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Impacts of road pricing upon travel demand in an integral city region: a case study of London and its surrounding regions

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Summary¹: This paper aims to study ways in which the impacts of road pricing upon travel demand can be examined in the wider city region, with a view to inform the design and possible future adaptations of road charges. Its theoretical framework incorporates the medium to long term impact of transport costs (including road charging) upon business location and commuting patterns. A case study is carried out on London and its surrounding regions, through a review of existing evidence and a set of simulation tests using a land use/transport model that has been calibrated to represent realistic travel demand elasticities. The new feature of these simulation tests is that they account for business productivity effects as well as land use/transport interaction. A generic, city-region wide marginal social cost pricing scheme is estimated together with different land use development scenarios to identify directions and range of the effects. The model results show that the social marginal cost based road pricing scheme can have significant long term impacts upon travel demand if they trigger land use changes, which could either enhance or negate the initial travel time savings and reliability benefits.

1 Introduction

Reviewing the experience of the Stockholm congestion charging scheme, Eliasson (2009a) calls for moving the debate forward on road pricing from naïve questions about whether congestion charging ‘works’ to more constructive discussions on, e.g. how road charges should be designed and how revenues should be used. Indeed we owe a great deal to the recent, successful implementation of the Stockholm road pricing scheme and others in Sweden for creating the momentum for progressing with the debate and building up a knowledge base that can be used to support future policy interests.

This paper is a response to that call, aiming to explore one of the less visited facets in the debate: the medium to long term impacts of road pricing upon travel demand, i.e. in the order of 20-30 years. This is arguably one of the least known aspects of road pricing given that the long time scales involve a multitude of uncertainties over how firms and households adapt to the charges and the dynamics that creates (REFs). However, those very uncertainties also imply an opportunity: i.e. the knowledge about the potential effects of road pricing over time may help guide policy commitments to

¹ Note: This is still a working version of the paper and in particular the simulation model results and their interpretations are yet incomplete and subject to change before the Conference.

infrastructure investment and land use planning that engender conditions for sustaining and enhancing the initial benefits of road pricing, such as seen in central London and in the Swedish cities. Since neither infrastructure investment nor land use planning can change directions at short notice, how well a continuation of current policies works with road pricing over time would also be of high policy interest. In this paper we set out to explore the range of relevant scenarios and carry out tests that are expected to be informative.

Why city region?

Since travel demand and the underlying patterns of production and consumption rarely respect administrative boundaries, and over time the knock-on effects will work through the chain of economic linkages, the geographic scope of our analysis here will necessarily have to be that of an integral city region: in a service-dominated economy this means the core city (or cities) plus the hinterland for commuting and business travel. Thanks to motorway and high speed rail, an integral city region in today's developed countries can often be an area with a radius of more than 100km from the centre of the main business districts².

The requirements above for extensive temporal and spatial coverage, however, are not more onerous than those demanded for good planning in general. There is little disagreement in principle that the effects of road pricing should be assessed from a system level and over time. There are many practical barriers, however. Even monitoring implemented schemes would prove challenging: it requires data collection and monitoring over an extensive geographic area, which is costly and logistically difficult to coordinate; it also requires a long time series of data – years if not decades of observation would be required as the effects at this scale take long to ripple through; yet, as it often turns out, the more data and the longer the time series of observations, the more difficult it becomes to discern from the data set the compensating effects and the influence of external shocks – a *prima facie* look of the empirical data tends to give away few if any identifiable effects for the city region as a whole. For cities that have not implemented road pricing schemes, or schemes of very limited impacts, the challenge is greater. This means that a robust analytical framework is required to help discern and decompose the effects from the observations available, and to assimilate evidence from other cities where relevant.

We have chosen London and its surrounding regions as a case study in this paper, because the monitoring, analytical and modelling work there has accumulated to an extent that it starts to become feasible to overcome at least some of the analytical barriers mentioned above. First of all, there has been intensive monitoring of the Central London Congestion Charging Scheme, including the recent Western Extension (REFS). Secondly, there has been systematic testing of the Congestion Pricing options for Central London since its initial design stage in the early 1990s using regional transport models (REFS) and land use models (REFS), which provide a fairly thorough understanding of the mechanisms that affect travel demand patterns under particular pricing and land use assumptions. Thirdly, there has been a series of modelling studies that investigate the interactions

² Commuters and business travellers are travelling ever longer over time, thus pushing the boundary of the threshold outwards. However, at any given point in time, a hinterland boundary can be drawn pragmatically and the collective impacts of travellers crossing the boundary are more effectively accounted for through including the airports and railheads they use in the city region.

between strategic land use planning and transport policy options in the city region, and their impacts on productivity and welfare (REFS), which give an insight into the magnitudes of the land use impacts that arise from transport accessibility changes, and the subsequent feedback on travel demand. Fourthly, the quality and granularity of land use data, particularly in relation to employment location and its use of premises (REFS – ABI; VOA) have improved in recent years, which together with the decennial population Census supports further empirical analysis of the long term background shifts in the location of businesses and residents, which are an important driver of travel demand changes.

In this paper we first establish a theoretical framework that can be used to investigate the medium to long term impacts of road pricing on travel demand on the city region scale, in Section 2. In Section 3 we review the existing evidence from London and the surrounding regions. This is followed by Section 4, in which we investigate the possible impacts of road charging that aims to relieve congestion on travel demand over the period 1997-2050, using an updated land use and transport model (the London and Beyond Model or LAB version 1.0) for London and two of its neighbouring regions. In Section 5 we assess the robustness of the results and consider potentially promising directions for further work.

2 Theoretical Framework

In practical policy contexts, road pricing has been considered for a myriad of roles: congestion relief, fund-raising, fuel and carbon demand reduction, pollution and air quality control, etc. For the purpose of this paper, we focus upon its principal role of congestion reduction which stems from the incipient economic analysis of its effects (Vickery; Other REFs). This means that our scenarios of road pricing will be considered solely from the point of view of tackling congestion. The implications of funding, fuel and carbon demand and air quality will be assessed as consequences of the scenarios, rather than drivers of scenario design here.

[short para on welfare justifications]. Recent analysis of the US metropolitan regions shows that unlike expansion of road or public transit networks, which do not appear to reduce traffic, congestion pricing should be expected to do so, particularly during the peak hours of traffic (Duranton and Turner, 2008).

Thus naturally, the theoretical understanding of the key behavioural mechanisms and effects of road pricing has been centred upon improvements of travel time, and the reliability of travel time [REFS]. The analysis usually is confined to the transport market or sometimes to the road transport market, which considerably simplifies the analysis and provides the opportunity to explore the finer details of road user behaviour. This approach may be appropriate for limited road charging schemes such as car user licensing in a small area in the city centre (such as with the Central London Congestion Charging Scheme) or low road charges over a wider area (such as with the Stockholm Congestion Charging Scheme). For good reasons, the effects in the non-transport markets are largely absent from the road pricing literature.

However, will the need for congestion charging ever arise for it to be implemented over wider geographic areas, or at higher prices? In cities with a prosperous economy, rising incomes, ever higher expectations of 'journey quality' and constraints of new road expansion, the answer is probably yes: it seems to be just a matter of time. Under such circumstances, impacts in the non-transport markets are likely to be what we would seek to bring into play rather than trying to avoid, so long as the overall effects on the economy and welfare are beneficial.

The accumulated small road charges over large geographic areas or high road prices at highly congested locations may permeate through the larger city region through its underlying functional links, bringing into play unpriced effects of the non-transport markets, particularly for labour and land use. This may for example cause relocation of business activities and households and alter schedules of production, logistics and consumption in significant ways in addition to adaptations in the scheduling of trips and choice of modes. Given that it is the basic production, logistics and consumption practices and the associated land use that drives the long term patterns of travel demand, the wider ramifications in the non-transport markets are arguably what we strive for in the battle of 'changing travel behaviour'.

Existing literature on transport effects suggests that the main impacts of pricing during the peak hours of traffic (when road capacity is particularly scarce) are felt by those travelling on business³ and those who commute to work. We therefore focus below on the impacts upon business activities and the labour market.

2.1 Impacts on business activities

Business travel consistently appears to be the largest beneficiary of week day peak hour congestion charging (REFS). This is not surprising given it has usually high values of time, low price elasticity and favourable access to parking at destinations. Faster business travel alters the economic landscape through changes in the total economic mass accessible at each location, which lead to a change in productivity (REFS).

[Introduce results from Rice et al (2006) and Graham and Kim (2008) here regarding productivity elasticities wrt economic mass and magnitudes]

This productivity effect, all being equal, will attract those business activities that are sensitive to it to the more productive areas, at the expense of the less productive ones. This is of course a gradual process, although the shifts of employment location can be quite fast from the perspective of our medium to long term time horizon (for an example in London and surrounding regions, see **Figure 1**).

³ i.e. on employers' business rather than 'personal business'.

Figure 1 Employment by area in London and surrounding regions, 1968-2008

(Source: Annual Business Inquiry)

Obviously the relocation of business to the more productive locations will imply higher levels of traffic there. There will be interactions between productivity, economic mass and traffic congestion and this can only be understood within a wider urban market. Existing road pricing studies are not alone in ignoring the influences of economies of scale and agglomeration upon business decisions. Existing integrated land use activity and transport models, which purports to take account of the interactions between transport and land use, also in the main exclude the influences of economies of scale and agglomeration upon business decisions (REFS – note exceptions).

[Summary of causation (**Figure 2**)

Figure 2 Business location: transport costs, economic mass, productivity and pressure for development

2.2 Impacts on labour markets

[Agglomeration benefits plus induced labour supply (DfT, 2006)]

[Summary of causation (Figure 3)

Figure 3 Labour market: transport costs, business location, housing prices and commuting patterns

2.3 Hypotheses regarding directions and magnitudes of effects

It is quite obvious that accounting for long term effects of city region level road pricing will involve a significant extra work. Should we take the bother to put it into an already complex subject? This would be critically dependent upon the directions and magnitudes of medium to long term changes in travel demand pattern that may result from the interactions between transport costs on the one hand and business location and labour markets on the other.

Given that transport is merely a necessary rather than sufficient condition of activity location, we hypothesise that it would not be possible to determine the directions and magnitudes of change a priori. Land use control and physical forms of development play an important role in determining the location and scale of business activities and commuting patterns. This then interacts with the wider property market especially housing.

A complete study of these impacts would involve the modelling of the land and property markets. However, as an initial step insights can be gleaned from a set of exploratory scenarios that account for the extreme conditions. These polarising scenarios can be used to ascertain the possible directions and range of effects.

Such scenarios may include: very tight land use control (so existing land use patterns persists into the future); very loose land use control (so businesses move to where productivity improves) and transit-oriented development which exploits the potential of density pyramids around main rail nodes.

[Effects difficult to observe – modelling tools available: land use and transport interaction models – to model based on monitoring results already collected].

3 London and its surrounding regions: what is already known about road pricing impacts?

The extent of the London case study area is primarily determined by the commuting catchment of London (Table 1). This shows that in this city region the daily movements of people and goods cover a city region of approximately 100km in radius from central London, which includes jurisdiction of the Greater London Authority and the administrative regions of the East of England, the South East England, the southern fringes of the English Midlands, and the Eastern fringes of the South West. [Has been growing – shown in the successive Censuses]

Table 1: Percentage of employed residents commuting into London from different areas of Britain
(Source: Census 2001 journey to work matrices).

This integral city region is faced with a number of land use and transport issues that have significant long term implications. The service sector has been growing strongly in the past two decades, both in the financial centres of Central and Inner London, and farther afield. The demand on labour supply is such that no single change is capable of meeting the demand for employment. Increases of labour participation, of in-commuting, and of inward migration are all likely consequences of this demand. As a result, there is to be strong rise [x%] in the demand for business and residential space, and in commuting and business travel over the period to 2050.

The regional demography is undergoing its own transformation. Although the number of inhabitants is expected to increase relatively slowly, the number of households is to rise many times faster, exacerbating the demand for dwelling units. The demographic profiles of urban, suburban and rural

areas within the region are markedly different, thus exerting distinct impacts on land use and transport.

A significant proportion of households are to become full car owning (i.e. each adult having access to a car for own use). Since full car owning adults make more trips and travel a great deal longer, this change in car ownership may lead to a potentially strong rise in travel.

Furthermore, as the business markets develop, the inhabitants become more affluent, and more leisure time is available, there is potentially a strong demand for international travel. Hubs for international travel, such as airports, ferry ports and rail termini, are themselves a focal point of employment and traffic growth. Their impact on local communities in the vicinity and their long term influence on regional land use change are profound yet complex to predict.

Economic development and demographic change are currently exerting apparent pressure on land – greenfields and brownfields alike – in those locations perceived to be favourable for business or residential purposes. In contrast, in the region which has the highest average per capita income in the UK, there also exist a number of pockets which are among socially and economically the most deprived. How the growth and change will affect these areas is an interesting policy question which is required to be answered, if the policy measures are to be effective in promoting social inclusion.

In recent years policy makers have been conscious in promoting the management of travel demand. Pricing and non-pricing measures have been put forward for discussion, with an aim to facilitate a reduction in the need for travel, and to encourage a shift from private car to public transport modes. [considerations of congestion charging at local and regional scales]

3.1 Monitoring of the Central London Congestion Charging Scheme

[Initial reductions in congestion levels – but this seems to have reverted back to the pre-CC levels of 2002 – road space allocation impacts, and the consequent impacts on business travel times to C London]

[Reported neutral impacts on C London businesses in the monitoring reports]

3.2 Studies of congestion Pricing options for Central London

[since its initial design stage in the early 1990s using regional transport models (REFS) and land use models (REFS), which provide a fairly thorough understanding of the mechanisms that affect travel demand patterns.

[Comparison of modelled and observed elasticities; Evans (2009)]

3.3 Modelling studies that investigate the interactions between strategic land use planning and transport policy options

[their impacts on productivity and welfare (REFS), which give an insight into the magnitudes of the land use impacts that arise from transport accessibility changes, and the subsequent feedback on travel demand.]

[Attempts to do area-wide pricing (the right thing to do) but only limited to analysis of transport impacts; Analysis of Wider Economic Benefits without feedback loop or long term effects appear to lead to doubtful results]

3.4 Background land use data of employment location and business premises

Data (REFS - ABI; VOA) has improved in recent years, which together with the decennial population Census provides the evidence for significant long term background shifts in the location of businesses and residents.

[ABI – figure]

[VOA – figure]

4 Model simulation of road charging in the London region: 2016, 2030 and 2050

Model simulation has been carried out using the London and Beyond (LAB) land use and transport model (version 1.0), that is derived from the London and South East Regional Model (LASER) version 3.0 that has been used to study a wide range of strategic land use and transport scenarios, most recently in the EPSRC Solutions Project. LAB1.0 updates the input land use assumptions in line with the most recent projects of population and employment for 2016 and 2030 in the UK Department for Transport's NTEM database (REF), and makes its own population and employment projection for 2050 based on a projection of NTEM and the UK Office of National Statistics population projections to 2051.

LAB1.0 has not changed the basic model structure of LASER, which is designed to examine how changes in land use affects transport and vice versa, in particular how changes in employment affect the choice of residential location and commuting, how the future location of employment and households affects the demand for travel, and how congestion and overcrowding affect travel and land use patterns.

Like LASER3.0, LAB1.0 covers Greater London and the Government Office Regions of the South East and the East of England, including the main ports and airports. It does not yet cover the near fringes of the English Midlands or South West – this is a limitation in particular for the later years in scenario runs, e.g. 2050.

The simulation of land use and transport interaction is based on two main model components: a land use module based on administrative areas at below the local authority level (315 fully modelled zones), and a multimodal transport model based on networks.

The main model inputs are: future employment projections in each area, future demographic profile for the modelled region as a whole, transport infrastructure and service improvements, and levels of car operating costs and public transport fares. The main model outputs are: household and local service employment by area, commuting, education, business and other journeys between zones, using all means of travel including walking and cycling, morning peak (7-10 am) travel costs, times, road traffic speeds, congestion, and crowding on rail, and traffic flows on individual links, for project screening purposes. Alternative employment growth patterns, demographic projections etc are treated as alternative model scenarios.

Employees and households are classified into detailed categories to capture their behaviour under different transport network and housing supply conditions. Travel demand is allocated between car, bus, rail and walking/cycling based on travellers' perceptions of costs, travel times (including any congestion or overcrowding), and the convenience of using the mode for different trip purposes. The road and rail traffic patterns output from the model represent a realistic estimation of what will happen given the land use and transport policy measures proposed.

The model's strength lies in its estimation of long term travel demand responses under any given land use and transport scenario. It includes a large number of demographic and socio-economic variables. As a result, it is capable of representing a wide range of travel demand responses under a policy scenario. Its geographic resolution is not as detailed as local traffic models and is not meant to provide detailed traffic forecasts for specific links.

[The model thus enables us to examine weekday morning peak charging – most of the analysis; we follow this here – non-peak times still has a lot of capacity; in fact part of the aim of RP is to get more of the off peak capacities used, therefore journeys to work, to school, and to business: the first and third more important for longer journey lengths. One caveat being Sunday pms in London – a separate subject to be dealt with in separate paper, as the mechanisms are different.]

Figure 4 **LASER3.0 model zones: London**

Figure 5 **LASER3.0 model zones: the South East and the Eastern Regions**

4.2 Marginal social cost based charging – road charge estimation procedure

Procedure developed by Williams and Lindsay (2007; DfT, 2007)

4.3 Baseline scenarios: 1997-2016-2030-2050

[Base trajectory of development 1997-2016-2030-2050]

Whilst the land use activities increase, it is assumed that the road capacity will not expand beyond 2016: instead, marginal social cost based congestion charges are estimated by road link by direction and they are applied to the car trips under the road pricing scenario using the method presented in Section 4.2.

Figure 6 presents the average road charges by year (weighted by pcu-kms). The charges are shown at the zonal level instead of at the link level for clarity. As expected, the charges are highest in central and inner London. The area of high charges extends towards the west and south west, where the traffic congestion levels are high, and then seen in some of the urban areas outside London. Over time, the congestion charges rise as expected, with the high charging areas coloured in red and orange expanding from central and inner London outwards, particularly along the busy motorway corridors.

Compared with the baseline, non-charging scenario, the road charging scheme is shown, as expected, to improve overall accessibility for business and commuting travel during the morning peak. This is primarily due to increased car and bus speeds. Using the current UK Department for Transport's measure of economic mass (REF), Table 2 shows that the economic mass for accessing workplace employment through business travel improves by 11% overall, and the economic mass for accessing labour through commuting travel improves by 2%. However, the improvements are by no means constant across the areas. By destination area, the ring of inner London areas outside central London and outer London appears to gain the most in terms of economic mass.

However, by comparison with central London (or even outside London), this ring of inner London and outer London has the lowest own price elasticity wrt car travel cost⁴ (Table 3). Access to public transport in the ring of inner London and outer London are far less good than central London. This needs to be investigated through different land use planning and public transport access scenarios to see what effects the road charges have on travel demand, depending on whether they trigger relocation of business activities across the city region.

⁴ which includes road charging but excludes parking fees.

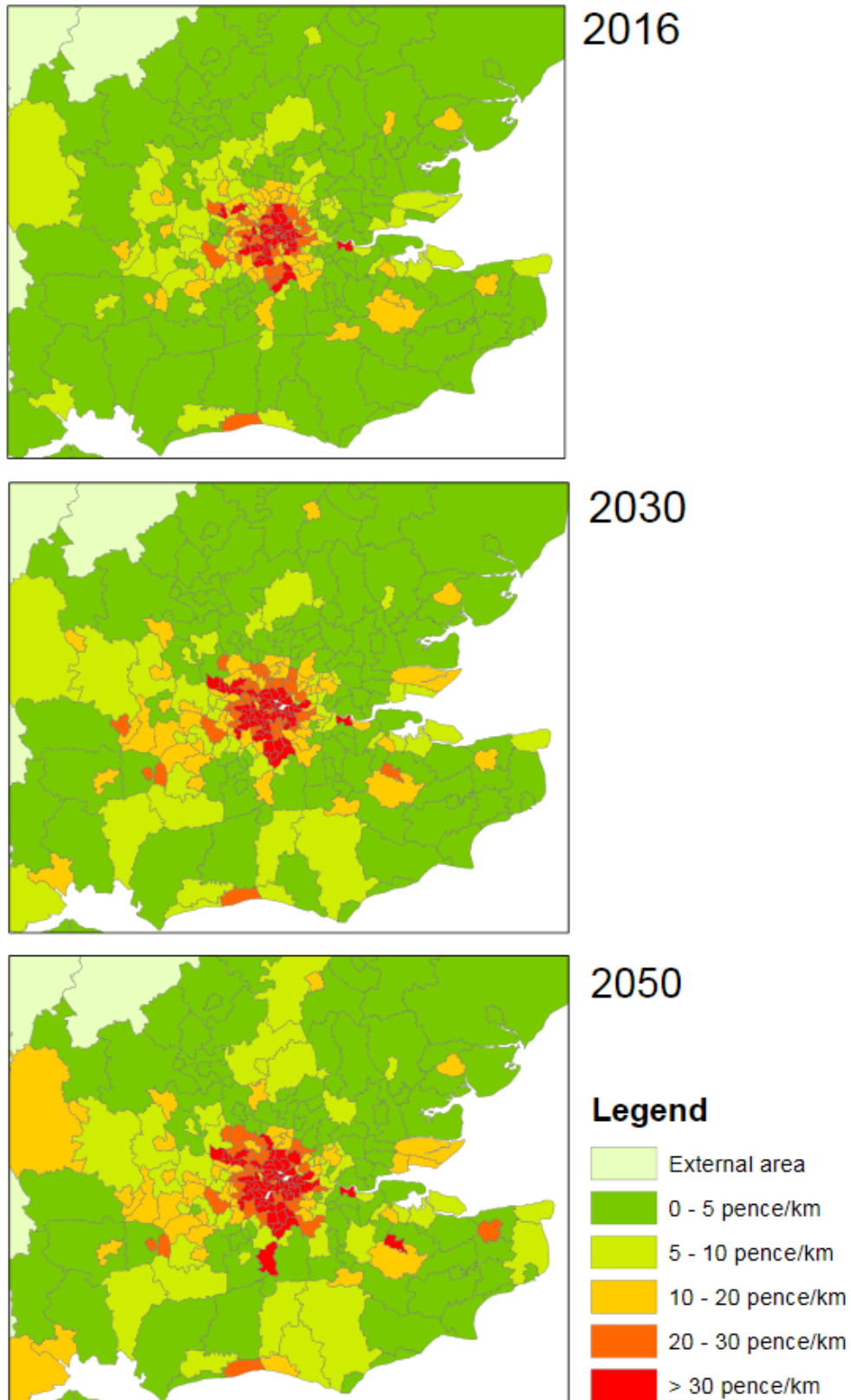


Figure 6 Congestion charges for morning peak period (7-10am): 2016, 2030 and 2050

Note: Whilst the road charges are estimated and applied by road link by direction, these charges are presented in the maps above as model zone averages for clarity. The charges are in 1997 prices.

Destination area	Economic mass for accessing workplace employment (through business travel)	Economic mass for accessing labour (through commuting travel)
City of London and South Camden	10%	2%
Other Central London	11%	4%
Rest of Inner London	17%	5%
Outer London	13%	1%
South East	8%	2%
East of England	5%	0%
All Areas	11%	2%

Table 2 Changes in economic mass for accessing workplace employment and labour: with congestion charging vs without, 2030

Destination area	Mode and route switching – all trips	Mode and route switching plus change of trip origins and destinations – all trips	Mode and route switching plus change of trip origins and destinations – business trips only
City of London and South Camden	-0.17	-0.22	-0.25
Other Central London	-0.12	-0.12	-0.16
Rest of Inner London	-0.04	-0.08	-0.04
Outer London	-0.04	-0.08	-0.04
South East	-0.08	-0.18	-0.08
East of England	-0.08	-0.20	-0.09
All Areas	-0.07	-0.17	-0.10

Table 3 Own price elasticity of car passenger-kms wrt total car travel cost by trip destination area, 2030

[Summary of the polarising scenarios – aim is to see the range of effects.

Three land use scenarios are then tested: 1) very tight land use control (so existing land use patterns persists into the future); 2) very loose land use control (so businesses move to where productivity improves) and 3) transit-oriented development which exploits the potential of density pyramids around main rail nodes, especially where the rail infrastructure already exists.

4.2 Tight land use control over development of business premises

[Closer to traditional British practice and existing location pattern]

[Results]

4.3 Loose land use control over development of business premises

[Businesses attracted to where the economic mass has improved significantly - Likely scenario under a dash for economic recovery/competitiveness]

[Results]

4.4 ToD and density pyramids over main rail nodes

[Planner's scenario; integration with the rail/underground markets as well as land use planning]

[Results]

5 Conclusions

[Summary of theoretical framework]

[Case study of London and surrounding regions, through model simulation that account for the economic mass/productivity effects as well as land use/transport interaction]

[Focus on city region wide road pricing, using a generic, marginal social cost pricing consistent with our understanding of the behavioural time values of the different travel demand segments. Make clear that this is much wider coverage and higher charging prices than current London or Stockholm scheme]

[Direction and magnitude of the impacts indeterminate – shown in polarising scenarios under generic marginal social cost based pricing schemes]

[There can be significant long term impacts upon travel demand, which could either enhance or negate the initial time savings seen in short term modelling/monitoring under different scenarios.]

In turn, we expect the research on the design and full-cycle impacts of road pricing will help to reignite policy interests in those metropolitan areas where such schemes were considered and then shelved in the recent past, and guide the practical design of future schemes if and when traffic congestion creeps back to the political agenda.

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Appendix A A short description the LAB model

Appendix B Key equations for estimating marginal social costs in a MEPLAN-based model