Complementing Distance based Charges with Discounted Registration Fees in the Reform of Road User Charges: the Impact for Motorists and Government Revenue.

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Abstract

The call for a congestion charge is getting louder and more frequent in many countries as major metropolitan areas experience increasing levels of road congestion. This is often accompanied by a recognition that governments need to find new sources of revenue to maintain existing road networks and to invest in new transport infrastructure. Although reform of road pricing is almost certain to occur at some time in the future in a number of countries, a key challenge is in selling the idea to the community of road users as well as a whole raft of interest groups that influence the views of society and politicians. Simply announcing a need for a congestion charge (often misleadingly called a tax) does little to progress the reform agenda. What is required is a carefully structured demonstration of what might be done to progressively introduce adjustments in road user charges that are seen as reducing the costs to motorists while ensuring no loss of revenue to government. In this paper we show, in the context of Sydney (Australia), that this can be achieved by the reform of registration fees in the presence of a distance-based charging regime that can deliver financial gains to motorists, with prospects of revenue growth to the State Treasury.

Key words: road pricing reform, political process, revenue implications, staging reform, appealing solutions, use-related registration fees, distance-based charging, implementation costs

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Introduction

Road pricing reform is much touted by economists and others who see the current charging instruments inadequate in both delivering efficient outcomes for road use (especially in controlling levels of traffic congestion), as well as raising sufficient revenue to fund new infrastructure and much needed maintenance of existing road networks (see Verhoef *et al.* 2008, Manville and King 2012, and Small 1992). The literature is clear about the welfare impacts of road pricing as a first best solution, and the impact of compensatory schemes for drivers with budgetary neutral packages (e.g., De Borger and Mayeres 2007; Proost and Van Dender 2001). However this literature does not address the greatest challenge in reforming road user charges, which is not about welfare impacts but about devising a scheme which gains public acceptance. The benefits of such a scheme must be convincing to voters, convincing to politicians concerned about their electoral future (see Marcucci et al. 2005, Goodwin 1989, Hensher and Bliemer 2012, Bliemer et al. 2009, Hensher et al. 2013) and satisfy the Treasury[1]. The public sentiment, albeit often misinformed, is well illustrated by the following summary of a recent radio conversation.

> *Setting: ABC Sydney Radio 702 Tuesday 4 Oct 2011 8.30-8.55am.*
> *Hensher discusses the merits of Road Pricing Reform (after stating clearly that it is more than a congestion tax, and to please stop using the emotive language of a congestion TAX). Calls are invited from the public.*
>
> *A plumber calls and says (paraphrase): "…I spend up to 5 hours on the roads every day between jobs and now you are telling me I have to pay a congestion tax on top of all of my existing costs for the 5 hours. What is he thinking (the Professor needs to get real)… I do not earn enough income now as it is."*
>
> *Hensher's response (paraphrased): "…I made it very clear I thought that the aim is to reform the entire set of charges (including registration fees) and to set the kilometre based charges to reflect the traffic conditions with the aim of not only enabling you to save time (which is money as well) but to give you realistic options on levels of charge and time of day to travel. It is expected that you will spend less time travelling and can convert such saved time into more productive income earning time."*

This paper promotes the belief that road pricing reform will be achieved only by a slow but progressive set of steps in situations where a 'trial' is not put in place that allows motorists to see its merits (Schuitema *et al.* 2010). The predominant interest of car drivers, when first asked about congestion charges, is what it will mean financially to them (with rare reference to its value in improving travel times) as evidenced by referendums in the UK which failed to support congestion pricing packages (Gaunt *et al.* 2007, De Borger and Proost 2012). Indeed, in identifying congestion charging schemes that voters would opt for, the literature identifies

[1] Politicians in countries we are familiar with are heavily influenced by the flow of revenues to government, and Treasuries frequently remind their Minister about this. So from a political perspective, this is paramount.

that support is influenced by the perception of societal benefits, but the impact of personal well-being is stronger (Jaensirisak *et al.* 2003. Eliasson and Jonsson 2011). The paper is therefore predicated on the idea that reform must start with some initiative that has an easier staged sell in respect of the "hip pocket" rather than with the explicit end objective to reduce traffic congestion, if it is to achieve acceptance and buy-in.

The paper is organised as follows. We begin with a discussion of how registration fees can be packaged with peak[2] distance-based charges to obtain financial gains to key stakeholders[3]. This is followed by an explanation of the method we have adopted, together with the data we have used from the Sydney Household Travel Survey data (expanded to the population), to undertake scenario analysis in determining the financial and usage implications of varying registration fees and distance-based charges in the peak. We then present compelling evidence to show how road pricing reform can make both drivers and government better off financially, although we recognise that the need for some upfront investment in the data capture technology may involve a significant outlay by government. The conclusions summarise the main policy implications and topics requiring further research.

Registration-Usage Pricing Reform

Whether any proposed road pricing reform begins with a driver-wide compulsory application or a voluntary opt in and opt out plan is secondary to establishing if there is financial merit in a scheme in terms of its impact on drivers. In addition to motorists, government, and especially Treasuries, also have a keen concern for the revenue implications of road pricing reform. The approach we propose in this paper is to start with a budgetary constraint that represents the need for Treasury to be financially no worse off (and possibly better off) while establishing a charging regime that will also make drivers, on average, financially no worse off (and possibly better off). The Treasury of interest is a State organisation which does not collect fuel excise (a federal tax), but collects registration fees. We recognise that in some countries such as the UK, the collection agency is at the National level, whereas in Australia and the USA, for example, there is the distinction between State and Federal agencies. There will be implications for fuel excise which is a Federal responsibility in Australia. The implications for fuel excise revenue is not central to this paper, lying as it does outside the reforms proposed, but could easily be included in this framework if a national agency perspective is sought.

[2] We also investigated all day distance-based charging, and while there may be some merits for this, including the view that the perception of an all day charge might look better as it is less at (3) cents per km, on balance we believe that it will be more difficult to sell this as the first step, and so we have focussed on peak period only distance-based charging.

[3] The appeal of a registration fee reduction is that it is transparent and more clearly linked to the reform of road pricing, in a way that makes it easier to gain buy in to a road pricing reform package. A 50 percent reduction in the registration fee is likely to be perceived much more as a good deal compared to the same amount being sold as a concession on income tax which will amount to a very small percentage. Prospect theory highlights this through perceptual conditioning.

The reform framework we adopt, as proposed in Hensher and Bliemer (2012) that has these desired attributes, involves the introduction of a distance-based charging regime in return for a discount on the current annual registration fee, in full or in part. Although governments often raise the prospect of increasing the annual registration fee to raise revenue (a recent example being the release in December of the New South Wales (NSW) Long Term Transport Master Plan (TfNSW 2012)), we would argue that discounting of the registration fee can be used as part of a carrot and stick initiative to move to use-related charging to relieve a cost burden on motorists, at least in the initial phase of securing buy in to road pricing reform. To be able to say that a reform strategy will not make drivers worse off financially[4] will be a major step forward in dulling the immediate critical response from motoring organisations and politicians! A resulting bonus of this reform plan, which is not available under a registration only fee regime, given the disconnection with kilometres travelled, is drivers enjoy the resulting travel time savings. The reduction in kilometres travelled, especially during peak periods, need not be radical in order to make enough of a difference in traffic congestion. The best evidence of this is the difference between peak period travel times on roads during school holidays and during normal times of the year, typically associated in Sydney with up to five percent less traffic (or 1 in 20 vehicles) as a conservative estimate[5].

Sourcing Data to Quantify the Potential Cost and Revenue Impacts of the Reform Plan

The primary data on car driver trip activity and cost outlays is sourced from the Sydney Household Travel Survey (HTS), the largest and most comprehensive source of personal travel data for the Sydney Greater Metropolitan Area. The HTS was first conducted in 1997/98 and has been running continuously since then. About 5,000 randomly selected households are approached each year to participate in the survey[6]. The sample of the

[4] Some individuals may be (slightly) worse off financially even though most will be better off. Some form of a compensation package may have merit in such circumstances, with monies coming from the additional revenue gain beyond the revenue neutral outcome for Treasury. See also Levinson (2010).

[5] Based on data from the Sydney annual Household Travel Survey and http://www.rta.nsw.gov.au/publicationsstatisticsforms/downloads/travelspeeds_sydney_metro_area.html
During school holidays, traffic lightens by about 7 to 10 percent outside school drop off hours, yet the influence that this has on traffic flow is immense. (See http://www.privatefleet.com.au/congestion/). The National Road and Motorists Association (NRMA) of Australia uses a rule of thumb that when traffic on congested roads falls by 5 per cent, speeds increase about 50 per cent (though this might only mean an average speed increase from 20 km/h to 30 km/h).See http://smh.drive.com.au/roads-and-traffic/how-do-you-spell-the-end-of-the-school-holidays-gridlock-20120715-224ag.html. We calculated a 4.77 percent drop in traffic volumes during school holidays in Sydney in 2005 on all the major arterial roads, freeways and tollroads (sourced from http://www.rta.nsw.gov.au/trafficinformation/downloads/aadtdata_dl1.html.)

[6] The HTS consists of a face-to-face interview survey carried out every day from July to June of each financial year. This collection method ensures high data quality and maximises response rates. A simple travel diary is used by each householder to record the details of all travel undertaken for their nominated 24-hour period. An interviewer then interviews each householder to collect the details of each trip. The interviewer records the mode of travel, trip purpose, start and end location, and time of departure and arrival. Vehicle occupancy, toll roads used and parking are recorded for private vehicle trips and fare type and cost for public transport trips. The HTS sampling method was designed for BTS by the Statistical Consultancy section of the Australian

continuous HTS is designed on a three-yearly cycle, so that the pooling of three years of data gives a sample size similar to that achieved in the traditional once in 10 years metropolitan household interview survey.

We have used pooled data of residents of occupied private dwellings in the Sydney Metropolitan Area from five waves, June 2007 to October 2011, weighted to the June 30 2010 population. Population weights are based on the estimated resident population as at 30 June 2010. The data is based on an average day, and is scaled up to the full year. We have undertaken all of the analysis at the geographical level of the Sydney Statistical Division (SSD)[7]. There are 14 SSD's in Sydney; however we have excluded the Statistical Division of Gosford Wyong (SSD7), which is unlikely to be exposed directly to road pricing reform[8] since it is over 65 kilometres north of what is generally regarded as the Sydney region (see Figure 1).

In designing a scenario-based application framework, we need to identify the 'before' or status quo financial outlays and kilometres travelled by drivers in the peak and off-peak periods. Some costs are use-related, such as fuel costs (distinguishing the fuel excise from the other fuel costs passed to motorists), and tolls, while the registration fees are annual fixed charges unrelated to usage. We also need to calculate the revenue obtained by State Treasury under the status quo situation. In this study we are interested in the revenue implications for the State (of NSW) Treasury who collect registration fees only, and who will, under a distance-based charging regime, also collect the use-related revenue. Fuel excise is collected by the Federal government and is disbursed as they see fit, with some of the funds returning to the States in many forms. Tolls are collected by the tollroad operators and are retained as part of the public-private partnership concession arrangements, and are not available to State Treasuries. The tollroad network in Sydney is extensive by the standards of most cities (see Li and Hensher 2010).

Bureau of Statistics (ABS) such that the relative standard error (RSE) decreases and the statistical reliability increases as more waves of data are pooled.

[7] We have data at the postcode level which is at a greater level of spatial disaggregation; and while it is useful for studying sources of systematic variation that influence total kilometres travelled per driver, there are sample reliability concerns for the analysis undertaken herein. We use SSDs, but undertake some additional scenario analysis to assess the range of annual kilometres of drivers from each SSD.

[8] There may be implications for residents of Gosford-Wyong who commute to the other Sydney SSDs; however this can, in future analysis, be included if required.

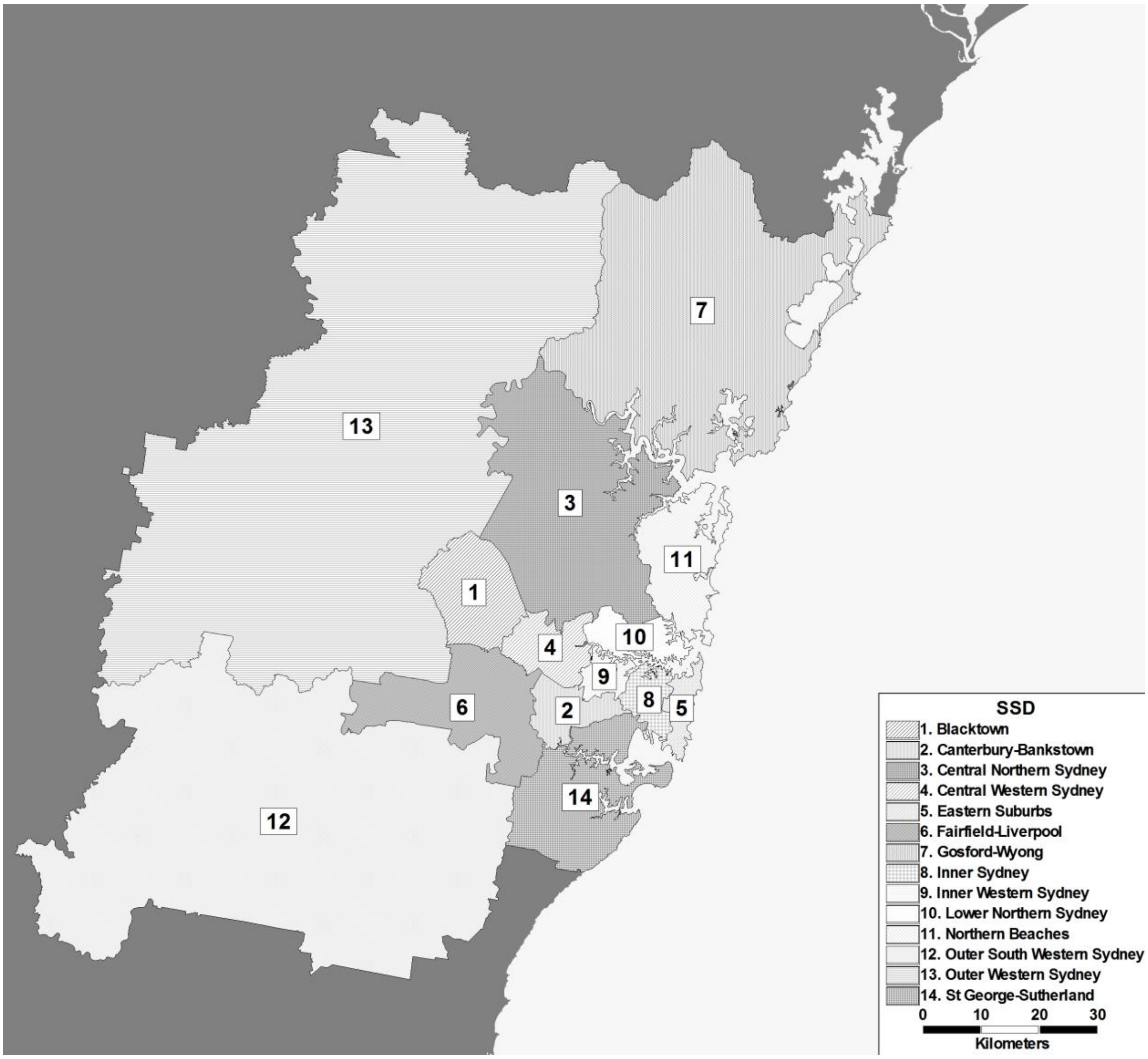

Figure 1 The location of the 14 SSD's in Sydney

To determine the behavioural response of car drivers, expressed in terms of changes in peak and off peak kilometres, to the introduction of peak period distance-based charges (DBC)[9], we need to assume a DBC elasticity of kilometres travelled, *ceteris paribus*. Li and Hensher (2013) provides one review of the evidence, although they find that the focus of most road pricing studies that have reported elasticity estimates has not been in terms of changes in kilometres travelled. Hensher *et al.* (1992), in a longitudinal study of household demand for automobile by type and kilometres travelled in Sydney, obtained static and dynamic short run

[9] It is often suggested that the same outcome for motorists can be achieved by simply reducing the registration fee, and increasing fuel taxes. We do not support this view, given that fuel excise is a sum per litre of fuel that is essentially independent of the *specific* kilometres of travel. The idea of *specific* kilometres (and its link to locations and times of the day) is focussed on relating travel to sources and magnitudes of externalities such as traffic congestion and emissions (Hensher and Bliemer 2012), and it has been well established that energy based taxes fail to deal adequately with traffic congestion problems (Greene 2011). We do, however, acknowledge that there is a link between variations in fuel consumed per kilometre and specific kilometres, but not enough to influence the evidence presented in this paper.

and long price elasticities for fuel and registration charges in the context of annual kilometres travelled. We have drawn on this study to select price arc elasticities of -0.25 and -0.35 respectively for peak and off-peak kilometres, which we suggest are generally in line with expert opinion[10]. Sensitivity testing around these mean estimates enables us to determine the influence these estimates have on the change in kilometres travelled. These elasticities are applied to the fuel and toll costs[11] together with a peak period distance-based charge, assuming no change in total *status quo* kilometres. Formulae were developed to calculate the peak kilometres under a peak only DBC[12]:

$$PKM^{AEC} = [PKM^{BEC}*(1-(((TC^{A}|TKM^{BEC}-Regn^{A}) - (TC^{SQ}-Regn^{SQ}))/ (TC^{SQ}-Regn^{SQ})) * Abs\ Elas)] * TKM^{AEC} - TKM^{BEC}*(1-PropPKM)$$

$$TC^{A}=Regn^{A}+DBC+FuelCost+(Toll-(Toll*((TKM^{Before}-TKM^{After})/(TKM^{Before})))$$

where:
PKM^{AEC} = annual peak kms after the elasticity application
PKM^{BEC} = annual peak kms before the elasticity application
$Regn^{SQ}$ = annual registration fee before (i.e., status quo) reforms
$Regn^{A}$ = annual registration fee after reforms
TC^{SQ}= total costs before (i.e., status quo) reforms
TC^{A} = total costs after reforms
TKM^{Before} = total annual kms after DBC but holding kms to SQ levels
Abs Elas = the direct elasticity without sign
PropPKM = proportion of total kms that are peak kms.

Table 1 summarises the kilometre activity of motorists resident in each SSD together with the mean personal income, as background to the setting where the extent of changes in annual kilometres in the peak and off peak periods change in the presence of reforms to the cost of owning and using cars is to be identified. As might be expected, the quantum of kilometres of residents of each SSD varies significantly, and in large measure is due to location relative to the Sydney Central Business District, reflecting the radial-centric nature of Sydney. The data has an implied direct elasticity of daily kilometres per driver with respect to distance from the CBD of 0.21 (obtained from a linear regression model in which distance to the CBD was statistically significant, with a t-value of 3.64, and in which the overall explanation of variation (adjusted R^2) is 51 percent); hence a 10 percent increase in the average distance to the CBD increases average daily kilometres per driver by 2.10 percent, *ceteris paribus*.

[10] We recognise that these elasticities are drawn from a study that focussed on fuel price changes, and that we are using these estimates in the absence of elasticities that are specific to a DBC or a registration fee. However we would suggest that the range reported and assessed is a good starting position until we have evidence for specific costs.
[11] In Sydney, all tolled roads are cashless with electronic tags (ETAGS). ETAGS tend to make payment seamless and change the perception of toll payments since the driver is not having to be reminded in the same way as having to find cash and stop. This tends to reduce the price sensitivity and brings it closer to the fuel cost response.
[12] There is no account taken for changes in travel time.

Interestingly, when we add in personal income, retaining distance to the CBD, we find that the parameter associated with the natural logarithm of income is not statistically significant (t-value of 1.29), but with an implied mean direct elasticity of daily kilometres per driver with respect to mean personal income per SSD that is very close to unity (1.03). If distance to the CBD is removed from the model, the personal income parameter is negative (-0.85) and highly non-significant (t-value of -0.95). At the mean, therefore, there appears to be no statistically significant relationship between average daily kilometres per driver and income.

When we use equivalent data at the postcode level, the overall fit of the model is poor, (adjusted R^2 of 0.027), although both distance from the CBD and personal income, as the only variables in the model, are statistically significant with respective t-values of 12.76 and 11.79. The implied direct elasticity of daily kilometres per driver with respect to distance from the CBD is 0.27, not dissimilar to the SSD level evidence of 0.21, and with respect to personal income it is 0.15.

We now take a closer look at the combinations of a distance-based charge and discounted registration fees that satisfy the budget neutral (or better) requirement of State Treasury, and which also deliver no overall financial impost on drivers.

Table 1 Descriptive Profile of SSD level Data

SSD	**SSD Name**	**Mean Personal Income**	**StdDev Income**	**Mean Kms per day per driver**	**StdDev KmDay perDrv**
SSD1	Inner Sydney	62.89	41.07	13.97	21.45
SSD2	Eastern Suburbs	63.38	43.73	17.14	21.75
SSD3	Inner West	56.42	40.86	16.22	22.64
SSD4	Lower Nth Sydney	62.22	44.03	19.5	23.64
SSD5	Central Nth Sydney	59.96	43.24	26.43	31.09
SSD6	Northern Beaches	61.04	43.27	20.5	24.72
SSD8	Central West Sydney	57.28	42.52	22.75	29.03
SSD9	Canterbury-Bankstown	49.66	36.54	17.85	22.91
SSD10	Blacktown	53.43	37.22	28.18	32.59
SSD11	Fairfield-Liverpool	51.42	37.68	25.68	30.25
SSD12	Outer South West	52.87	38.94	18.24	39.63
SSD13	St George Sutherland	57.18	39.56	24.16	28.72
SSD14	Outer West	56.65	39.23	32.86	37.82
SSD	**SSD Name**	**Drivers**	**Total kms per day per driver**	**Population**	**Total Licence Holders**
SSD1	Inner Sydney	113,525	1,585,942	362,074	178,624
SSD2	Eastern Suburbs	103,756	1,778,382	261,089	173,161
SSD3	Inner West	79,607	1,291,231	195,230	127,167
SSD4	Lower Nth Sydney	136,065	2,653,274	321,383	194,170
SSD5	Central Nth Sydney	186,687	4,934,141	463,330	146,962
SSD6	Northern Beaches	118,165	2,422,390	250,506	211,984
SSD8	Central West Sydney	180,976	4,117,210	360,720	291,151
SSD9	Canterbury-Bankstown	131,798	2,352,592	338,390	212,523
SSD10	Blacktown	129,705	3,655,082	313,057	188,005
SSD11	Fairfield-Liverpool	161,531	4,148,128	386,326	130,943
SSD12	Outer South West	116,234	2,120,108	257,647	171,410
SSD13	St George Sutherland	216,495	5,230,509	465,594	325,089
SSD14	Outer West	161,735	5,314,614	330,454	104,697

Identifying the Preferred Mix of a Peak Period Distance-based Charge and Discounted Annual Registration Fee

To establish the financial implications of alternative combinations of a peak period DBC and discounted annual registration fees, we built a scenario decision support system (in Excel). The key inputs, for each SSD and status quo (i.e., before) situation, are the mean annual kilometres, the proportion of kilometres in the peak periods (AM and PM)[13], the average daily cost per driver (comprising fuel and tolls, distinguished by peak and off peak periods), annual registration fees, and mean direct elasticities of peak and off peak kilometres with respect to usage costs. In addition, for the reform scenarios, we considered a DBC varying from 2c/km to 10c/km in the peak, and allowed annual registration fees to vary from 30 to 75 percent of the status quo annual fee. These ranges were determined from an initial assessment of likely adjustments that would satisfy the binding constraints to be neutral to government revenue and driver cost outlays.

As part of scenario definition, given the absence of any evidence on cross elasticities of kilometre switching by time of day under a move from a fixed annual registration fee to a DBC use-related charge, we have assumed that all kilometres that have moved from the peak period do not move to the off-peak[14]. This is a limiting assumption, with an expectation that we have under-predicted the change in off-peak kilometres (Bliemer *et al.* 2009). If we had allowed for some of peak kilometres to switch to the off peak, then the financial cost of these kilometres would be the same as before, with a possible small reduction on fuel costs given the different traffic conditions. Since the off-peak kilometres do not have a DBC cost element, the impact on State Treasury is zero; although there is a reduction in Federal fuel excise for kilometres no longer undertaken. In the absence of evidence on cross elasticities, we speculate that the majority of the previous peak kilometres will move to the off peak shoulders, with a small amount being curtailed, and very little switching to public transport (given the Sydney situation).

The decision support system calculates the status quo total costs and kilometres for all drivers and revenue to State Treasury, distinguishing outlays and receipts for the peak and off peak periods. We then introduce the range of peak-period DBCs and discounted registration fees, and calculate the combination of these two cost outlays for motorists of each SSD that results in *both* a reduced mean cost outlay to motorists and no loss in revenue to State Treasury. At the SSD level, we expect to obtain different DBC levels for a given discount on the registration fee, and indeed that is what was obtained. The range is three to eight cents/km. as shown in Figure 2. Taking the lowest value would ensure net gains to each SSD motorist, but would result in the loss of neutrality (or better) to Treasury revenue. Placing different charges on motorists over the metropolitan area would raise clear concerns from many perspectives, including the political ramifications.

[13] The peak is defined as 6.31am to 9.30 am and 3.01pm to 6pm Monday to Friday.
[14] When we introduced an all day DBC, we would also get a change in off-peak kilometres, but that scenario is not considered in this paper.

A preferred solution is to take a system wide approach (essentially a weighted averaging of the SSD data), and to identify a single DBC, given a discounted registration fee, that achieves the required financial outcomes for drivers and State Treasury. Table 2 summarises the findings in which the selected peak period DBC is 5c/km with a discounted registration fee of $185, slightly greater than a 50 percent reduction. On average, a driver saves $9 per annum and Treasury gains $32 per driver per annum. These are extremely low amounts per driver, but they translate into sizeable financial gains to all drivers (Figure 3) and State Treasury (Figure 4 and Table 3). Figure 3 highlights the total mean differences in cost outlays for drivers resident in each of the SSDs, with eight SSDs having positive gains and five SSD's with negative gains. There is a total cost gain of $43.6m and a total cost loss of $28.8m. When converted to an additional cost outlay per driver per km, the amount for the five affected SSDs is 0.34 cents/km, contrasted with 0.65 cents/km gain for the eight SSDs.

In exploring the financial implications on drivers of moving away from an SSD-specific DBC solution, Table 4 is particularly informative in that it identifies the average gains or losses in cost outlays *per driver per annum* in each SSD. The bolded cells represent the preferred outcome when each SSD is assessed independently; and this is contrasted with the cells based on the system wide 5 cents/km solution. For SSD's 5 and 13, the SSD-specific and system wide DBC charge is the same. The evidence in Table 4 suggests that, on average, car drivers are better off under the system wide DBC than under the SSD-specific solution for SSDs 1-4, 6, 8-9, and SSD 12, but Treasury is worse off; and worse off for SSDs 10 and 11, with Treasury better off. The average annual financial gains and losses per driver at 5 cents/km are relatively small, ranging from $91 for SSD1 to -$40 for SSD10. Of the SSDs located the furthest distance from the CBD (notably SSDs 10-14), drivers are better off under the 5 c/km DBC in SSD8 and SSD12, whereas in the other SSDs drivers are worse off, with annual cost outlay increases varying from a high of $84 (SSD14 - Outer West) to a low of $3 (SSD13 – St George Sutherland). These are still, however, very small financial imposts on drivers. Importantly, however, as shown above, there appears to be no evidence of an income effect as a consequence of moving from SSD-specific DBCs to a system wide DBC.

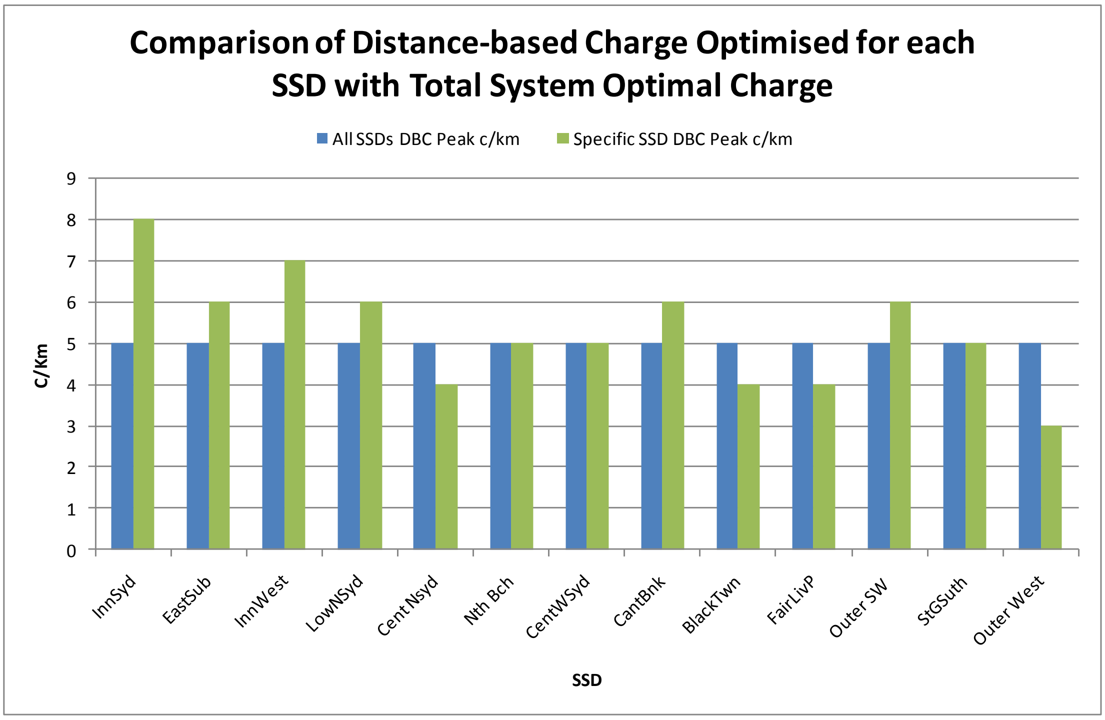

Figure 2 A Comparison of the System wide DBC versus SSD Specific Pricing

Table 2 Identifying a DBC and Discounted Registration Fee that makes Motorists and Treasury Financially No Worse Off

		ALL SSDs		
		Positive = gain, negative = loss		
		Car driver	Treasury	change in peak km
Regn fees halved and DBC for peak kms only C/km	2	130	-113	-102
	3	88	-64	-154
	4	48	-16	-205
	5	**9**	**32**	-256
	6	-29	78	-307
	7	-66	123	-358
	8	-102	167	-409
	9	-137	210	-461
	10	-171	252	-512

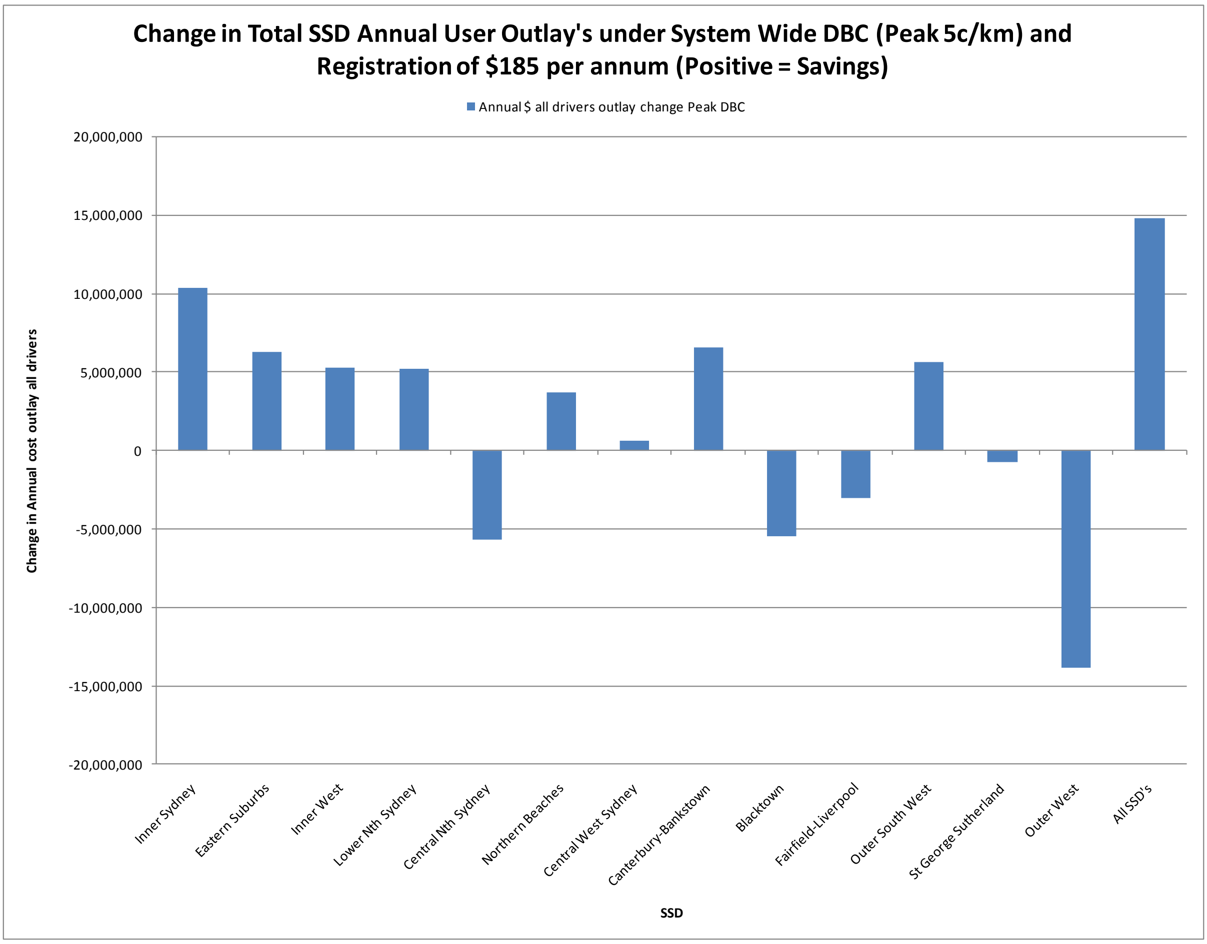

Figure 3 Impact of Pricing Reform on Annual Costs of Driver per SSD

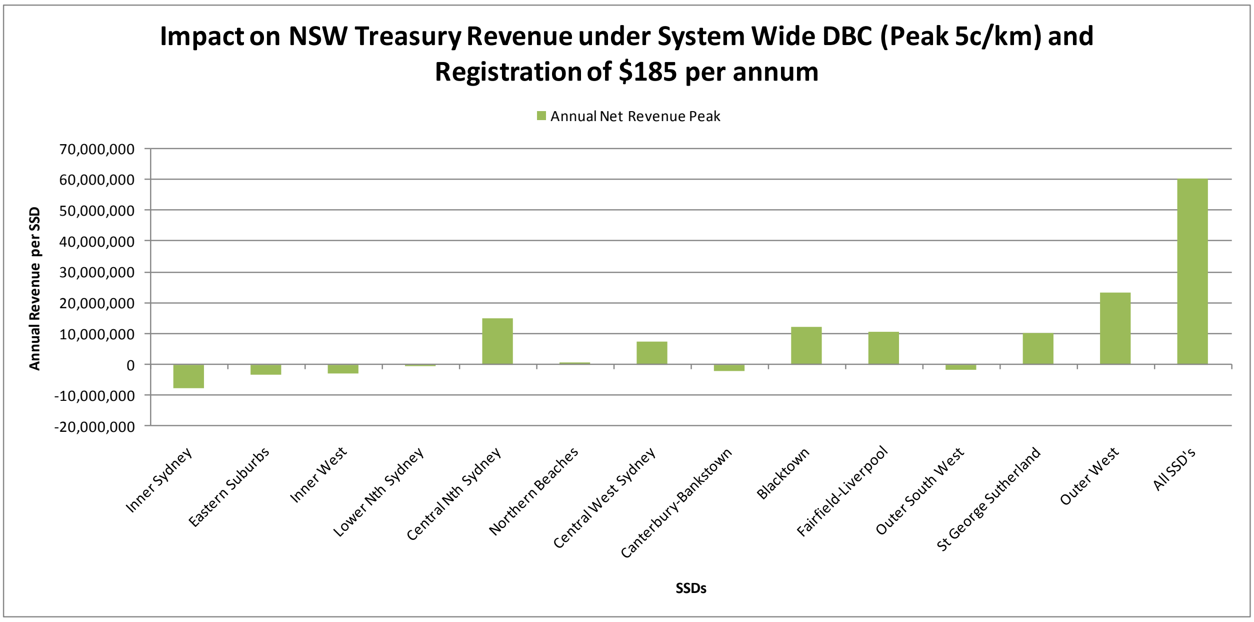

Figure 4 Impact of Pricing Reform on Treasury Revenue

Table 3 Impact of Pricing Reform on Treasury Revenue per Driver and for all Drivers

SSD	SSD Name	Treasury Impact Peak PA	Annual Net Revenue Peak
SSD1	Inner Sydney	-68	-7,690,883
SSD2	Eastern Suburbs	-31	-3,184,248
SSD3	Inner West	-36	-2,885,496
SSD4	Lower Nth Sydney	-3	-428,670
SSD5	Central Nth Sydney	80	15,002,723
SSD6	Northern Beaches	3	412,293
SSD8	Central West Sydney	40	7,202,676
SSD9	Canterbury-Bankstown	-16	-2,157,321
SSD10	Blacktown	93	12,001,333
SSD11	Fairfield-Liverpool	65	10,432,742
SSD12	Outer South West	-16	-1,851,350
SSD13	St George Sutherland	46	10,043,318
SSD14	Outer West	145	23,453,308
	All SSDs	**302**	**60,350,423**

Table 4 Summary of SSD-Specific Optimal DBC compared to the Systemwide 5c/km Impact
Note: The red shaded cells represent gains to motorists and Treasury

DBC for peak kms only	SSD1			SSD2			SSD3			SSD4		
Pos=gain, neg = loss	InnSyd			EastSub			InnWest			LowNSyd		
	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km
2	164	-154	-56	151	-139	-72	153	-141	-75	141	-128	-83
3	139	-125	-84	120	-102	-108	124	-106	-113	106	-85	-125
4	115	-96	-113	90	-66	-144	95	-71	-151	71	-43	-167
5	91	-68	-141	60	-30	-180	66	-36	-188	37	-3	-208
6	68	-40	-169	32	4	-215	39	-3	-226	4	37	-250
7	45	-13	-197	3	38	-251	12	30	-264	-28	77	-292
8	23	14	-225	-24	72	-287	-14	62	-301	-59	115	-333
9	2	40	-253	-50	104	-323	-39	93	-339	-90	152	-375
10	-19	66	-281	-76	136	-359	-64	123	-377	-119	189	-416

DBC for peak kms only	SSD5			SSD6			SSD8		
Pos=gain, neg = loss	Cent Nsyd			Nth Bch			CentWSyd		
	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km
2	113	-93	-124	139	-125	-88	127	-110	-113
3	64	-34	-186	103	-82	-133	85	-60	-170
4	17	23	-248	67	-39	-177	45	-10	-227
5	-30	80	-311	32	3	-221	5	38	-283
6	-75	135	-373	-2	43	-265	-34	86	-340
7	-119	189	-435	-35	83	-310	-71	132	-397
8	-162	242	-497	-67	123	-354	-108	177	-453
9	-204	293	-559	-98	161	-398	-143	221	-510
10	-244	344	-621	-128	198	-442	-177	263	-567

DBC for peak kms only	SSD9			SSD10			SSD11		
Pos=gain, neg = loss	CantBnk			BlackTwn			FairLivP		
	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km
2	147	-133	-86	109	-89	-125	118	-100	-118
3	114	-94	-128	58	-28	-188	72	-44	-177
4	82	-55	-171	8	32	-251	26	10	-236
5	51	-18	-214	-40	90	-313	-18	64	-295
6	21	19	-257	-88	148	-376	-61	116	-353
7	-9	55	-300	-134	204	-439	-103	167	-412
8	-37	91	-342	-179	259	-501	-143	217	-471
9	-65	125	-385	-222	312	-564	-183	265	-530
10	-92	158	-428	-264	365	-627	-221	313	-589

DBC for peak kms only	SSD12			SSD13			SSD14		
Pos=gain, neg = loss	Outer SW			StGSuth			Outer West		
	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km	Car driver	Treasury	change in peak km
2	146	-133	-80	124	-107	-113	91	-67	-152
3	113	-94	-120	81	-55	-169	31	5	-228
4	81	-55	-161	38	-4	-225	-27	75	-304
5	49	-17	-201	-3	46	-281	-84	143	-380
6	19	21	-241	-43	95	-338	-139	211	-456
7	-11	57	-281	-82	143	-394	-193	276	-532
8	-41	93	-321	-120	189	-450	-245	340	-608
9	-69	128	-361	-157	235	-507	-296	403	-684
10	-96	162	-402	-193	279	-563	-345	464	-760

Importantly, the new reform package results in a 4.7 percent reduction in total annual peak period kilometres, and a 2.96 percent reduction in all kilometres[15] (given in Table 5 and

[15] We recognise that this will likely be smaller when trips moving to off-peak periods are considered. It is of course true, that if motorists have similar total outlays before and after but travel less km, then the average cost per km travelled must increase. This means, as a referee has pointed out, that the decrease in costs to motorists is essentially a function of the decrease in kilometres driven. When taking account of fuel costs, if the peak kilometres all move to the off peak then the cost outcome is more or less unchanged (noting marginally lower fuel costs under less congested condition in the off peak). We have not introduced the possibility of some kilometres being moved to the off peak or switching to public transport, and nor have we accounted for the public transport fare or any possible loss of value associated with trips eliminated.

Figure 5 for each SSD and overall for all SSDs). This percentage change of close to 5 percent in the peak is in line with evidence on what it takes to get a noticeable improvement in levels of traffic congestion, which are often associated with the reduced traffic during school holidays (see footnote 4 which reports a 4.77 percent drop in traffic volumes during school holidays in Sydney in 2005). Hence if the reform package of a combination of a peak period DBC of 5c/km is combined with a discounted registration fee of $185 on average, we can expect noticeable improvements in traffic congestion, without a cost hike to motorists or a revenue loss to State Treasury. There will, however, be an overall 2.96 percent loss in fuel excise to the Federal government.

Table 5 Impact of Pricing Reform on Annual Kilometres

SSD	Total Daily Peak Kms Before	Total Daily Peak Kms - Peak DBC, 50%Rego	Total Daily Off peak Kms Before	OffPk Kms - Peak DBC, 50%Rego	Total Daily Kms Before	Tot Daily Kms - Peak DBC, 50%Rego
Inner Sydney	960,137	915,997	625,805	625,805	1,585,942	1,541,802
Eastern Suburbs	1,100,758	1,047,854	677,624	677,624	1,778,382	1,725,478
Inner West	819,932	779,731	471,299	471,299	1,291,231	1,251,030
Lower Nth Sydney	1,661,215	1,579,473	992,059	992,059	2,653,274	2,571,532
Central Nth Sydney	3,175,539	3,021,395	1,758,602	1,758,602	4,934,141	4,779,997
Northern Beaches	1,480,543	1,414,676	941,847	941,847	2,422,390	2,356,523
Central West Sydney	2,653,106	2,526,716	1,464,105	1,464,105	4,117,210	3,990,821
Canterbury-Bankstown	1,502,772	1,434,478	849,820	849,820	2,352,592	2,284,298
Blacktown	2,282,529	2,185,637	1,372,553	1,372,553	3,655,082	3,558,189
Fairfield-Liverpool	2,596,794	2,474,630	1,551,333	1,551,333	4,148,128	4,025,964
Outer South West	1,327,221	1,267,888	792,886	792,886	2,120,108	2,060,774
St George Sutherland	3,263,618	3,100,803	1,966,891	1,966,891	5,230,509	5,067,694
Outer West	3,345,305	3,190,485	1,969,309	1,969,309	5,314,614	5,159,794
All SSD's	**26,169,470**	**24,939,764**	**15,434,133**	**15,434,133**	**41,603,603**	**40,373,897**
Percent Change		**-4.70%**				**-2.96%**

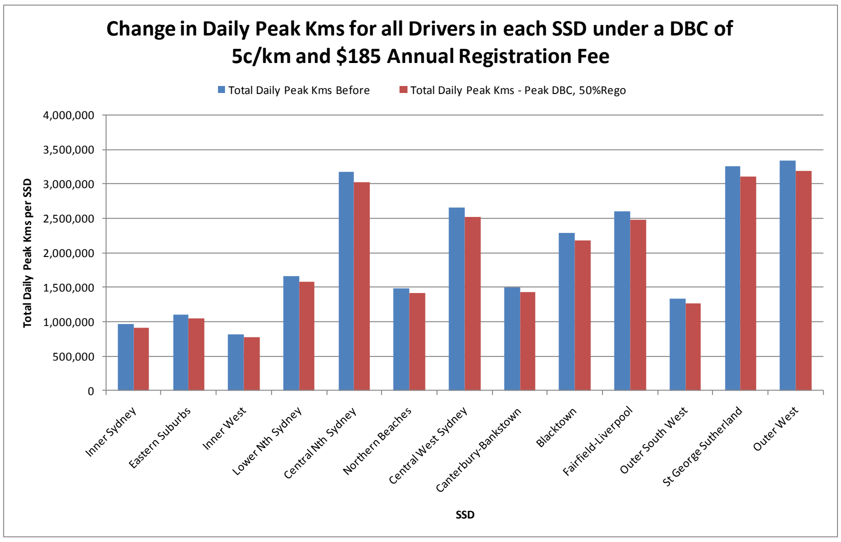

Figure 5 Impact of Pricing Reform on Total Driver Kilometres per SSD

The analysis reported so far has been based on the average driver in each SSD. To investigate the likely implications on cost outlays and revenue raised of deviations around the mean, we have taken the two extremes of all drivers in each SSD having high and low kilometres. The relevant levels for each SSD are given in Table 6, and range from a high of 75 kilometres per driver per day to a low of 8 kilometres per driver per day, both in the Outer West. Under these kilometre assumptions, we find that the peak period DBC is reduced to 2c/km for the high kilometres, and increased to 10c/km for the low kilometres, given the same discounted registration fee of $185. If all drivers were at the high or low kilometre level, State Treasury is financially much better off than under the 5c/km DBC, due to either the greater number of kilometres in the peak periods, or the higher DBC. Drivers, however, are worse off if they all operated at the high kilometres, while substantially better off at the low kilometres. Clearly this evidence is not what will occur in reality, because of a distribution of annual kilometres across all drivers. Even with a user loss of $14.076m, that is equivalent to only 2.01 cents per day per driver, hardly noticeable!

Table 6 Implications of High and Low Annual Kilometres in each SSD
Peak period DBC =2c/km for high kms and 10c/km for low kms
Annual registration fee is held at the discounted fee of $185
Positive = savings

SSD	Annual Kilometres per driver per day		Change in Driver Costs $ per annum per SSD		Change in Treasury Revenue $ per annum per SSD	
	Low	High	Low Kms	High Kms	Low Kms	High Kms
Inner Sydney	10	40	5,296,833	7,775,340	-1,500,051	-4,737,915
Eastern Suburbs	12	45	1,000,505	4,901,139	3,352,227	-1,636,590
Inner West	12	45	642,193	3,497,667	2,872,721	-861,481
Lower Nth Sydney	15	65	-5,896,785	-4,007,725	13,197,394	10,334,920
Central Nth Sydney	12	65	685,461	-6,488,833	7,781,749	15,661,644
Northern Beaches	10	55	5,420,140	1,430,670	-1,392,256	3,000,003
Central West Sydney	10	55	7,455,849	649,823	-598,481	6,893,282
Canterbury-Bankstown	10	50	5,518,786	3,174,935	-611,578	1,732,272
Blacktown	15	70	-5,537,584	-6,185,996	12,460,972	12,647,825
Fairfield-Liverpool	12	65	1,488,862	-4,737,450	5,442,874	12,246,831
Outer South West	9	50	6,902,847	3,137,157	-3,161,920	1,019,429
St George Sutherland	12	65	2,375,002	-6,199,179	6,854,364	16,197,659
Outer West	8	75	12,161,459	-11,024,484	-7,483,515	19,795,630
All SSDs	**10**	**55**	**37,513,570**	**-14,076,936**	**37,214,501**	**92,293,510**

Another way of considering variations in total peak and off peak kilometres is to stay with the DBC of 5c/km and to calculate the impost on drivers with high and low kilometres (Table 7). Although State Treasury is significantly better off under both low and high kilometres, drivers are much better off under low kilometres, but substantially worse off under high kilometres, as might be expected. It is clear that if say, 20 percent of all drivers have peak kilometres that are much greater than the weighted average for all SSDs, then some adjustment down in DBC will be required or a further discount of the registration fee. The ‘optimal’ DBC of 5c/km is the lowest we can obtain if State Treasury is to be no worse off (see Table 2); however if we reduce the registration fee, we may be able to establish a possible ‘solution’. A zero registration fee does not work at all for Treasury; a $150 registration fee will satisfy the Treasury budget constraint at 5c/km (gaining $11 instead of $32 per driver per annum) while making drivers better off (gaining $32 compared to $9 per annum), but only at a very slightly higher kilometres than the average kilometres.

Table 7 Implications of High and Low Annual Kilometres in each SSD
Peak period DBC =5c/km for high and low kms
Annual registration fee is held at the discounted fee of $185
Positive = savings

SSD	Annual Kilometres per driver per day		Change in Driver Costs $ per annum per SSD		Change in Treasury Revenue $ per annum per SSD	
	Low	High	Low Kms	High Kms	Low Kms	High Kms
Inner Sydney	10	40	14,307,805	-15,677,906	-12,409,414	23,271,470
Eastern Suburbs	12	45	11,036,737	-19,611,823	-8,860,372	27,773,194
Inner West	12	45	8,340,664	-15,609,974	-6,583,207	22,200,438
Lower Nth Sydney	15	65	10,631,043	-50,773,151	-6,980,738	66,591,138
Central Nth Sydney	12	65	19,235,148	-71,886,155	-15,001,543	94,818,182
Northern Beaches	10	55	14,825,949	-32,313,832	-12,812,007	43,390,513
Central West Sydney	10	55	22,119,151	-52,916,193	-18,690,467	71,773,956
Canterbury-Bankstown	10	50	16,176,667	-32,091,947	-13,723,064	44,359,965
Blacktown	15	70	10,174,725	-54,085,857	-6,713,031	70,240,430
Fairfield-Liverpool	12	65	17,079,316	-60,165,202	-13,613,448	78,938,656
Outer South West	9	50	15,427,902	-27,582,892	-13,557,438	37,974,358
St George Sutherland	12	65	23,019,199	-80,243,178	-18,404,516	105,239,380
Outer West	8	75	22,857,881	-75,335,331	-20,518,909	97,263,195
All SSDs	**10**	**55**	**205,232,187**	**-588,293,441**	**-167,868,152**	**783,834,875**

What is emerging from this analysis is that if we can increase the net revenue to Treasury substantially, while not making users worse off on average, then we can use the net Treasury gains to compensate drivers who have kilometres in excess of the average, possibly limiting this to 25 percent or more above the average. As the annual savings are very small per driver for users and Treasury (shown in Table 3), an increase in cost, say of $100 per year, amounts to a minimal amount per trip. For example, in Table 2, if we had a peak DBC of 10c/km, the average cost increase per driver per day would be 46 cents on average, or 2 cents per kilometre over all kilometres. The resulting increase in net revenue to State Treasury can then be available to compensate high peak kilometre drivers[16], and based on the evidence in Tables 2 and 3, this could amount to over $60m per annum available for disbursement. A user loss of $588.29m is equivalent to 89 cents per day per driver (or $324 per annum), or 3.8 cents per kilometre, which again is very small! We might suggest, given these very small numbers, that a case can be made for a higher DBC above 5c/km, as a way of ensuring sufficient additional funds to compensate high peak kilometre drivers.

Conclusions

The road pricing reform proposal developed in this paper is designed to provide a pathway to gaining buy in from the community that is essential to securing the support of the political process. With demonstrated evidence in the initial phase of reform that the majority of drivers and the State government will not be worse off financially, it is easier to obtain buy in,

[16] This will need very careful consideration. It should be fair as well. If high peak km drivers get a lot of compensation, they pay much less per km than people that drive below average kilometres. So this would more or less mean that the first kms are charged at a higher rate, while the rate diminishes. Does this have the desired effect? In the end, high peak km drivers may have less and less incentive to decrease their kilometres driven.

regardless of the implications for reduced traffic congestion and faster trips. The real bonus, and effective selling point, will occur when drivers see real time savings, and motoring associations finally are convinced that their members do gain from such pricing reform.

This is the first study that we are aware of that has systematically investigated a reform package that can appeal to key stakeholders, and that places quantitative evidence on the table for an entire Metropolitan area. The great majority of well articulated academic and consultancy research has generally failed in this endeavour. Indeed a recent comment by Poole (2012) best summarises this position: "I'm struck by what seems to be a huge disconnect between the systems being modeled by academic economists and the proposals emerging from field tests and demonstrations involving actual motorists." (Poole 2012). There are, however, some excellent exceptions, but they relate to cordon-based charging, as in Stockholm (Eliassson *et al.* 2009), or have an environmental focus (Parry 2012).

This road pricing reform plan would require drivers to purchase an on-board unit (OBU) (approximately $50 once off cost[17]) that will record the kilometres by time of day. The off peak kilometres are not charged, but peak kilometres will be charged at the agreed cents/km. This scenario implies that if an OBU is not installed, all kilometres will be charged as peak kilometres, giving an incentive to install a meter (with the expectation that all motorists will do so), just like households have had with off peak electricity meters or with water meters when they were first introduced. Indeed, linking this to the availability of 'Pay As You Go' insurance could provide additional benefits to users (Greaves and Fifer 2010, Parry 2012). There could be considerable implementation, operating and enforcement costs of a metropolitan wide (i.e., all roads) charging system for the state if a state of the art system was put in place. This would upset the revenue/cost balance (and which may require a variation in the 'optimal' DBC) unless the costs of such implementation can be spread over other reforms such as insurance reform. We believe that an additional cent per km may be all that is required, at least initially, or a smaller amount of the investment is amortised over say a 10 year period. This would increase the net revenue to $70m per annum or at least $800m to $1bn over 10 years, excluding adjustments for inflation, but factoring in growth in car use. In the Sydney context, there is already a system in place to capture data on the tollroads using ETAGs which have the capability of capturing time of day kilometres (indeed distance-based time of day charging already exists on one of the longer tollroads in Sydney). Technology experts advise us that conversion to GPS capture is feasible, if required.

In ongoing research using the same data and analysis framework, the vertical equity implications of the road pricing reform scheme is being investigated to identify if low-income drivers as a class benefit at least as much as the costs they bear, and that disadvantaged residents (including non-drivers) benefit overall. A popular view is that revenues must be dedicated to transport improvements to be politically feasible, but some analyses indicate that alternative distributions that include broad tax reductions or financial rebates benefit the

[17] Based on the expected volume of installations.

largest number of citizens, and therefore may be more politically popular (Littman 1996, Hensher and Li 2012, King et al. 2007, Levinson 2010).

In the current paper we have focussed on a peak DBC; however we have also considered the possibility of an all day DBC, which will be lower than the 5c/km peak charge, optimised at 3c/km. There are arguments for and against peak versus all day charging. For example, charging only in the peak may make some people worse off, especially those that cannot avoid the peak period because of fixed working hours, in comparison to others that have flexible working hours, although the higher DBC in the peak with no off peak charge may result in them being no worse off, given the percentage of all kilometres that are in the peak. Clearly, this effect may be increased, subject to the relativity of a peak only and an all day DBC, because all revenues need to come from peak hours, such that the peak rate needs to be higher, but for Sydney the difference is only 2c/km. As part of ongoing research on the vertical equity impacts of the reform package, we are exploring the possibility that, although *on average*, the current paper shows that drivers are no worse off financially under a peak DBC, a peak rate only scheme might lead to large differences, where many may be much worse off, and many will be much better off. Having an off-peak rate might spread the financial impact more, and may not create such equity issues.

This paper has focussed on motorists resident in Sydney, and is designed to move to a more efficient use of roads by using the price signal to underpin motorist's travel behaviour. However, there is a good case to extend the reform package to all vehicles, freight and passenger, as well as all jurisdictions under the control of a single government (in our case it would be New South Wales[18]). In doing this, vehicles would be more closely paying for the damage done to roads. However, a charge related to damage is likely to be a lower all day DBC than is suggested by this paper, and would be similarly replacing an element of registration charge when implementing the scheme outside of capital cities where traffic congestion is not an issue. When initial reform is bedded down and accepted, a case for increasing the DBC may be considered, as a way of raising much needed funding for future investment in public transport and roads as a consequence of the diminishing revenue base from traditional and more inefficient sources.

Finally, in ongoing research, the next steps involve building in such pricing reforms into an integrated land use and transport planning model system so as identify the wider set of economic, social and environmental impacts. Specifically, in this paper, there is no valuation of the cost to motorists for the kilometres no longer driven. However, lower kilometres driven in the peak will benefit from travel time savings (also not included) and those not transferred

[18] It is important to note that we are focussing on the Sydney metropolitan area as if it were a closed system. There will be a need to consider the entire state of NSW, and to recognise that the DBC may be lower if it is defined to capture all externalities as well as cost the road damage. Since congestion is not an issue in regional and rural NSW, a lower DBC may have to be considered. If, in addition, government would want a common registration fee structure throughout the State, then we would have to recalculate the financial implications on Treasury of a lower DBC for rural and regional residents. Visitors to specific locations in NSW would also be subject to the pricing reforms, with the same payment paths open to them that are currently offered on tollroads in Sydney (i.e., a phone number to call to pay within 24 hours or acquire an ETAG and open an account).

to the off-peak which is not charged must have a lower valuation than the marginal cost of doing so. In any first best and second best solution that removes kilometres from the system, there is likely to be a deadweight loss of this sort. However, whilst this might be considered as a negative effect, we do not claim an economic valuation of the before and after reform. A full economic evaluation would need to balance these negative effects against the positive environmental effect and reductions in congestion. This takes us beyond the scope of the paper, which is motivated by and aims to establish an evidence-based approach to a real reform of road pricing, to establish a case that has a real chance of getting buy in from stakeholders who ultimately determine the possibility of reforms.

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