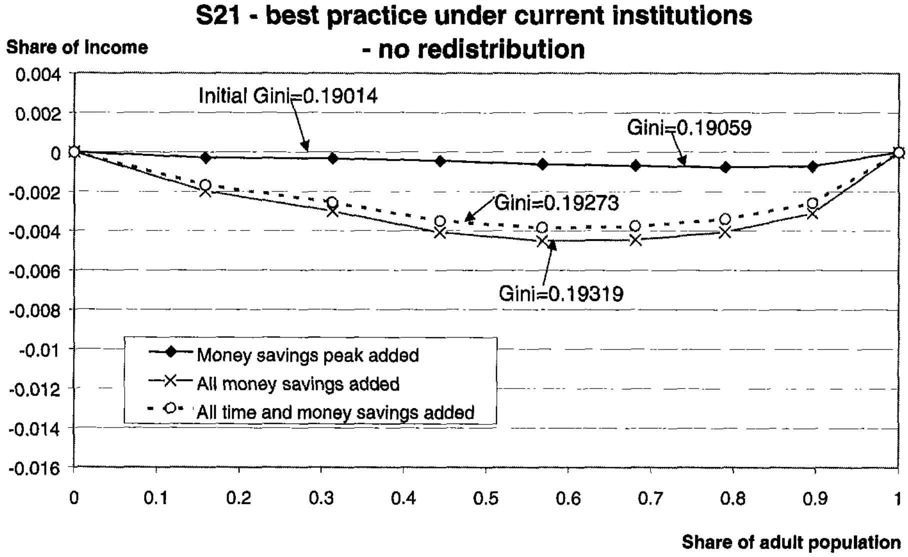

Figure 5.7: *Oslo. Lorenz curve differentials for the S21 scenario (second-best under current institutions), assuming a 0.25 shadow price of public funds and no or proportional redistribution of revenue.*

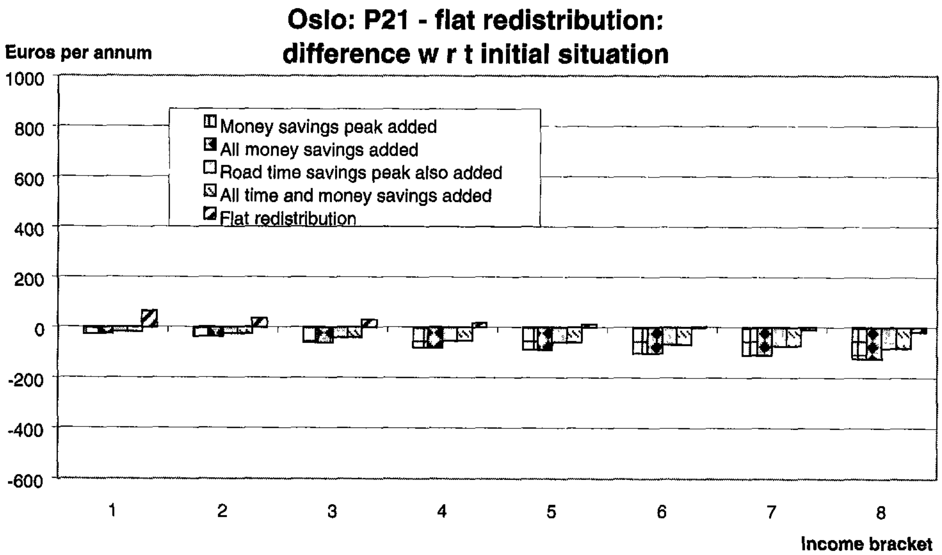

Figure 5.8: *Oslo. Differential effects of best practice second-best pricing under current institutions, by household income per consumption unit, assuming a zero shadow price of public funds and flat recycling of revenue.*

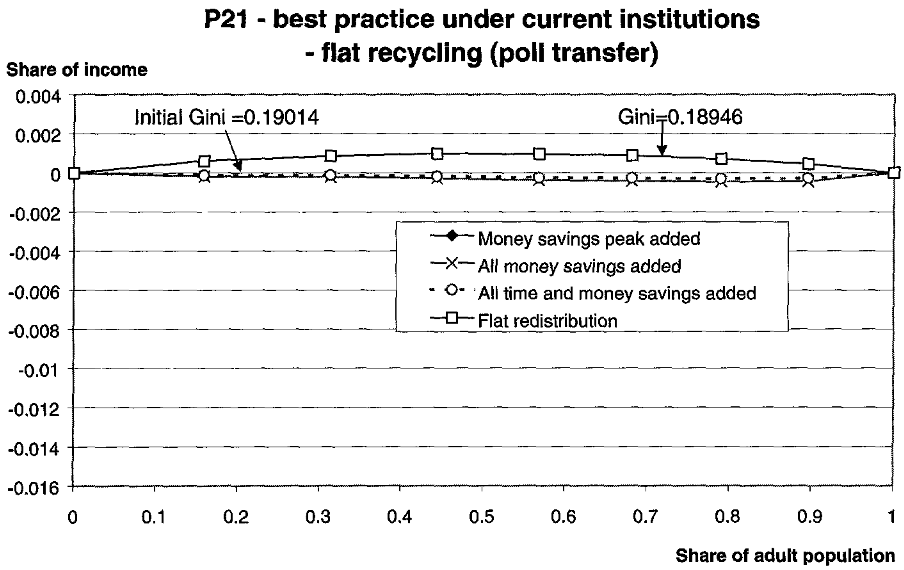

Figure 5.9: Oslo. Lorenz curve differentials for the P21 scenario (second-best under current institutions), assuming a zero shadow price of public funds and flat redistribution of revenue.

On the other hand, income distribution effects are less severe (compare Figures 5.7 and 5.3). The *Gini* coefficient increases from 0.19014 to 0.19273 in the *S21* scenario – an unfavourable but rather modest income distribution effect.

A rather different picture emerges under zero cost of funds and flat redistribution. Here, the welfare improvements are very small indeed, and negative for the two uppermost income brackets (Figure 5.8). The income distribution improves, but – on account of the relatively small amounts of money which shift hands – the income distribution impact is quite small as well (Figure 5.9).

5.1.3 The S22/P22 scenario for Oslo (short-term second-best after institutional reform)

In Figures 5.10 to 5.13, we exhibit similar results obtained under the *S22/P22* scenario.

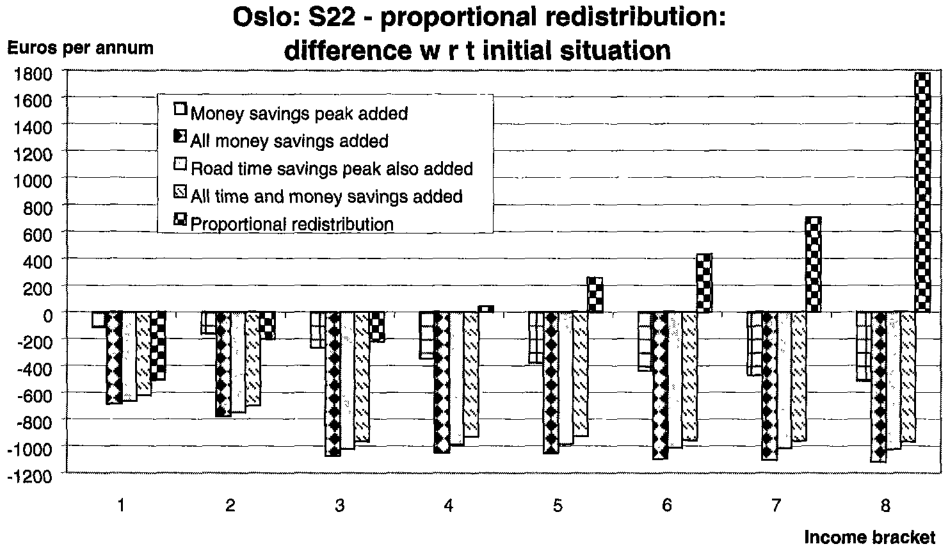

*Figure 5.10: Oslo. Differential effects of short term best practice second-best pricing after institutional reform, by household income per consumption unit, assuming a **0.25** shadow price of public funds and **proportional** recycling of revenue.*

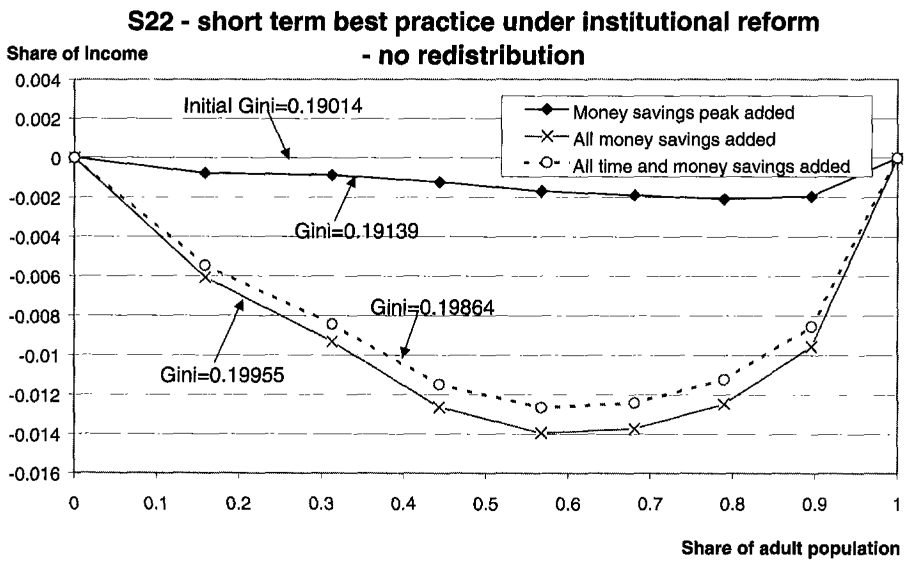

Figure 5.11: Oslo. Lorenz curve differentials for the S22 scenario (short-term second-best after institutional reform), assuming a 0.25 shadow price of public funds and no or proportional redistribution of revenue.

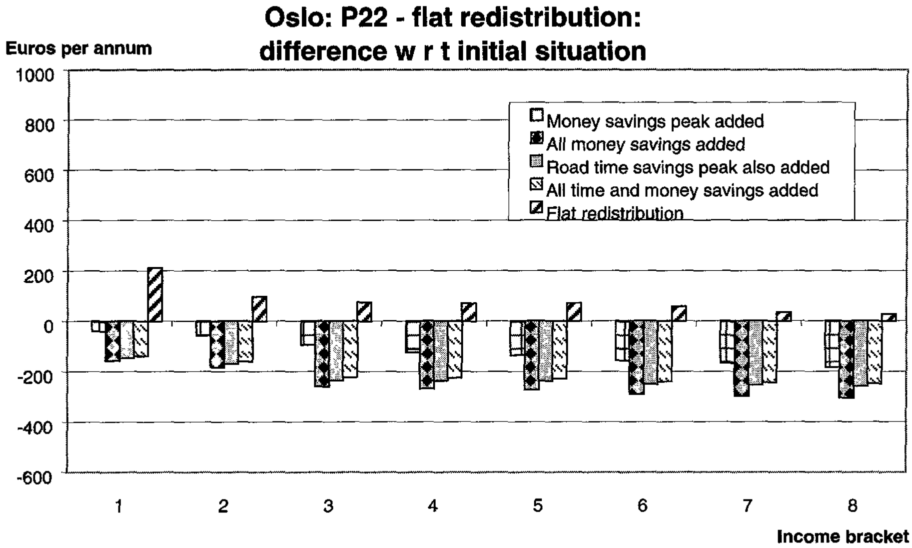

*Figure 5.12: Oslo. Differential effects of short-term best practice second-best after institutional reform, by household income per consumption unit, assuming a **zero** shadow price of public funds and **flat** recycling of revenue.*

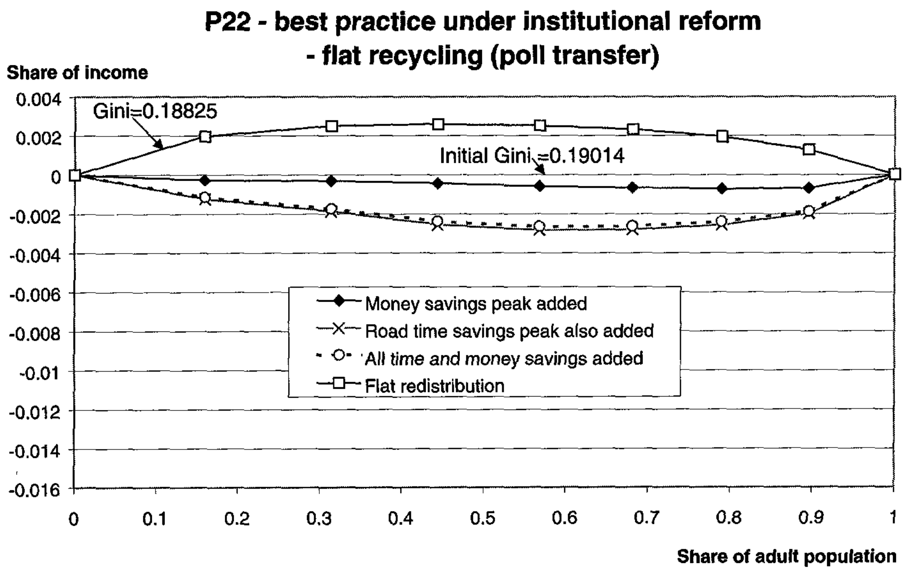

*Figure 5.13: Oslo. Lorenz curve differentials for the P22 scenario (short term second-best after institutional reform), assuming a **zero** shadow price of public funds and **flat** redistribution of revenue.*

Under non-zero cost of funds and proportional recycling, the large welfare gains accrue to the more affluent, while the low income groups incur a loss (Figure 5.10). This is so because the *S22* policy generates a very large revenue, which – by assumption – is recycled mainly to the higher income brackets. The equity impact is correspondingly adverse (Figure 5.11).

To an even larger extent than in the in the first-best solution, the charges levied on off-peak travel has an adverse distributional effect, bringing the *Gini* coefficient from 0.19139 to 0.19955.

If a poll transfer type of recycling is envisaged, and the shadow price of funds is consequently set to zero, much smaller, but more equitable welfare improvements are obtained (Figure 5.12). Here, all income groups obtains a small benefit after recycling, and the *Gini* coefficient improves from 0.19014 to 0.18825 (Figure 5.13).

5.1.4 The S22b/P22b scenario for Oslo (medium-term second-best after institutional reform)

The *S22b* scenario exhibits, again, considerable welfare improvements for the higher income brackets, but at the cost of adverse distributional effects (Figures 5.14 and 5.15).

Note that, in this scenario, there is an additional cash flow to be accounted for, viz the cost savings obtained by private households as they reduce aggregate car ownership (by 10.9 per cent in the *S22b* scenario and 9.7 per cent in the *P22b* case). These savings are not included in first or second column shown in Figure 5.14 (whence the label "All *variable* money savings added"). They are, however, taken account of in the fourth column ("All time and money savings added").

As noted in Section 4.3.1 above, we disregard – in this scenario – the welfare loss due to reduced availability of private cars for interregional (or longer distance) travel. On account of this, the consumer surplus gains calculated under this scenario are somewhat overstated.

The *P22b* scenario, in which no extra value is attached to public revenue and this revenue is redistributed as a poll transfer, provides small welfare gains for all income groups and a somewhat improved distribution (Figures 5.16 and 5.17). The equity improvement is, however, smaller than in the *P22* scenario, although the overall efficiency effects are almost identical.

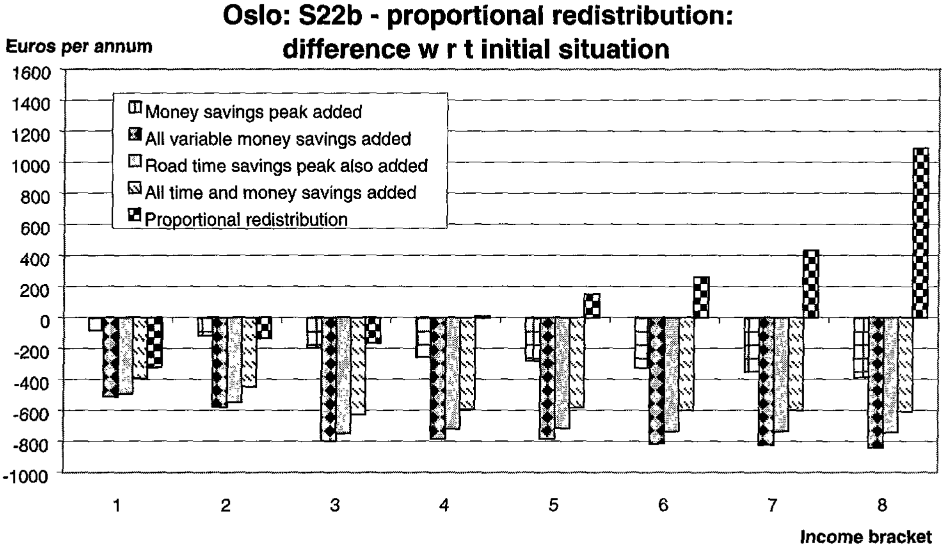

*Figure 5.14: Oslo. Differential effects of medium-term best practice second-best pricing after institutional reform, by household income per consumption unit, assuming a **0.25** shadow price of public funds and **proportional** recycling of revenue.*

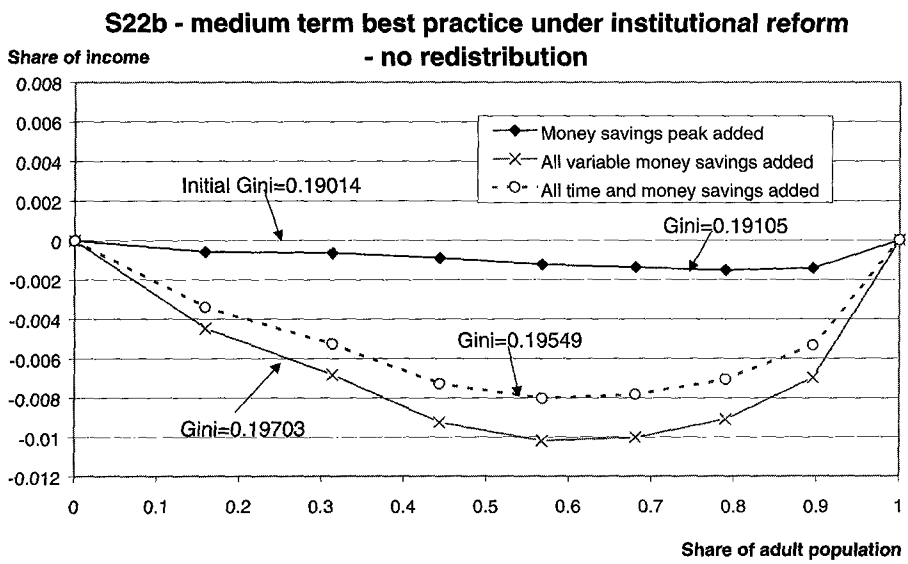

*Figure 5.15: Oslo. Lorenz curve differentials for the S22b scenario (medium-term second-best after institutional reform), assuming a **0.25** shadow price of public funds and **no** or **proportional** redistribution of revenue.*

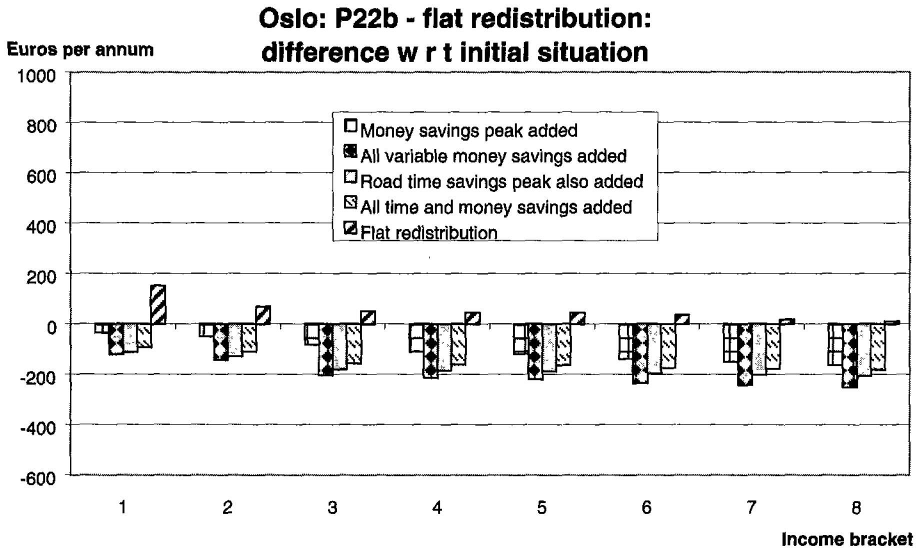

Figure 5.16: Oslo. Differential effects of medium-term second-best after institutional reform, by household income per consumption unit, assuming a ***zero*** *shadow price of public funds and* ***flat*** *recycling of revenue.*

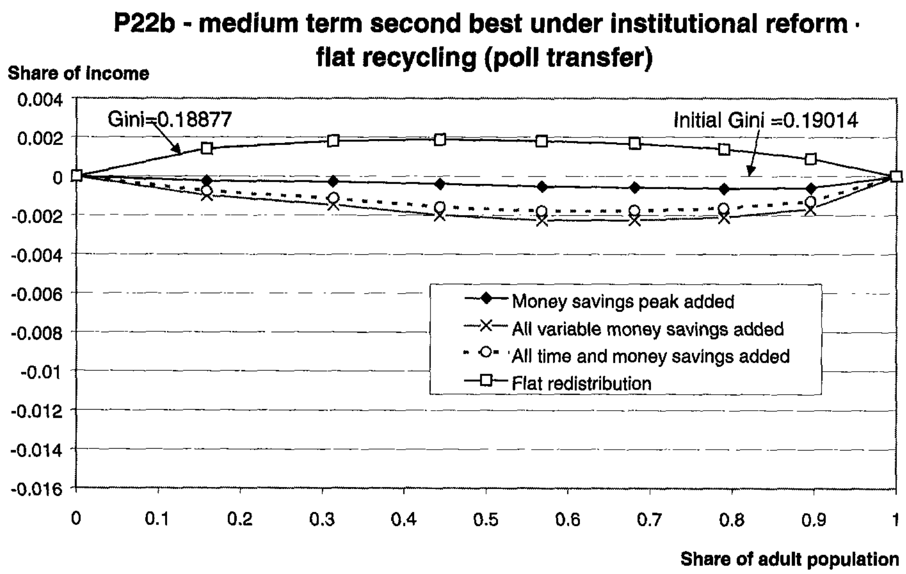

Figure 5.17: Oslo. Lorenz curve differentials for the P22b scenario (medium-term second-best after institutional reform), assuming a ***zero*** *shadow price of public funds and* ***flat*** *redistribution of revenue.*

5.1.5 Income distribution effects for Edinburgh

For Edinburgh, the *Gini* coefficient was derived using four income groups. The *Gini* values are based on some broad assumptions regarding car use by income group as it was not possible to trace the effect of pricing strategies on each income group through the whole modelling process.

According to the model simulations done by the START model for Edinburgh, all road pricing scenarios produce an *improvement* in the income distribution even before revenue recycling. Starting from a value of 0.2015 in the base case, the *Gini* coeffcient reduces to 0.1989 in the *S11* and *S21* scenarios, to 0.1948 in the *S22* scenario, to 0.1976 in the *S3* scenario, and to 0.1996 in the *S4a* scenario. When revenue is recycled on the basis of flat (equal) amounts per household, further improvements are achieved, with *Gini* coefficients reaching 0.1869, 0.1928, 0.1889, 0.1956, and 0.1880, respectively.

The fact that road pricing appears to improve equity in Edinburgh, even before recycling, are conditioned by the assumptions made regarding the cost of car use within different income segments. These assumptions imply that households in the higher income groups spend more on car use than the lower income groups, hence road pricing tends to inflict larger expenses on the higher income groups[13]. Recycling by equal amounts adds to this effect by redistributing revenue from higher to lower income groups.

Although only illustrative, the *Gini* coefficients show that in terms of equity after recycling the first-best systems appear preferable, although such is not the case prior to recycling. In fact the table ranking after recycling resembles that of the *EEFP* ranking.

Other recycling regimes were also calculated based upon more progressive or regressive schemes. In the most progressive variant, all revenue is redistributed to the lowest income group until this group is brought up to the level of the next income group; these groups are then merged and the process continues. Regressive recycling of revenues is the opposite and revenues are given to the highest income group. The effects on the *Gini* measure are dependent upon the revenue collected and the *Gini* coefficients are lowered significantly under the progressive regime and increased under the regressive regime as expected. The magnitude of the changes in *Gini*, although dependent upon the revenues, are always greater than those produced by the recycling of equal absolute amounts per household. The range of *Gini* results from progressive to regressive regimes merely adds to the argument that the use of revenues is perhaps more important than the road pricing system effects under first-best assumptions.

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[13] Similar assumptions are implicit in the Oslo equity analyses, as demonstrated in Figures 5.2, 5.6, 5.10 and 5.14. Here, however, the distribution of monetary costs among income segments is a model output, following from the land use and travel demand pattern, rather than an explicit input.

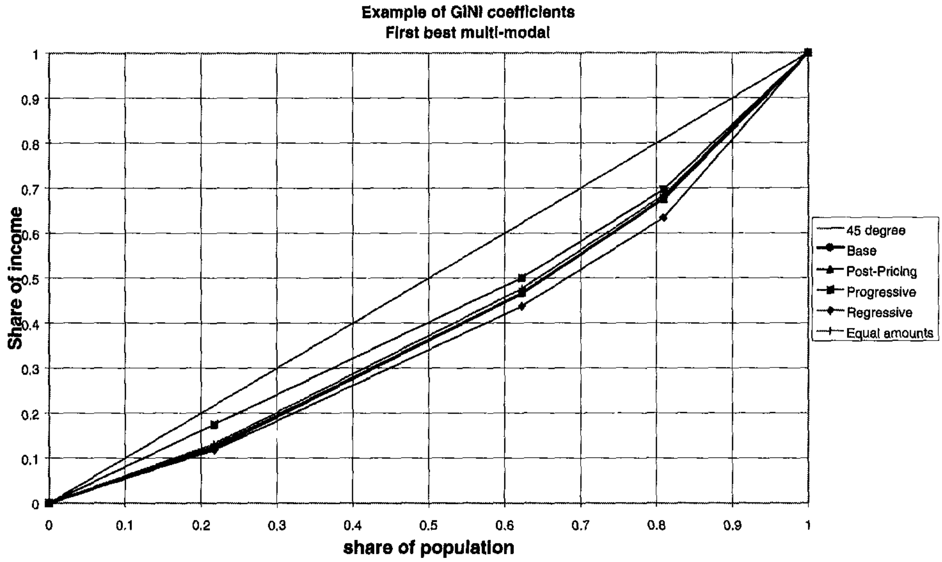

Figure 5.18: Edinburgh. Example of Lorenz curves for the first-best scenario, under alternative revenue recycling schemes.

Basically the greater the revenue generated, the greater is the possibility of affecting the *Gini* coefficient. The transport effect on the *Gini* coefficient seems small compared to the revenue effect. Figure 5.18 shows the *Gini* curves for the first-best (*S11*) scenario.

5.2 Spatial accessibility

For Edinburgh, detailed analyses have been made to study the impact of road pricing on spatial accessibility, i.e. on the extent to which residents in the various zones have their travel opportunities diminished or enhanced as a result of the various policy packages.

Figures 5.19 to 5.28 show the percentage changes in commute accessibility for each zone for the car, public transport and composite modes for various examples of the charging systems. Note that zones 1, 2 and 12 form the central business district (CBD) and the cordon for the city centre, zones 1-14 (excluding zone 8) are within the outer cordon, while the higher zone numbers are generally further from the centre of the study area.

Figures 5.19 and 5.20 show the changes in accessibility for the first-best (*S11*) package with and without a "guided bus" system implemented, respectively. A direct comparison shows that the public transport improvements were due to the guided bus implementation and the zones affected were in the city centre and those along the guided bus corridors. These spikes form a common element of all other packages as all include the guided bus system.

The first-best effect on car accessibility is best shown by Figure 5.20: large reductions in accessibility for all zones by car, with greater reductions for the outer zones. Note that these are percentage reductions in accessibility so the absolute change in the outer zones will be far greater than that of inner zones. The effect of the first-best system is to reduce composite accessibility for all zones as shown in Figure 5.20.

Figure 5.21 shows similar results for the smart card system to the first-best results in Figure 5.19. It is difficult to see major differences though one might expect that the longer trips would be affected less as a maximum charge of 4 Euros now applies, however this effect is combined with the minimum charge of 1 Euro for any car trip.

Figure 5.22 shows the fuel tax system under the *S3* acceptance regime. This much lower charge per km results in lower overall reductions in car accessibility, though the pattern is to affect the outer areas the most. The improvements to public transport are due to fare reductions, frequency increases and the guided bus implementation.

Figure 5.23 shows the effect of the outer cordon distance based system under the acceptance regime. Note that the pattern shows greatest reductions in car accessibility for those living within the cordon as they are charged for all car trips. Again the public transport effects are due to the fare, frequency and guided bus changes.

Figure 5.24 shows the effect of the outer cordon toll based system under the acceptance regime. Note that compared to the distance based charge the effect is greatest for zones which lie outside the cordon (zone 8 is also outside the cordon); the greatest effect being in zones 8 and 15-17 which border the cordon. The effect on those living in the city centre is lower as generally people commute to jobs within the cordon.

Figure 5.25 shows the outer cordon toll based system under the *S21* constrained regime with no change in fares and frequencies. Comparing Figure 5.25 with Figure 5.24 shows the general effects on public transport accessibility of the fare reductions and frequency increases and the spikes produced by the guided bus.

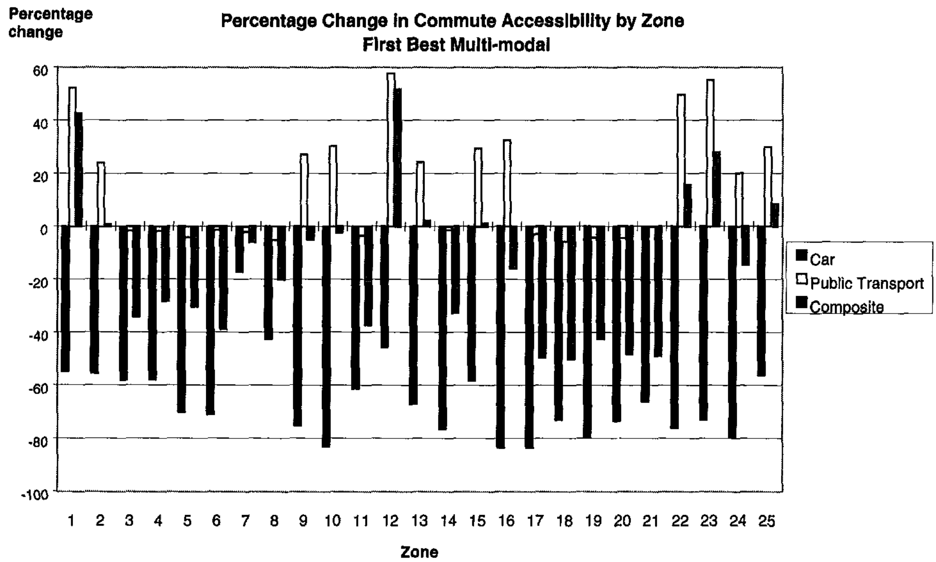

Figure 5.19: Edinburgh accessibility. First-best scenario (S11).

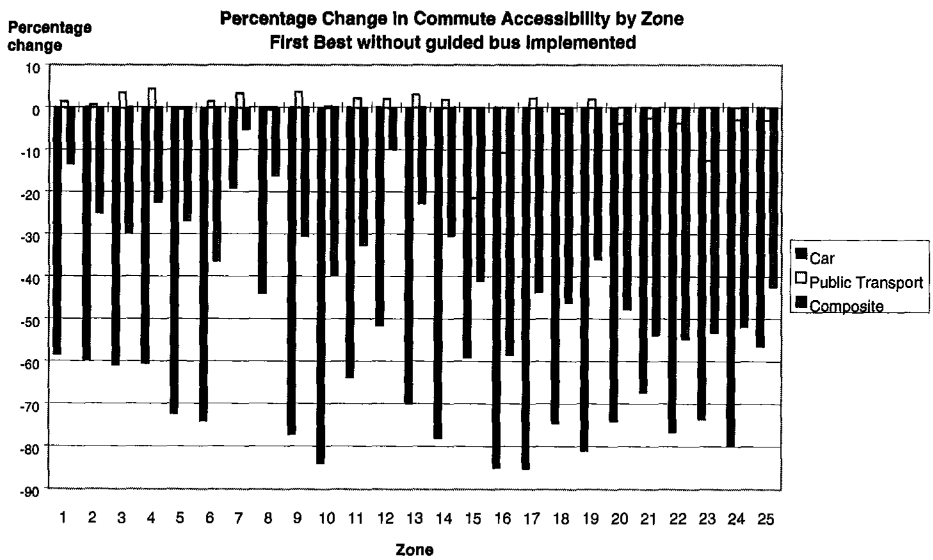

Figure 5.20: Edinburgh accessibility. First-best without guided bus implemented.

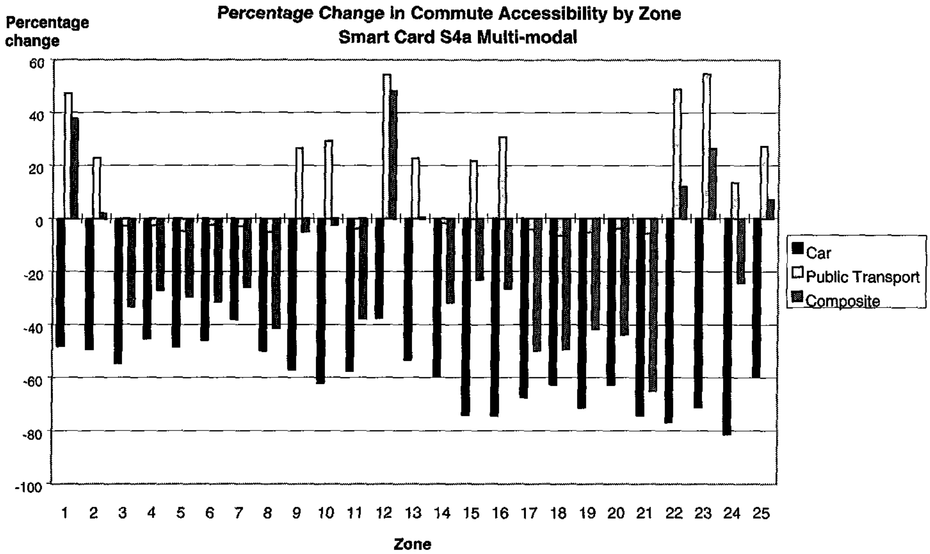

Figure 5.21: Edinburgh accessibility. Smart card system S4a.

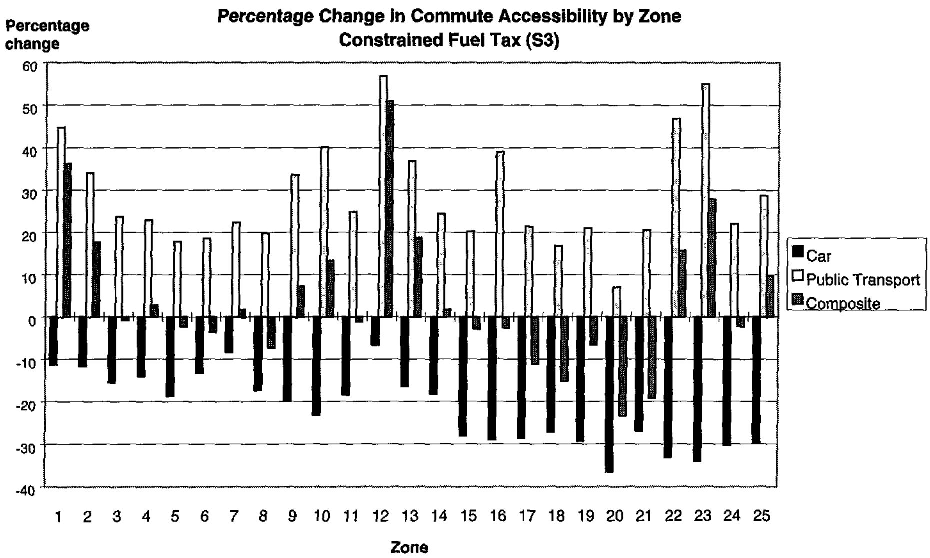

Figure 5.22: Edinburgh accessibility. Fuel tax instrument, restricted to max 5 Euros.

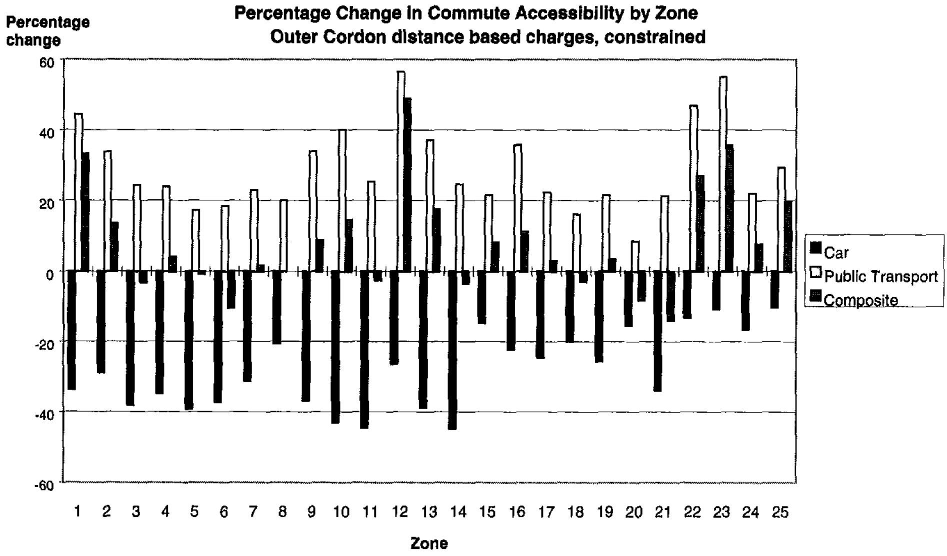

Figure 5.23: Edinburgh accessibility. Outer cordon distance based charges, restricted to max 5 Euros.

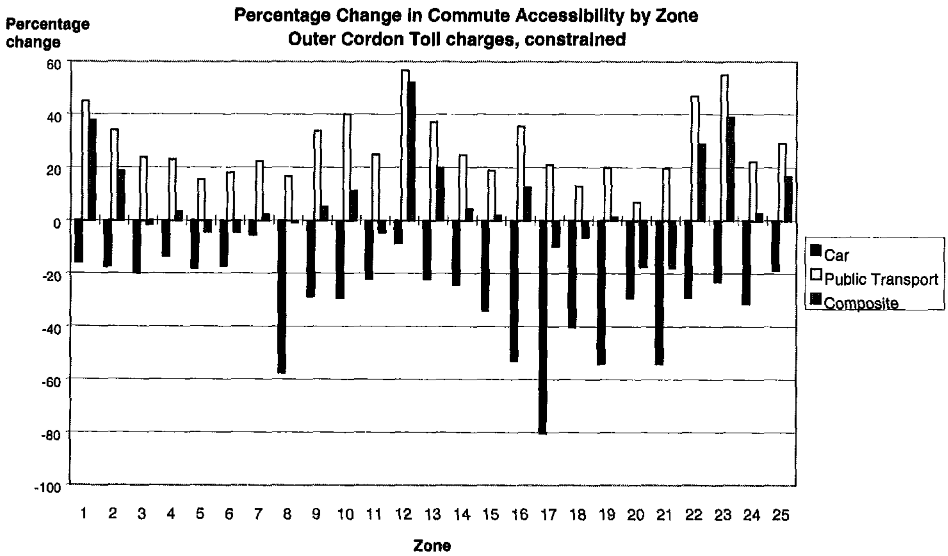

Figure 5.24: Edinburgh accessibility. Outer cordon toll charges, restricted to max 5 Euros.

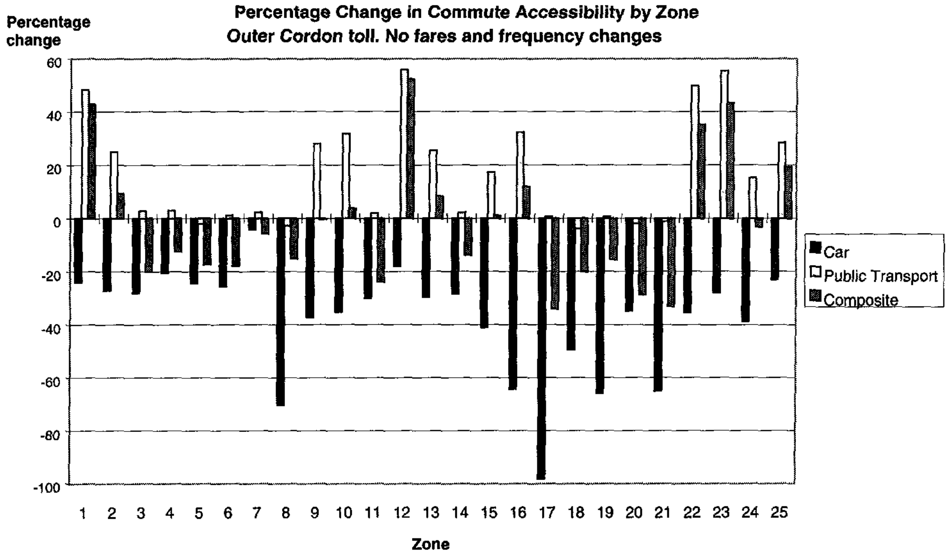

Figure 5.25: Edinburgh accessibility. Outer cordon toll (S21). No change in fares and frequencies.

Figure 5.26 shows the city centre cordon toll based system under the acceptance regime. The effect on accessibility is generally quite small with the greatest effect on those within the city centre in zones 1 and 2.

Figure 5.27 shows the city centre cordon toll based system without fare and frequency changes. The car accessibility is similar whilst the public transport changes are those produced by the guided bus system.

Finally Figure 5.28 confirms the effect of the guided bus system as it shows the results with no road pricing system. The guided bus affects the central zones and those along the corridors with some additional benefits to zones which contain park and ride systems for the guided bus. The small decreases in accessibility by car can be explained by the increases in parking charges.

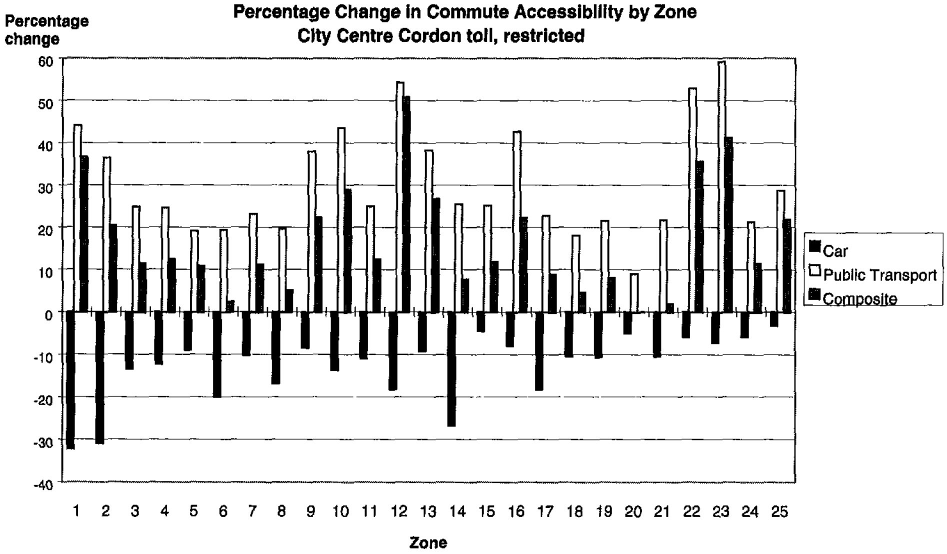

Figure 5.26: Edinburgh accessibility. City centre cordon toll, restricted to max 5 Euros.

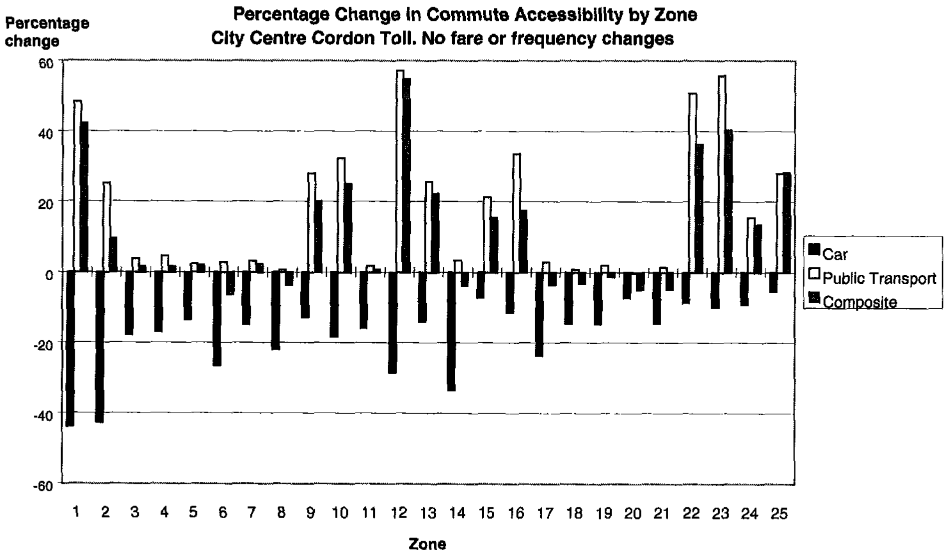

Figure 5.27: Edinburgh accessibility. City centre cordon toll. No change in fares or frequencies.

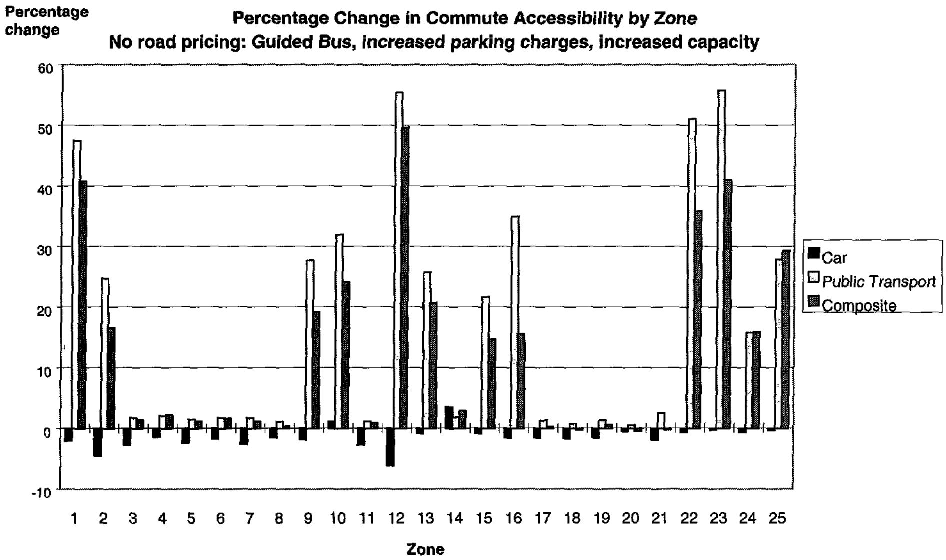

Figure 5.28: Edinburgh accessibility. No road pricing, guided bus, increased parking charges, and increased capacity.

In summary the spatial effects of different measures are vastly different. The spikes produced by the guided bus system are due to the general cross-shaped system which runs through the city centre.

The effect of tolled cordons is to create boundary effects with the small city centre cordon hitting those who reside within the cordon more than those who reside outside of the cordon; basically the cordon is small enough to allow routing around the charged area. The larger cordon toll based system affects those outside the cordon as the cordon is large enough to allow free movement within the area and to limit the opportunities for re-routing around the cordon.

However the larger cordon with distance based charges has the opposite effect whereby those within the cordon are charged on all trips compared to those living outside the cordon who can travel to some zones without extra charge.

The fuel tax system affects all areas but the effect increases with average trip length or for those living in the outermost zones. The first-best and smart card systems give a similar pattern of changes in accessibility and would reduce composite accessibility for all zones if guided bus were not implemented.

6 The land use effects of marginal cost road pricing

As the only model available to the AFFORD team of researchers, the MEPLAN model for Helsinki allows for an interesting analysis of long term land use effects of marginal cost pricing.

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. The general worry in the European cities is that the expanding trend will continue.

The Helsinki demand model structure consists of different types of households and employment sectors and the floorspace that they use for locating in a zone. The study area consists of 81 zones and covers an area of 14,400 square kilometres and includes the not only the Helsinki Metropolitan Area but also the surrounding cities. The model has therefore some characteristics of an inter-urban model.

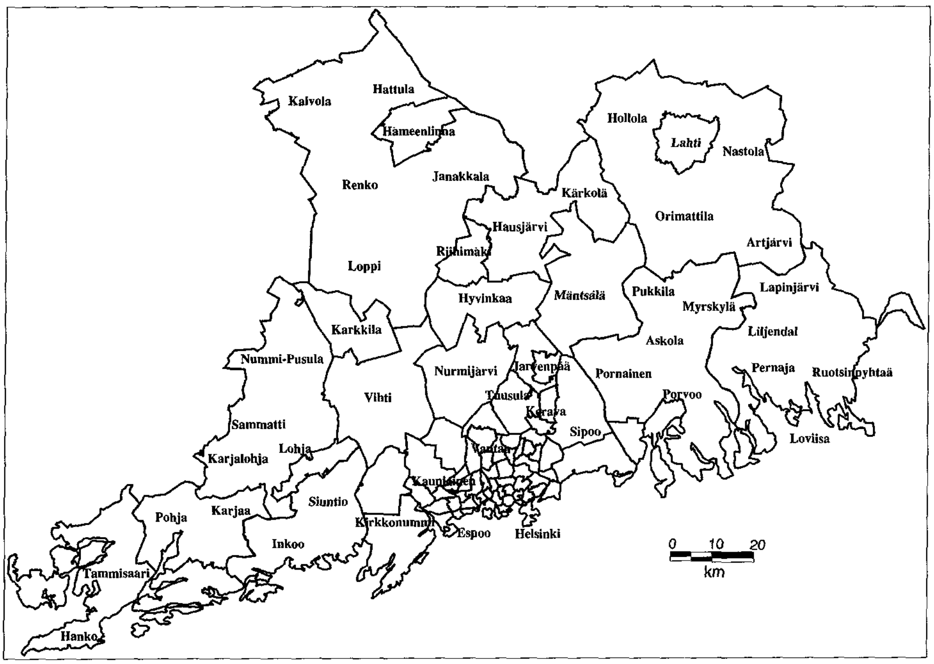

Figure 6.1: The Helsinki zoning system.

There are 1.4 million inhabitants in the area. In the model, households are disaggregated according to their socio-economic characteristics into 8 classes and also according to the car ownership into a further 3 classes. In total, the number of household categories is 24.

The employment categories are disaggregated by standard industrial classification into 8 groups. Here also the fundamental differences in choosing the location or the functional connections between employment sectors was an important factor for the structure of the model. As an example, retail and wholesale are separated as wholesale is not consumed directly by the households and therefore do not generate shopping trips. The industrial employment does not include agriculture, construction and transport employment, which by their nature locate differently.

The design of the input-output framework in the model of the Helsinki Region did benefit from a regional input-output table that was a constructed in a separate thesis study. It enabled the model to represent the whole economic structure of the modelled region with intermediate demand and good estimates of the exports and final consumption. The household consumption (which determines for example the home based shopping trips) was modelled using a household expenditure survey as a source. The connection from employment to households was in turn developed based on a sample of anonymised records from the Finnish census.

The nested logit model structure for active households is route choice, mode choice, choice of location and the choice of car ownership. Car availability for a trip is an important issue for mode choice. Therefore, in the land use – transport interface the trip generation model includes a large set of car availability, trip type and socio-economic status combinations, which are combined into homogenous groups from 256 separate categories down to 15 aggregate categories. Transport matrix generation, modal split and assignment is also done separately for peak and off-peak conditions as the composition of trip purposes vary between different time periods.

The foreseen (reference) scenario (*P02*) affects the level of the alternative packages through its assumptions. 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 and a substantial package of transport infrastructure investments for both road and public transport. These are also supported by policies for dense land use patterns along the transport corridors. The population is expected to grow by one third during the forecast period 1990-2020.

There is an urban sprawl effect in the foreseen scenario. The increase in incomes, insufficient availability of developable land for housing in the central areas, and the large transport investment program have lengthened the average trip by 10 per cent, and the average time per trip has grown even more. The substantial increase in travel costs has not been sufficient to offset the other factors. The petrol price has been expected to rise by 2 per cent per annum in line with yearly growth in the gross domestic product. Public transport fares are project to rise by 1.3 per cent annually. Thus, even in the foreseen base case year of 2020, there still seems to be room for savings in resource, accident and environmental costs by means of demand management.

Using marginal cost pricing 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. The marginal cost curves applied in the assignment procedure has a very limited impact on the land use themselves (see Figure 6.2) if the distance-based externalities and resource and operation costs are not changed from the reference scenario. The relocation process just adjusts the geographical pattern of transport demand so that the congestion can be avoided.

When the constant 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 6.3).

Overall the effect is as Figure 6.4 shows. The inhabitants centralise towards the city centre, where the jobs are, while the jobs decentralise to reduce the travel distances.

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 6.5). 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 6.3 the car owning households drive the non car-owning households away from the metropolitan area where the effective provision of the public transport is.

Overall the second-best package shows a land use relocation effect as seen in Figure 6.6. The overall effect is a more balanced spread of inhabitants over the metropolitan area (within 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 design of the public transport system.

The spatial pattern and the level of impact depend on the initial situation, external factors and the policy instrument details. The effects of land use relocation could be in long term more fundamental than the change in pure transport mobility and trip demand. A proper investigation of the welfare effects of the relocation should nevertheless be done 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.

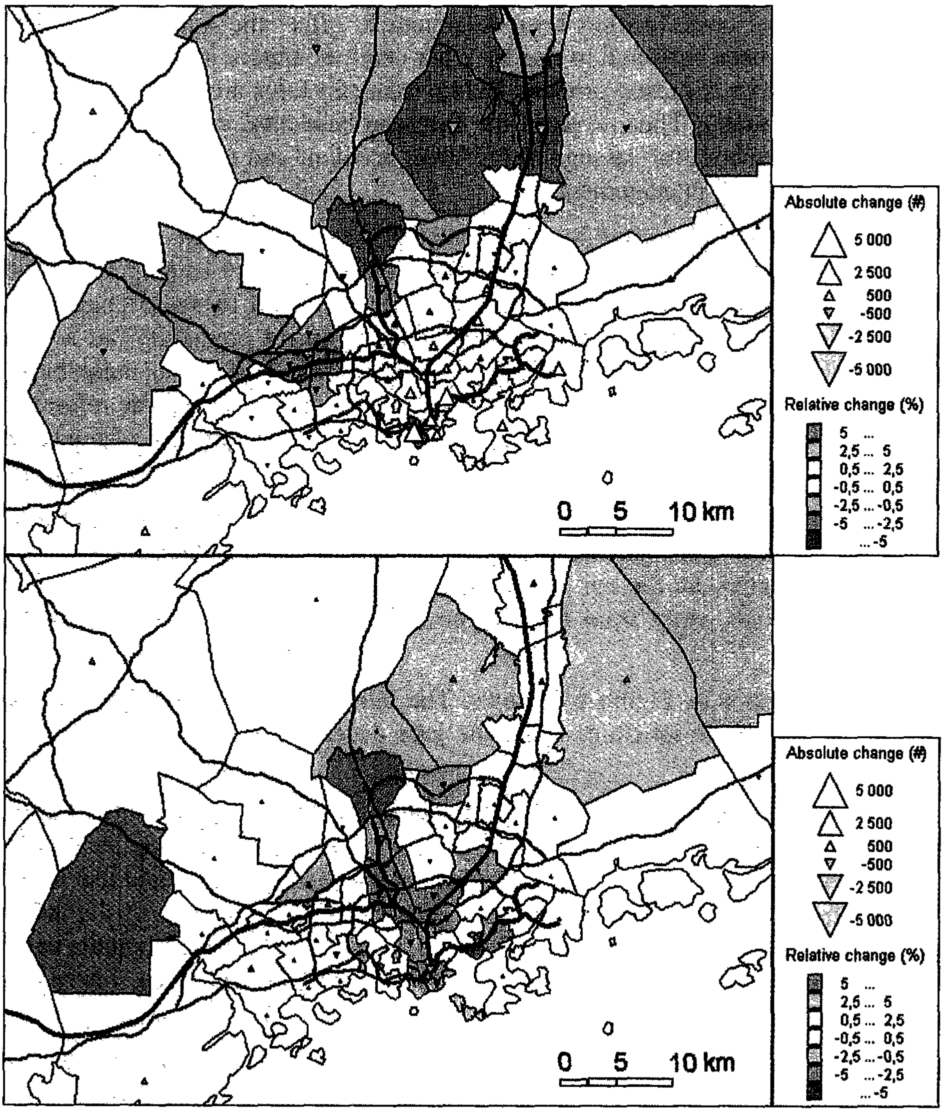

Figure 6.2: Helsinki. The land use relocation effect of inhabitants (top) and jobs (bottom) due to ideal marginal congestion cost curves without changes in other distance based charges. A sub-zone coloured blue indicates relative reduction of land use activities (with a green triangle pointing down to indicate the absolute figure). Accordingly a red sub-zone (with yellow triangle pointing up) shows an increase in the land use activity.

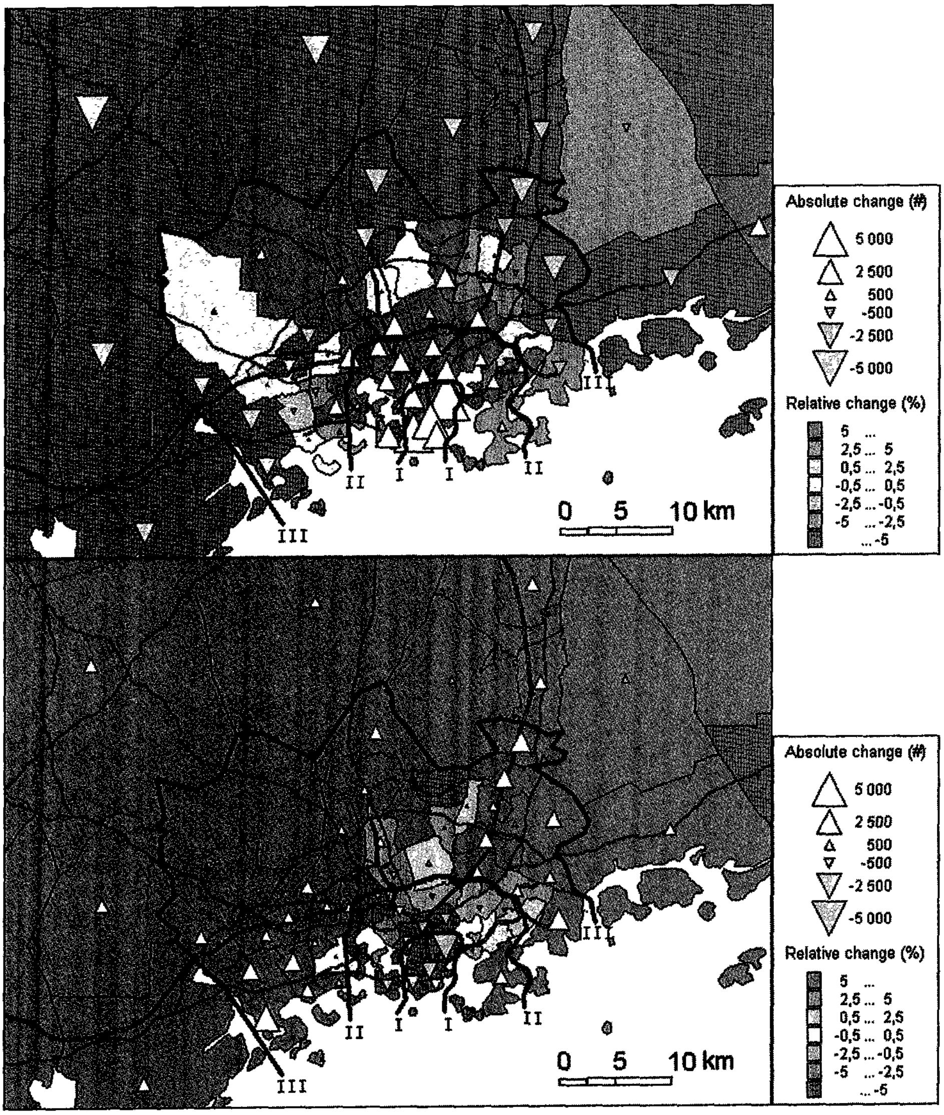

Figure 6.3: Helsinki. The land use relocation effect by car owning households (top) and non car owning households (bottom) when the travel costs increase due to petrol tax and a distance based congestion tolls in the metropolitan area marked as concentric rings: I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre is set up.

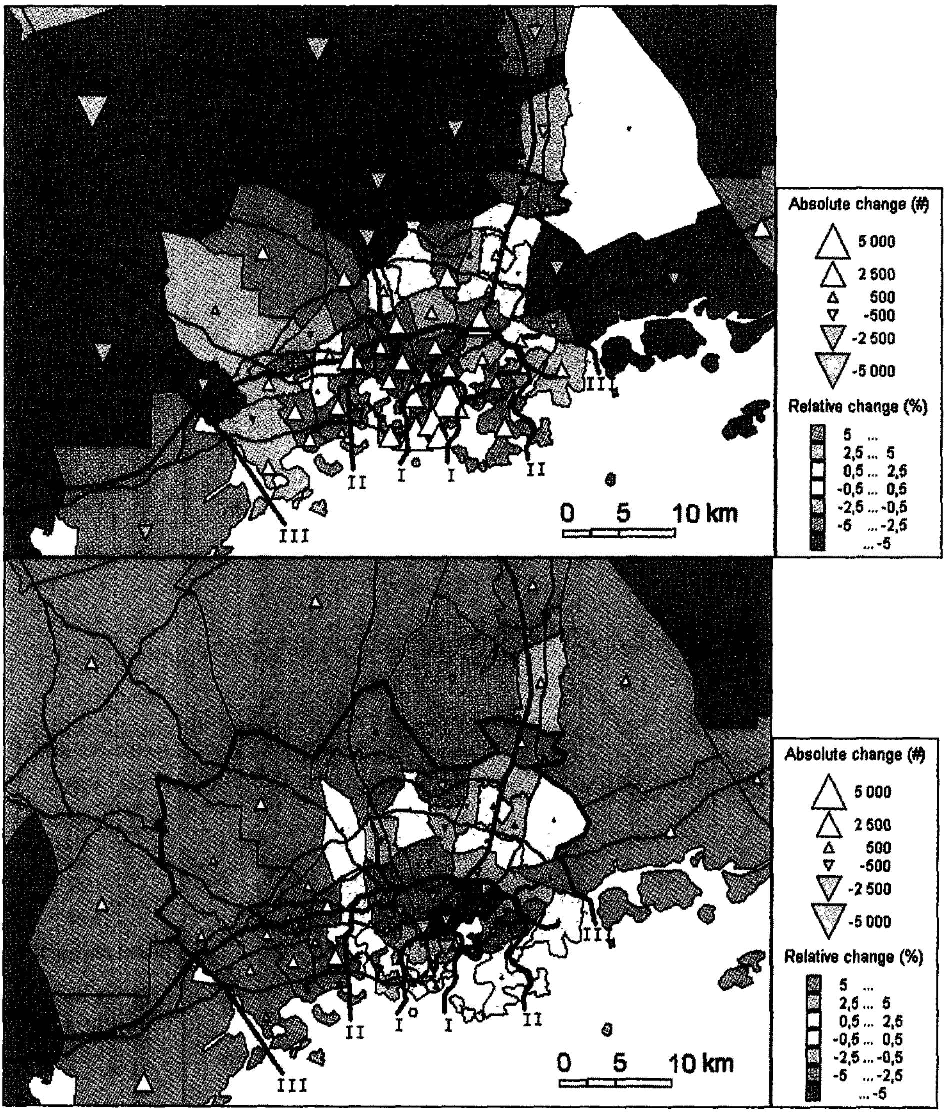

Figure 6.4: Helsinki. The land use relocation effect by inhabitants (top) and jobs (bottom) when the travel costs increase due to increase petrol tax and setting up a distance based congestion tolls in the metropolitan area marked as concentric rings: I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre.

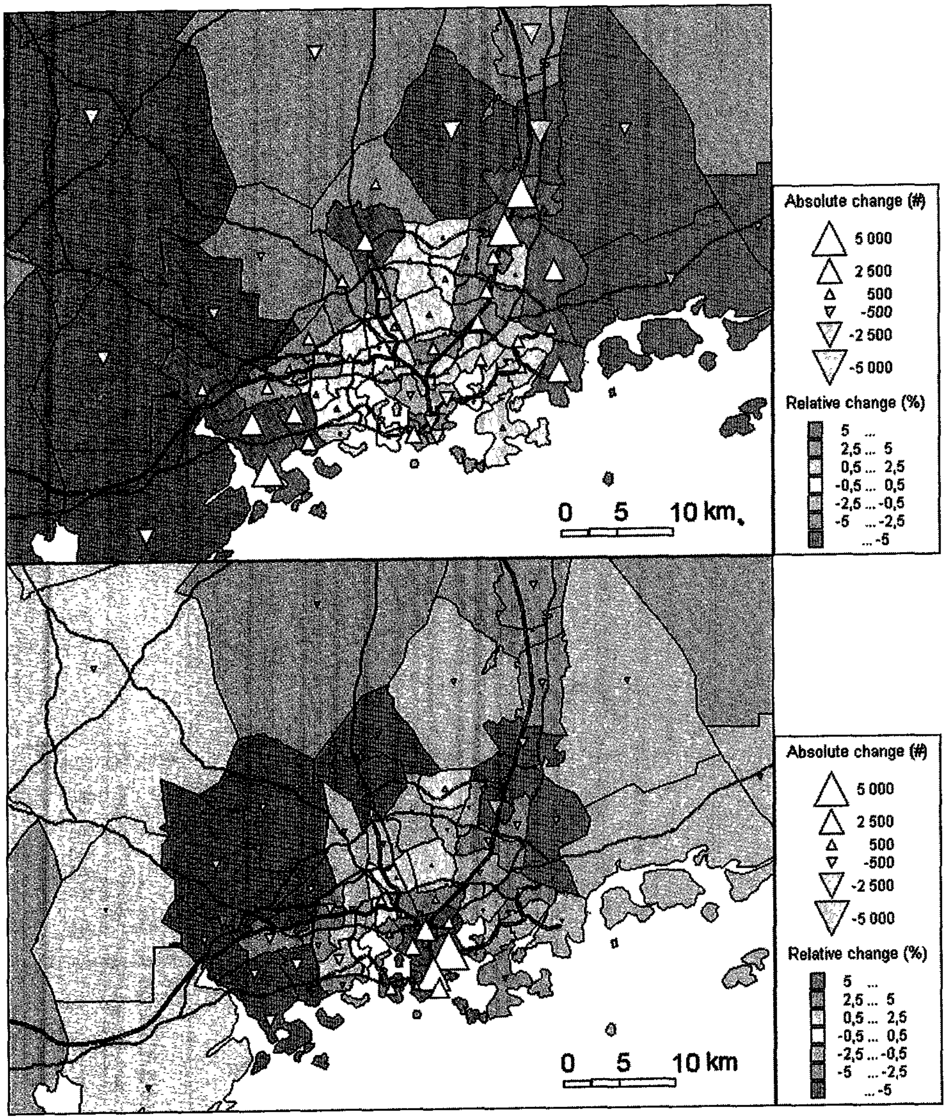

Figure 6.5: Helsinki. The land use relocation effect by inhabitants (top) and jobs (bottom) when the public transport fares decrease by 50 per cent in the metropolitan area. Note that the dark dotted lines present the rail services and the grey ones main roads in the area.

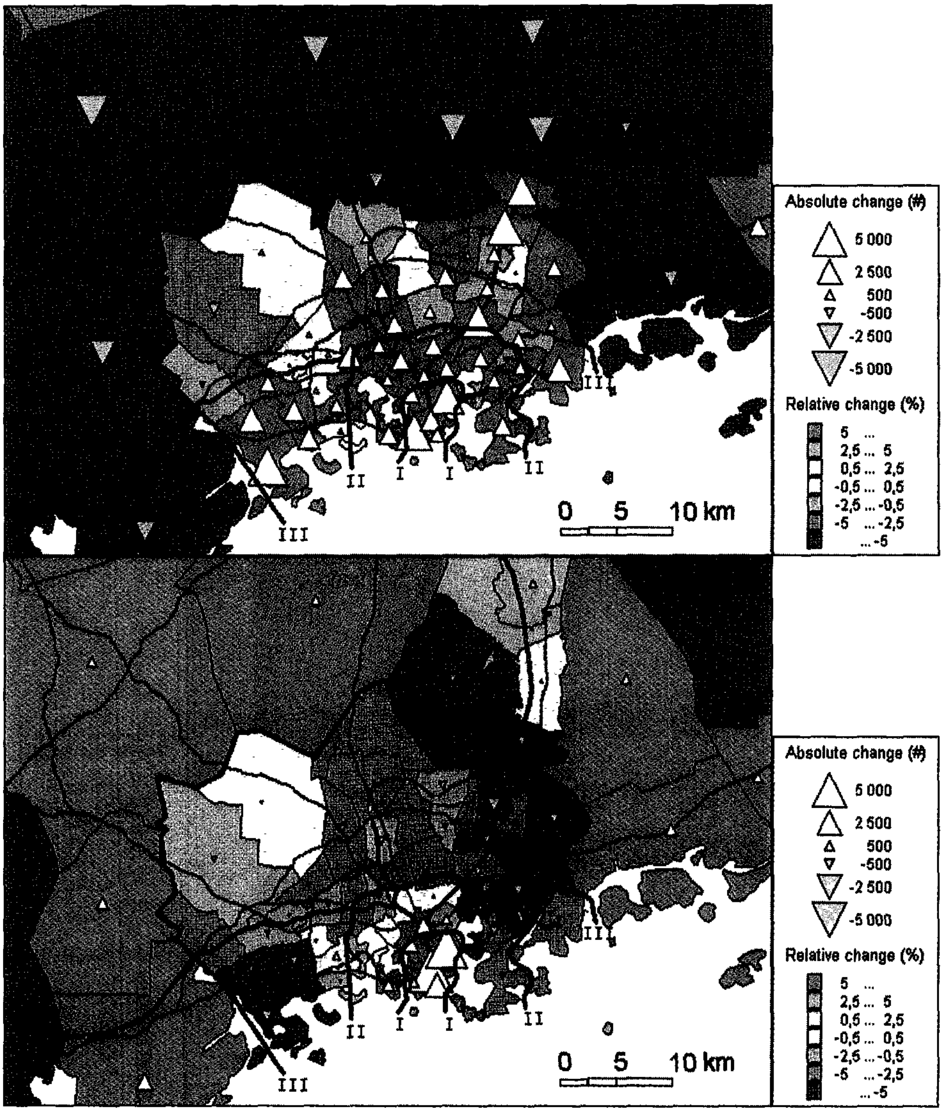

Figure 6.6: Helsinki. The land use relocation effect by inhabitants (top) and jobs (bottom) when the travel costs increase due to increase in petrol tax, setting up a distance based congestion tolls in the metropolitan area marked as concentric rings: I (0.1 Euro/km) – II (0.07 Euro/km) – III (0.03 Euro /km) around Helsinki centre and a fare reduction of 50 per cent in the metropolitan area.

7 Summary of results

7.1 Edinburgh

The introduction of a road pricing system significantly increases the social welfare benefits as measured by the EEFP function which is a modified Cost-Benefit Analysis to include the effects of local externalities and which includes a shadow price on public funds.

The ***first-best*** multi-modal solution gives substantial welfare benefits to the system as a whole at the expense of the transport users as both car and public transport users face increased charges.

Only when the revenues are recycled do the monetary benefits become insignificant and the majority of the benefits under the first-best system are then due to efficiency and environmental benefits.

If a shadow price on public funds is applied in the first-best case then the value of these funds increases the total welfare gain significantly, though efficiency remains the major contributor to total gain.

With no shadow price on public funds the total welfare gain is reduced by one third, the optimal charges are reduced but not so much as to reduce the impact on efficiency and environmental benefits.

The assumptions about the recycling of revenues are critical in determining the effect on equity and acceptability.

Limiting the spatial coverage of the charging measures by implementing cordons, by definition creates ***second-best*** systems.

The use of fare reductions and frequency increases in conjunction with these second-best cordon systems can improve the EEFP value further and allow lower optimal charges.

The use of small city centre toll cordons can create boundary effects and increase average trip lengths.

Larger toll cordons can also have boundary effects, though if large enough they have little adverse effect on those residing within the area.

Larger distance based cordons have the effect of increasing average trip lengths and adversely affect those living within the cordon to a greater extent than those living outside the cordon.

Applying simple ***acceptable*** limits on the parking charges and road pricing charges reduces the social benefits (EEFP values) for all systems compared to the unconstrained package.

Introducing more complex systems with minimum and maximum charge levels increases the benefits to 96 per cent of the first-best total welfare gain whilst improving acceptability by imposing lower maximum charges.

The nature of the ***strategic model*** meant that the first-best system was restricted to use a combination of flat rate charges per km for externalities and link specific charges for congestion applied in three time periods. As congestion was only present in the central area of the model, this "limited" first-best system allows a complex "second-best" system such as that based on a smart card to mirror the charging pattern and hence almost reproduce the first-best results.

7.2 Helsinki

The geographic model simulations for the Helsinki Region show moderate, 150 – 300 Euros per capita per annum, socio-economic welfare gains from the first-best and second-best pricing policy packages under investigation. 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).

The pricing policies can increase the efficiency in the transport sector. 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. More benefits would be gained from the savings in external costs (resource, accidents and environmental) as urban sprawl is avoided. The acceptable scenario failed due to over-investment in roads.

The definitions of the packages were determined according to Deliverable 1 of the AFFORD project. As the model is run for year 2020 and it includes the relocation effect in land use activities all of the tests represent long term effects. The packages were optimised and assessed under two alternative assumptions concerning the cost (shadow price) of public funds. This is to take into account the possibility to transfer labour tax burden to less distortionary transport pricing. The "simple" packages did not use shadow price and the "full" packages did. The value (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. The value of the shadow cost has not been determined to match

Finnish conditions and the assessment is therefore only indicative. If the optimisation of the first-best policy would not consider the cost of public funds the users would gain even before the redistribution.

The policy tools tested to find the optimal real life (i.e. second-best) solution (after institutional reform) covered various tolls and charges (including parking) to maximise the social welfare (in transport markets). The 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 overlapped with these and were not as efficient as the chosen tools.

Under the assumption that the marginal cost of public funds is zero, meaning that (alternative) public revenue is raised without loss of efficiency throughout the economy, the welfare gain obtainable from an ideal, ***first-best*** marginal cost road pricing scheme has been calculated at 216 Euros per capita per annum over a 30-year period including the environmental costs, resource costs and accident costs. The ***second-best*** solution is able to gain 168 Euros per capita per annum or 78 per cent of the first-best package.

The inclusion of cost of funds increases welfare as stated by the objective function but reinforces the polarising effect of leaving the transport users worse off and collecting more revenues for the government. The impacts on externalities are more or less the same.

In the ***second-best*** scenario *S22*, 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 168 in the "simple" case. The "full" second-best benefit is 85 per cent of the "full" first-best welfare gain.

7.3 Oslo

Strategic model simulations for the Oslo greater area exhibit moderate to large potential welfare gains from first-best and second-best road pricing policies.

Common to all practically feasible road pricing strategies is that they provide welfare improvements in the form of time savings, but at the expense of a reduced monetary travellers' surplus. That is, unless the public revenue generated is somehow redistributed to private consumers, they are considerably less well off than before, despite the fact that their time costs have been reduced.

If, on the other hand, this revenue is indeed redistributed, most road pricing strategies are able to keep private consumers at least equally well off, their willingness-to-pay for the time savings being larger than the value of foregone travel opportunities and cash. In addition, certain environmental and safety benefits may be reaped.

Modelling results are derived under two alternative assumptions regarding the cost (shadow price) of public funds. It turns out that, for Oslo, this assumption is of paramount importance for the size of the welfare improvement.

The welfare gains obtainable by realistic ("second-best") road pricing strategies are of the order of 50-150 Euros per capita per annum. A major part of this benefit is, however, due to the assumed "double dividend" obtained by placing the tax burden on road users, rather than relying on some other, distortionary type of taxation.

If such a double dividend does not apply, the welfare gain from road pricing in Oslo is considerably more modest.

Under the assumption that the marginal cost of public funds is zero, meaning that (alternative) public revenue can be (and – indeed – *is*) raised without loss of efficiency throughout the economy, the welfare gain obtainable from an ideal, ***first-best*** marginal cost road pricing scheme has been calculated at *75 Euros per capita per annum* over a 30-year period.

The ***second-best*** solution ***under current institutions*** (*P21*) invokes the use of (i) cordon toll rates (peak and off-peak), (ii) parking charges. Optimal use of these instruments is, however, only able to produce a rather small welfare improvement, calculable at a mere 16 per cent of the theoretically optimal ("first-best") gain, when no extra value is assigned to public funds.

After institutional reform, i.e. assuming that the fuel tax instrument can be used for urban transport pricing purposes, a somewhat larger, but rather modest benefit can be obtained, amounting to 17 Euros per capita per annum, or 23 per cent of the first-best gain (*P22*).

It turns out, however, that when a 0.25 shadow price of public funds is assumed, much larger welfare benefits can be achieved from second-best road pricing. The ***first-best*** optimum (*S11*) increases to 199 Euros per capita per annum, while the ***second-best*** optimum ***under current institutions*** amounts (*S21*) to 56 Euros per capita per annum, or 28 per cent of the first-best gain. ***After institutional reform***, a short-term annual per capita benefit of 157 Euros, or 79 per cent of the first-best gain, accrues. Since, however, households will react to this scheme by owning and using fewer cars, thus evading part of the fuel tax burden, the medium term effect is smaller: 110 Euros per capita per annum (55 per cent of first-best).

Marginal cost road pricing has, in other words, the double effect of *discouraging congestion* and *raising public revenue*. To the extent that public funds are a scarce resource, the latter effect may be well the more important as seen in an economic efficiency perspective.

This would, however, depend on how the road pricing revenue is used. If it is used to step down distortionary taxation somewhere else in the economy, or to extend the supply of a public good for which the willingness-to-pay exceeds the marginal cost of production, then a "double dividend" accrues. If, on the other, the revenue is redistributed to the private sector in a way that does not improve the incentive structure faced by economic agents, there is no extra dividend to be accounted for, and a major part of the efficiency gain may be lost through the redistribution procedure.

References

Atkinson A B (1970): On the measurement of inequality. *Journal of Economic Theory* 2:244-263.

Ballard C L, Fullerton D, Shoven J B & Whalley J 1985): *A general equilibrium model for tax policy evaluation.* University of Chicago Press, Chicago.

Ballard C L & Medema S G (1993): The marginal efficiency effects of taxes and subsidies in the presence of externalities – a CGE approach. *Journal of Public Economics*, 52:199-216.

Brekke K A (1997): The numéraire matters in cost-benefit analysis. *Journal of Public Economics* 64: 117-123.

Brekke K A (1998): Reply to J. Drèze and P.-O. Johansson. *Journal of Public Economics* 70: 495-496.

Brendemoen A & Vennemo H (1996): The marginal cost of public funds in the presence of environmental externalities. *Scandinavian Journal of Economics* 98:405-422.

Dagum C (1987): Gini ratio. Pp 529-532 in: Eatwell J, Milgate M & Newman P (eds) *The new Palgrave: a dictionary of economics.* Vol 2. The Macmillan Press Ltd, London.

Dahlby B (1998): Progressive taxation and the social marginal cost of public funds. *Journal of Public Economics*, 76.

Drèze J (1998): Distribution matters in cost-benefit analysis: Comment on K. A. Brekke. *Journal of Public Economics* 70: 495-496.

European Commision (1996): Towards fair and efficient pricing in transport. *Bulletin of the European Union*, Supplement 2/96.

Ghali M O & Smith M J (1999): Detailed modelling results using the Edinburgh network. Interim report, Workpackage 3, Project AFFORD, funded by the European Commission, 4th Framework – Transport RTD. Department of Mathematics, University of York.

Gini C (1912): Variabilità e mutabilità. *Studi economio-giuridici, Università di Cagliari* III, 2a.

Goodwin P B, Hallett S, Kenny F, Stokes G (1991): Transport: the new realism. Transport Studies Unit, University of Oxford.

Goodwin P B (1993): New transport policies - what can go wrong? Proceedings of Seminar F, PTRC 21st Summer Annual Meeting, Manchester, p 233-241

Hansson I (1984): Marginal Cost of Public Funds for Different Tax Instruments and Government Expenditures. *Scandinavian Journal of Economics*, 86.

Hansson I & Stuart C (1985): Tax revenue and the marginal cost of public funds in Sweden. *Journal of Public Economics*, 27:331-353.

Holmøy E & Strøm B (1997): *Samfunnsøkonomiske kostnader av offentlig ressursbruk og ulike finansieringsformer – beregninger basert på en disaggregert generell likevektsmodell.* Report 97/16, Statistics Norway, Oslo.

Johansson P-O (1998): Does the numéraire matter in cost-benefit analysis? *Journal of Public Economics* 70: 489-493.

de Jong G (1990): An indirect utility model of car ownership and private car use. *European Economic Review* 34:971-985.

Jorgenson D W & Yun K Y (1990): Tax reform and U.S. economic growth. *Journal of Political Economy*, 98.

Jorgenson D W & Yun K Y (1991): The excess burden of taxation in the U.S. *Journal of Accounting, Auditing and Finance*, 6.

Kakwani N (1977): Applications of Lorenz curves in economic analysis. *Econometrica* 45:719-727.

Kakwani N (1980): *Inequality and poverty: Methods of estimation and policy applications.* Oxford University Press, New York.

Kakwani N (1987): Lorenz curve. Pp 242-244 in: Eatwell J, Milgate M & Newman P (eds) *The new Palgrave: a dictionary of economics.*. Vol 3. The Macmillan Press Ltd, London.

Lorenz M O (1905): Method for measuring concentration of wealth. *Journal of the American Statistical Association* 9:209-219.

Maddison D, Pearce D, Johansson O, Calthrop E, Litman T & Verhoef E (1996): *The true costs of transport.* Earthscan Publications Ltd, London.

Mayeres I (1999): The control of transport externalities: a general equilibrium analysis. Proefschrift 126, Faculteit Economische en Toegepaste Economische Wetenschappen, Katholieke Universiteit Lauven.

Milne D, Niskanen E & Verhoef E (2000): *Operationalisation of marginal cost pricing within urban transport.* Project AFFORD, funded by the European Commission, 4th Framework – Transport RTD. VATT Research Reports No 63. Helsinki.

Pesonen H, Moilanen P& Rinta-Piirto J (1999): Interaction between transport and land use in the Helsinki Metropolitan Area. Ministry of Transport and Communications, LYYLI series 6, ISBN 951-723-344-2 (in Finnish)

Ramjerdi F & Rand L (1992): *The national model system for private travel*. Oslo: Institute of Transport Economics. Report 150.

Sandmo A (1998): Redistribution and the marginal cost of public funds. *Journal of Public Economics*, 70.

Schade J, Schlag B, Giannouli I & Beier A (2000): *Acceptability of marginal road pricing*. Deliverable 2C, Project AFFORD, funded by the European Commission, 4th Framework – Transport RTD. Technische Universität Dresden.

Schade J & Schlag B (2000): *Acceptability of urban transport pricing*. Project AFFORD, funded by the European Commission, 4th Framework – Transport RTD. VATT Research Reports No 72. Helsinki.

Sen A (1973): *On income inequality*. Clarendon Press, Oxford.

Vennemo H (1991): An applied general equilibrium assessment of the marginal cost of public funds in Norway. Discussion Paper No 62, Statistics Norway, Oslo.

Williams H C W L (1977): On the formation of travel demand models and economic evaluation measures of user benefit. *Environment and Planning* 9:285-344.

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