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A Conceptual Framework for the Reform of Taxes Related to Roads and Transport

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Preface

This report examines how transport services in Australia should be charged for, how such charges can contribute to economic efficiency and how capital works in the transport sector should be funded. The transport sector is a significant component of the Australian economy with transport specific industries comprising 4.6 per cent of GDP in 2006-07 and providing 4.7 per cent of total employment (BITRE, 2008). The significant role of transport industries is unsurprising given the substantial distances between Australia and the rest-of-the-world and between Australia's major cities. Efficient movements of people and goods affect efficiencies throughout the economy both directly and through transport's role as an intermediate input. Transport services therefore provide a key influence on national productivity and well-being.

The transport sector is highly taxed and involves substantial public capital cost expenditures. In 2005/06 road and bridge transport infrastructure spending totalled $11.2b out of total transport infrastructure spending of $14.4b. The major source of transport sector revenues for government was fuel excises of $10b in 2005 (BITRE, 2008). There are significant unpaid social costs of travel. For example, in 2005 the road sector alone imposed $9.4b in congestion and local pollution costs (BITRE, 2007).

This report concentrates on road transport and the supply of road services. Section 1 provides background to the general tax-transfer policy problems that arise in relation to road transport; Section 2 discusses partial and general equilibrium methodology issues; Section 3 discusses excises on fuels and other vehicle-related charges; Section 4 discusses congestion and pollution-related transport externalities; Section 5 singles out traffic accident and insurance externalities; Section 6 deals with road capital and maintenance issues; Section 7 considers general equilibrium and double dividend issues; Section 8 briefly considers rail, taxi, air services and shipping issues. Section 9 synthesises the main policy issues raised.

1. Road Transport – Background

Travel by private vehicle incurs costs borne by those travelling – time costs, fuel, vehicle capital and maintenance depreciation costs, traffic accident and insurance costs, car registration, licence fees, fines and sometimes road use and parking charges. Apart from these costs other social costs are generated by travellers including congestion, unpriced parking costs, pollution, noise, road damage and some traffic accident costs. These costs can be attributed to the journeys of those travelling but, without efficient pricing of road services, are not borne by those travelling. They are road transport externalities.

Provided that travellers take journeys if and only if the benefits accruing to them exceed the costs borne by them, then failure to account fully for external costs means that too many journeys are undertaken, journeys are undertaken in socially inappropriate locations and socially valuable journeys are not undertaken at all because some social costs are neglected. There will be socially excessive congestion, pollution, noise, road damage and road accident costs.

In a 'first-best' economic world without transaction costs or other constraints on policy these social costs would be internalised by levying a specific charge on that aspect of travel which creates these costs. This charge might depend on the identity of the driver, the type and mass of the vehicle driven and on both when and where the travel occurs.

In addition, if road use and parking are underpriced, there will be excessive demands for roads and parking places. If attempts are made to satisfy these under-priced demands, too much will be invested in capital items such as road supplies, parking spots and in maintaining roads. Moreover, road expansions may have limited efficacy in reducing social costs for 'triple convergence' reasons associated with the existence of latent demands for travel (Downs, 2004). In simple terms people will increasingly elect to make road journeys when congestion falls due to supply changes. Indeed paradoxes can arise for micro-level road network planning if congestion externalities are unpriced. Road network expansions can lead to deterioration in overall average travel times of commuters over all branches of a network (Arnott and Small, 1994). These problems of excess supply of road infrastructure and counterintuitive planning outcomes never arise if roads are correctly priced with all externalities internalised.

Finally, the failure of private road travellers to internalise all social costs generated increase the relative price of transport alternatives, such as bus or train services compared to private vehicle use, beyond what is socially optimal. This reduces quantities demanded of mass transport below what is socially optimal given that these services are typically associated with less negative externalities per commuter or per unit of freight than is private vehicle use.

With substantial fixed capital costs of providing train or bus transport services there can be an economies-of-scale rationale for public subsidies directed towards provision. In addition, there can be a case for subsidies as a 'second best' policy to promote efficiency if there are constraints on the ability to fully price private road use. Such subsidies can draw heavily on the public purse and can be reduced if moves are taken to fully price road use. To some extent, these economies will be offset by increased demand for public transport use consequent on road pricing. Transport service subsidies can therefore be an efficient response to provision of a service with low marginal costs but they can alternatively reflect inefficiencies stemming from underpricing roads and road use when they are driven by 'second-best' considerations

In fact rather few of these external social costs of travel are priced directly in Australia. Instead, a mix of fixed and variable charges on car travel is imposed that provides a complex two-part tariff on the use of private vehicles. Thus there are fixed (often annual) charges of driving private vehicles which cover registration and vehicle licensing costs and variable charges mainly based on fuel consumption that is mainly linked to distance travelled. In part too, these charges reflect revenue-raising objectives. Many transport-related activities (such as fuel purchases) are in relatively inelastic demand which provides the conventional efficiency-based rationale for concentrating excises needed to raise a certain tax revenue in these areas (Ramsey, 1927).

Charges include goods and services tax, tariffs on imported vehicles, taxes on insurance, stamp duty on motor vehicles, licence and registration fees. These may in part be regarded as attempting to cost-recover publicly-provided services. Thus car registration might cover registration costs themselves (a service) plus compulsory third-party personal insurance. Licence tests initially encourage minimum standards of driver education while the ongoing institution of licensing provides a check that limits driving by unsafe drivers. Sales taxes, import tariffs and stamp duty charges can, and are, used to promote use of particular types of cars (domestically-produced, non-luxury, low fuel use, alternate fuel use and low road damage costs). These charges, being fixed, have their main impact on once-and-for-all decisions to purchase vehicles but limited impacts on ongoing social costs once a vehicle has been purchased.

Vehicle-specific fixed charges can capture some externality costs. As mentioned road damage costs are related to the weight distribution of vehicles (specifically their 'axle load') as well as distances travelled and the location of travel. These damage costs are therefore better addressed by vehicle specific charges related both to 'axle load' and the extent and location of road use.

Excises on fuels are an important variable transport charge that provides significant revenue to government in many countries around the world. The costs to motorists from such excises vary with the extent of vehicle use. These taxes are popular with governments because fuels provide a broad tax base and, as mentioned, have relatively price-inelastic demands that provide a revenue motivation for taxing fuels. There might be also an implicit motivation to tax certain fuels to encourage substitutions away from exhaustible oil resources if it is supposed that current prices do not reflect future scarcity values. This might be construed as a public insurance policy to reduce the large adjustment costs fuel users *would* experience in the future if they were exposed to rapid fuel price increases reflecting oil reserve or indeed other non-renewable resource depletion. Given the substantial uncertainties about future fuel supplies, and pervasive uncertainties regarding the timing of the 'peak oil' production event, it is often assumed that current oil prices do not necessarily reflect future short-term fuel scarcities thereby encouraging appropriate caution. The appropriate policy may be to encourage agents to make some adjustments now.

Apart from such motivations fuel excises can be motivated as an *ex post* attempt to approximately capture some social costs generated in the absence of comprehensive road use pricing. This rationale for using fuel taxes as a surrogate for more specific externality taxes can be based on transactions cost obstacles to taxing road use externalities directly. The difficulty is that many externality costs depend on the type of vehicle driven and where and when it is driven rather than fuel consumption *per se*. Using fuel excises as a means of addressing such external costs saves some transactions costs and helps promote fuel efficiency but will only imperfectly internalise road use externalities.

Congestion costs are not well captured by fuel taxes since, although fuel usage does rise marginally in congested settings, travel in uncongested areas where no externality costs arise is taxed at close to the same rate as travel in congested areas. This penalises travel outside densely-populated city and urban areas. Similarly local pollution and noise damage associated with travel is setting-dependent and cannot be readily related to fuel usage alone.

Traffic accident costs are to some extent linked to distance travelled, and hence to fuel usage, but also depend on where travel occurs and on driver characteristics. For example, the incidence of accidents is concentrated among young male drivers. Therefore accident costs are best met by driver-dependent insurance cover and registration charges that depend on the extent of travel. These costs should not therefore be ideally recouped as fixed charges.

Finally, fuel taxes can be effectively used to internalise the global public bad characteristics of fuel consumption since carbon-based fuels release emissions that contribute to costly climate change. Such emissions however arise throughout the economy and are not restricted to the transport sector. This suggests there are strong arguments for relying on broader policies for dealing with economy-wide greenhouse gas emissions control such as the proposed *Carbon Pollution Reduction Scheme* which involves use of a 'cap-and-trade' emissions trading scheme (ETS) from 2010 to generate an economy-wide carbon price. It is important to understand, for a given price on greenhouse gas emissions, how carbon charging on fuels will operate both in situations where: existing fuel excises are to be discounted by this cost and when the fuel excise is to be increased by the carbon charge as proposed by some in the Green Movement (Climate Institute, 2008). Currently excises are to be discounted by the carbon charge which suggests that the carbon charge itself is seen as a component of current fuel excises.

A central concern of this paper is to assess whether the current set of fixed and variable charges that are applied to vehicle use can and should be replaced by charges that more directly reflect costs of road use such as congestion and road damage costs. An additional concern that is also addressed is to consider how such user charges might better inform road supply decisions.

2. Methodology for Assessing Transport Taxes and Charges.

There are two methodological approaches that one can apply to assessing road tax reform. The first is *partial equilibrium analysis* that aggregates various inefficiencies across different markets where each market is viewed as operating independently. The second approach is *general equilibrium analysis* and this looks at inefficiency costs in various markets while recognising interaction effects across markets.

2.1 Partial equilibrium approaches. The efficiency costs of the current system of taxes and charges on road use can in principle be assessed in a partial equilibrium setting by comparing the aggregated efficiency costs associated with the current set of taxes and charges (as measured by deadweight losses) with those remaining in an optimised transport system where all externalities are internalised and where costs of switching to a targeted regime are accounted for. This suggests the net aggregate potential benefits that might be realised from instituting a system of more targeted taxes and charges. The efficiency costs of taxes and charges are their *excess burdens* while, following convention, the efficiency costs of externalities are their *deadweight losses* (DWLs).

The attractive feature of targeted charges is that social 'bads' tend to be eliminated while revenues raised can, it is sometimes claimed, reduce the excess burdens of other more distorting taxes providing a 'double dividend' bonus. The *marginal* excess burdens of the various taxes and charges examined are also interesting since they suggest welfare gains realisable from incremental reforms.

This type of partial equilibrium analysis is a useful first step and has the virtue of simplicity. It suggests how excess burdens and DWLs are potentially reduced by switching to more targeted taxes and charges less any costs incurred in making this switch. This involves gaining an appreciation of the following costs.

- Excess burdens from current excises on fuels including petrol and diesel and charges such as licence fees, fringe benefits tax, insurance taxes, traffic fines and penalties, stamp duty, registration fees and tariffs on imported vehicles. With respect to fuel excises this measure should account for revenue-gaining objectives and for impacts of fuel price credits. The measure can be computed net of gains from controlling carbon emissions if a component of the excise is (implicitly) taken as reflecting a sought-after charge on carbon emissions as the current policy of rebating the effects of any such additional charge suggest. Carbon charges can also be regarded as fees paid by fuel vendors for consequent carbon emissions released under an ETS.

- DWLs associated with traffic congestion, inadequately priced parking, traffic-induced air pollution, noise and traffic accidents.

- Inefficiencies associated with current charging for road use where this has been implemented but where DWLs arise from not implementing efficient pricing. Setting charges above short-run marginal social cost impose DWLs through excessive charging at uncongested times and for 'second best' reasons because of the need to limit traffic diversions onto un-tolled roads.

- DWLs associated with road accident externalities – the possible extra accident costs imposed on existing drivers when more vehicles use roads (Small and Verhoef, 2007, p. 102).

- Waste associated with excessive spending on road maintenance that stem from not targeting appropriately activities that cause road damage. In addition, there is waste associated with excessive expansion of the road system if it is underpriced. For example, cost-benefit studies which justify road expansions if aggregated time savings exceed expansion costs are insufficiently selective if the value of the time saved is not computed net of associated external costs.

- Possible excess burdens eliminated by substituting 'green taxes' (congestion, parking) as well as well as optimal taxes on insurance that eliminate social bads for current taxes and charges (fuel excises, income and other taxes) which limit work effort and savings. There is sometimes claimed to be a 'double dividend' bonus in taxing externalities that increases the appeal of raising revenue in this way. This claim is however contested and requires analysis in a general equilibrium setting.

- Costs of switching to a targeted system of taxes and charges. For example there are transaction costs of implementing congestion and vehicle mass-based pricing and of implementing more effective accident insurance policies and of parking policies. There are also changed compliance costs with an altered tax and charging regime. Finally, there are costs of providing greater public transportation infrastructure to accommodate users who switch as a consequence of higher costs of private vehicle use. There can be implications for the size of public mass transport subsidies of such targeted charges.

The net benefits of switching to a more targeted set of taxes and charges are given arithmetically by the aggregate of the excess burdens and DWLs avoided less the costs of switching toward a more targeted regime. A global switch of policy of this type is however not the only conceivable policy option that might be considered so, as mentioned, marginal excess burdens are also of interest. Our partial equilibrium study is primarily organised around the points mentioned above plus a synthesis section which offers some general conclusions.

2.2 General equilibrium approaches. Until the 1990s the partial equilibrium approach to assessing tax reforms was most often used. The general equilibrium implications of raising taxes in particular markets on other markets were understood but normally assumed to be of second-order importance. This is now understood *not* to be so (Goulder & Williams, 2003). There are both general issues here that relate to assessing tax impacts in a general equilibrium setting and specific issues for the 'double dividend' debate (Schöb, 2003).

A major implication of the general equilibrium literature on excess burdens is that standard partial equilibrium measures of excess burden substantially understate the social costs of commodity taxes, in some cases by a factor of 10 or more. This occurs because such measures ignore interactions between markets for the taxed commodity and other markets, particularly the labour market. In some cases introducing a new commodity tax introduces more excess burden through general equilibrium interactions than it does through additional distortions in the market for the taxed good itself.

The 'double dividend' literature takes up the issue of the impact of an externality-correcting tax in a general equilibrium setting. The 'weak form' of the double dividend hypothesis suggests that tax revenues from an externality tax (such as a congestion toll) can offset any excess burdens created by the policy by cutting other distorting taxes. The 'strong form' of this hypothesis suggests that measures such as congestion charging promote welfare by improving the environment but also increase non-environmental welfare. In this case something like a congestion tax would be a 'no regrets' option so that even if environmental benefits were in doubt or were small, the congestion tax would be desirable because of its ability to enable other tax cuts. This analysis again involves a heavy emphasis on the role of labour markets. A congestion tax is generally seen as unlikely to improve non-environmental welfare if labour markets function well (Schöb, 2003).

A useful framework for focusing on Australian road transport issues is the paper by Parry and Small (2005). This assesses the case for switching to specific externality charges (such as congestion charges) from fuel excises and broad-based labour taxes. Although the empirical analysis in this paper relates to the US and the UK the framework itself is of relevance for Australia. This analysis is developed in Section 3 and in an Appendix.

Tackling general equilibrium implications of tax reform can be carried out using empirically-oriented general equilibrium models and by making qualitative judgements in simple low-dimension models. The latter approach is pursued here in Section 7 where it is argued that the main conclusions of this study are robust once general equilibrium complications are introduced.

3. Excises on Road Transport Fuels and Other Government Vehicle-Related Charges.

The main taxes and charges on motor transport are excises on fuels used by motor vehicles, the tariff on imported vehicles, the luxury car tax (LCT), the fringe benefit tax (FBT) on motor vehicles and other government charges such as vehicle registration and licence fees. In this section each tax is characterised and its efficiency costs discussed. Where sufficient data exists, the efficiency losses and marginal excess burden associated with the tax are estimated. Finally policy recommendations regarding tax design are provided.

The general approach is to consider whether a tax or charge corrects a market failure, proxies for a user-charge or can be justified as having relatively low efficiency losses relative to the revenue it raises, that is it can be justified as a Ramsey commodity tax.

The current transport tax system has several appealing features. In particular, it generally avoids taxing business inputs. Furthermore fuel excises have been considerably simplified. But the low tariff on imported cars still generates significant DWLs and the LCT induces distortions. There are no strong arguments for the tariff and LCT as market failure correctives and they do not raise substantial revenue. Though the use of a statutory formula in applying the FBT distorts driving choices, the costs of this relative to savings on recording costs are not known. Finally, state taxes introduce distortions into the market for new and used vehicles but, again, their significance is unclear. Though in this case, the distortions are unlikely to be large.

Summary of Section 3
The best econometric estimates available suggest that the Australian demand for petrol is highly price inelastic. Hence there is a role for fuel excises in raising revenue. Calculations indicate that whether the fuel excise is designed solely as a tax for correcting negative externalities or solely for revenue-raising that the current excise is too low.
The efficiency losses from fuel excises on petrol and diesel are unlikely to be large relative to the revenue raised.

If fuel is used as a business input, efficiency in production is improved by exempting such use from excise. While the current system exempts most fuel used, the exemptions could be extended to transportation by smaller vehicles that are used for business purposes.
A fuel excise may be used as an imperfect means for correcting negative externalities arising from congestion, traffic accidents and local pollution if it is too costly or difficult to directly charge for or otherwise regulate such external costs.
The excise on fuel should be thought of a tax on road transport. Hence, as additional fuels are introduced for transport (such as for hybrid vehicles) excises should be applied to these within the same framework.
If the excise for fuel is used to correct for negative externalities from local pollution there is a case for applying discounts to alternative fuels. These discounts are, however, unlikely to be large relative to the excise. Furthermore the appropriate excise is unlikely to be zero for any fuel.
If fuel excises are set solely to proxy for user charges or to correct negative externalities, it is appropriate to set a GST on the excise-inclusive price.
If fuel excises are set to raise revenue, then a GST on an optimal excise may create efficiency losses. As fuel demand is inelastic these are unlikely to be large. In addition, the current excise seems too low so adding a GST plausibly improves efficiency.
The case for retaining positive tariffs on motor vehicles is weak. They do not address market failures and create 'cost of protection' losses. The revenue raised is relatively small.
The LCT should be repealed. It does not address a market failure but rather creates efficiency losses. The revenue raised is small and the efficiency losses relatively substantial.
The limited evidence available suggests the higher threshold on energy efficient luxury cars is unlikely to have substantial effects on the types of luxury car purchased.
State taxes and fees on driving are substantial. There are potential efficiency costs but their size is unknown though they do not seem large. Some savings may result from making them as uniform as possible across states.
The statutory formula used to calculate FBT, if log books are not used, creates an incentive for excessive driving. There is evidence that this effect exists. The formula should be reviewed to consider if the record keeping savings are still greater than these potential efficiency losses.
Some fines, such as for parking, should be considered as prices and considered explicitly in terms of revenue raising for local and state government.
It would be useful, for policy purposes, to estimate econometric models of demand for a wider range of fuels and a more detailed demand model for motor vehicles.

It is informative to set out the consumption of different types of fuels. ABARE (2008. Table 48) provides estimates by fuel, for 2005-2006, of the energy consumed in road transport. Of the 1020.6 petajoules of energy consumed in road transport, 63 per cent was unleaded auto gasoline, 29 per cent was diesel, 7.5 per cent was liquid petroleum gas (LPG) with natural gas and bio-fuels providing 0.14 and 0.12 per cent respectively (ABARE, 2008). Alternatively, in absolute terms, ABS (2008) estimate the quantity consumed of the three main classes of fuels by motor vehicles for the twelve months ending October 31, 2007. Of the 30,047 million litres of fuel consumed by vehicles, there were 18,876 million litres of petrol, 9,372 million litres of diesel and approximately 1799 million litres of LPG, CNG (Compressed Natural Gas) and other fuels. Clearly petrol and diesel are the important fuels to analyse in road transport.

It is also of interest to review the revenue collected by each tax and government and the tax expenditures (a tax expenditure is an estimate of the tax foregone as a result of a particular exemption or policy). **Table 1** sets out the actual revenue collected from each tax along with the estimated tax expenditures for the most recent years available for the federal government (2007-2008) and for the states (2006-2007).

Table 1 Revenue from Taxes and Charges on Motor Transport

Tax	**Revenue $m**
Federal (2007-2008)	
Fuel Excise on Petrol and Diesel [1]	13633
Tax expenditure: Estimated exemption from excise of alternative fuels[2]	780
Import Tariff on Passenger Motor Vehicles[1,5]	1400
Luxury Car Tax[8]	464
FBT [6, 9]	< 3796
Tax expenditure: Application of statutory formula to value car benefits[3]	1700
State (2006-2007)	
State Taxes and Duties[4,7]	6100
Tax expenditures on State Taxes and Duties[4,7]	379
Sources: [1] *Budget Papers No. 1, 2009-2010*, page 5.29; [2] *Tax Expenditure Statement 2007*, pages 174-176; [3] *Tax Expenditure Statement 2008*, page 163; [4] Budget Papers for each state. [8] *Budget Papers No. 1, 2009-2010*, page 5: 27; [9] *Budget Papers No. 1, 2009-2010*, page 5.22.	
Notes: [5] No data is reported for revenue on other motor vehicles; [6] The total FBT collection is $3796m; [7] Because of inconsistencies in reporting across states this is probably underestimated.	

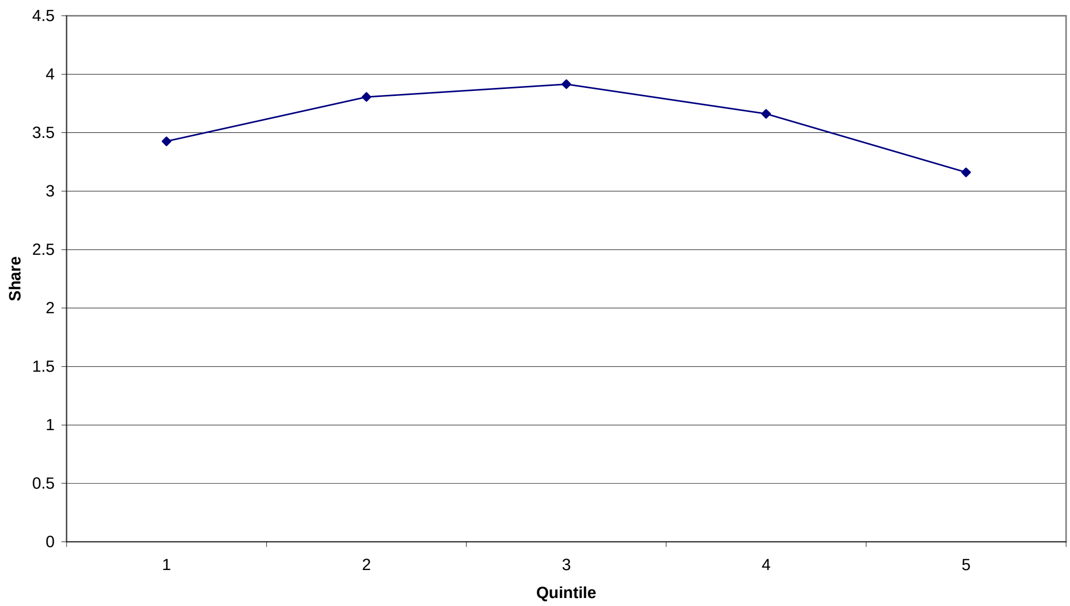
The revenue from fuel excise is substantially greater than from any other tax or charge on motor transport. However, excise revenue has declined in relative importance over time compared to income taxation and the GST. One reason for this is that excise ceased to be indexed from March 2001. Other significant charges include state taxes and duties, primarily on registration and transfer of vehicles. A separate item for FBT on cars is unavailable but it must be less than the total tax collected of $3796 million. Tariffs collected on imported passenger motor vehicles and the luxury car tax are the taxes yielding least revenue.

3.1 Fuel excises. Currently excises are applied to most fuels with varying exemptions for fuel that is used for business purposes. Under the Howard government, the excise system was being reformed towards a simpler system. The plan for fuel excises was for them to eventually apply to all fuels, but at different rates for, primarily, alternative fuels to petrol and diesel. While the ultimate design of the Rudd government for the excise system is still to be announced, the changes that have been legislated suggest it is worthwhile to analyse the proposed system. The theoretical bases for taxing fuel, providing exemptions to business and for different excise rates for alternative fuels are discussed below. While there are strong reasons for business exemptions, the case for different excise rates for alternative fuels is more qualified. For the immediate future, the greatest tax revenues and potential efficiency costs are associated with taxes on petrol and diesel, although these are themselves quite low. For example the nominal efficiency cost of the fuel excise on petrol is estimated below to be about $375m dollars for 2005-2006. The efficiency costs of taxing alternative fuels are likely to be much smaller again because the quantities consumed of these fuels are also much smaller.

Efficiency costs and benefits of excises. One motive for having an excise is to raise revenue. Another motive is that the excise can be used as a charge for a service provided by government. A third motive is to implement a tax to correct for a negative externality. All three of these motivations have been raised when discussing the features of the fuel excise system.

Before proceeding it is worth briefly discussing the nature of the good that is being taxed. Petrol is the fuel that is almost exclusively used for personal road transport and some business transport. To a lesser extent, diesel is the fuel used for certain types of business transport. Hence the excise on fuel is substantially a tax on road transport. The dominant roles of petrol and diesel may change in the future. If the price of fossil fuels rises, hybrid vehicles using electricity and petrol or possibly other fuels will be used more extensively. Whether the motivation for taxation is cost recovery, revenue collection or externality-correction, the excise on fuels should be expanded to include the broader set of fuels used in road transport.

Figure 1
Share of Household Expenditure (2003-2004) on Fuel, by Gross Income Quintile
Source: Table 2 of ABS Cat No. 6535.0.55.001.



In addition, it is worthwhile discussing the distributional consequences of taxes on petrol. In **Figure 1** it can be seen that expenditure on fuel, as a proportion of household expenditure rises and then falls as households move from the lowest to the highest gross income quintile. This suggests that increasing the tax will be mildly regressive over mid to high ranges of the income distribution though not at the lowest quintiles. However, as is argued at various points in the paper, questions of income distribution are best handled through the income-transfer system rather than through adjusting commodity taxes.

If the objective of a set of taxes is to minimise the efficiency losses from raising a certain amount of revenue then a well-established result, known as the Ramsey rule, provides some guidance (Hindriks and Myles, 2006). Aggregate efficiency losses are minimised by taxing intensively those products for which demand is inelastic. This means that quantity adjustments to the taxes will be proportionally similar across products. It is worth noting that the Ramsey rule is a 'second-best' result that presupposes that a fixed quantity of tax is to be collected. It also ignores the role of income taxes. The case for differentiated excises can be shown to disappear if utilities are weakly separable in leisure and income taxes are a policy instrument in addition to excises: See Section 7.

Because demands are relatively inelastic, fuel is a suitable candidate for an excise from this perspective (Breunig and Gisz, 2009; Litman, 2008). Note though that while in the past the range of fuels used for road transport was relatively limited, new fuels may be differently inelastic and different rates may be optimal for revenue-raising.

There are strong economic reasons for providing exemptions from fuel excise for business use in vehicles with a gross vehicle mass equal to or greater than 4.5 tonnes. It is argued that excises that distort producer input choices can be replaced with taxes on final goods that yield the same revenue with greater economic efficiency. This is an implication of the so-called Diamond-Mirrlees Production Efficiency Lemma (Hindriks and Myles, 2006). It provides a justification for zero taxation of inputs and, more generally, any tax system that does not alter the relative prices of all inputs.

The main negative externalities from motor vehicles are congestion, local pollution, global pollution and those arising from car accidents (Parry and Small, 2005; Parry, Walls and Harrington, 2007). Congestion and car accident externalities are believed to be correlated with distance travelled by motor vehicles. If the fuel excise is being used as a proxy tax to reduce these negative externalities, then there is no reason to distinguish between different fuels except on the basis of energy content. It also suggests that, unless these externalities are being charged for in other ways or the excise is not being used for revenue raising, the appropriate excise on alternative fuels is always positive.

Petrol, diesel and alternative fuels do differ in their contribution to global greenhouse gas emissions and to local pollution (such as carbon monoxide, hydrocarbons and nitrogen oxides). The contribution to global pollution (if any) is typically directly correlated with fuel consumption enabling a fuel excise to directly target this externality. However, if fuel is not exempt from the proposed Emissions Trading System (ETS), then differential contributions to global pollution will already be effectively charged for through the ETS.

Petrol, diesel and alternative fuels may make different contributions to local pollution. These are discussed in more detail below. However, externalities from local pollution are more directly related to distance driven than fuel consumed. Distance driven is related to fuel consumed but the latter can vary with speed and type of vehicle driven. Hence, fuel taxes are only an imperfect tool for targeting the externalities from local pollution.

Note too that local pollution will vary across localities depending on traffic levels. Local pollution is unlikely to be a significant problem in regional areas away from major roads. Hence exemptions or different excise rates for alternative fuels may not be the best means to reduce local pollution externalities. On the other hand, it may be administratively cumbersome to target them other ways. The strongest potential argument for using exemptions or different excise rates on alternative fuels to reduce local pollution is that other more targeted methods are likely to be administratively costly.

In **Table 2** revenue, tax expenditure and excise rates are summarised.

Table 2. Fuel Taxes and Tax Expenditures

Tax (Fuel)	**Actual Revenue from 2007-08[1] $m**	**Rate (cents per litre)**
Excise (Petrol)	6959	38.143
Excise (Diesel)	6674	38.143
Excise (Other Fuel Products) (2006-07)	803	2.854 (aviation fuel) OR 38.143 (vehicles)
Tax Expenditures[2,3]		
Concessional rate on Aviation Fuels	670	38.143 less 2.854
Exemption from excise for `alternative fuels'	780	Relevant rate for each fuel (including LPG and CNG).

Notes: [1] *Budget Papers No. 1, 2009-10*, Statement 5, Table 10, page 5.29. The estimate for Excise (Other Fuel Products) is from the equivalent table from the 2008-09 budget as it is not reported separated in 2009-10.; [2] Estimates. *Tax Expenditure Statement 2008*, pages 187-188; [3] There are negative tax expenditures for excise on fuels not used in internal combustion engines but these are reversed by fuel tax credits.

Note that the excise rate on petrol and diesel was formerly indexed but has remained fixed since March 2001. The excise rate, in March 2001 prices is now 30.45 cents so in effect there has been a real cut of about 8 cents in the excise rate.

As mentioned earlier, under the Howard government, the fuel excise system was being simplified and broadened over time to include a more complete set of fuels (DPMC, 2004; The Treasury, 2005). The ultimate system was to have the following features:

- Excise rates will be based on energy content. Alternative fuels receive a further 50 per cent discount on the excise as in **Table 3**;
- All fuels used off-road for business purposes will be excise-free.
- All fuels used on road for business purposes in vehicles with a gross vehicle mass (GVM) - the weight of the fully loaded vehicle – of 4.5 tonnes or more - will receive a fuel tax credit equal to the excise rate paid, less a non hypothecated road user charge. On road vehicles with a GVM of less than 4.5 tonnes will not receive a fuel tax credit.

Table 3. Proposed Excise system

Fuel Type	Energy content (megajoules/litre)	Excise rate (cents/litre)	Discount rate
High-energy content fuels: petrol, diesel, gas to liquids, biodiesel	Above 30	38.143	19.1 (biodiesel)
Mid-energy content fuels, liquefied petroleum gas, liquefied natural gas, ethanol, dimethyl ether	Between 20 and 30	25.0	12.5 (all)
Low-energy content fuels: methanol	Below 20	17.0	8.5 (methanol)
Other: compressed natural gas	38 - 41 (megajoules per cubic metre)	38.0 (cents per cubic metre)	19.0 (cents per cubic metre)

Source: DPMC (2004, p. 96).

The current transitional system differs in four ways to the proposed system: (i) Not all off-road uses receive an exemption from excise; (ii) Alternative fuels receive exemptions through various schemes; (iii) Alternative fuels used in regional areas receive tax credits and (iv) because there are subsidies for ethanol production

In the current system some, mainly off-road, business uses in agriculture, forestry, fishing, mining, marine and rail transport, electricity generation and non-fuel use, receive a full tax credit (38.143 cents per litre) on their use of petrol and diesel. Off-road activities not specified in the preceding list receive a 50 per cent (19.0715 cents per litre) credit.

In the current system, fuels other than petrol or diesel currently receive varying exemptions from excise or other subsidies under four different schemes. LPG, Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) are currently not subject to excise (ATO, 2009). Domestically produced ethanol receives a grant equal to the excise (38.143 cents per litre) (Ausindustry, 2009).

There is also an *Energy Grants Credit Scheme* (ATO, 2009a) for fuels such as LPG, CNG, LNG, ethanol and biodiesel. These credits range from 3.252 to 8.324 cents a litre for use in road transport and are restricted to vehicles that are 4.5 tonnes GVM or more. For vehicles above 20 tonnes all trips are covered. For vehicles from 4.5 to 20 tonnes only trips involving non-metropolitan travel are included. Finally, there is the *Cleaner Fuels Grant Scheme* whereby for bio-diesel and renewable diesel, a grant is paid, generally to the last licensed person in the distribution chain before the fuel enters the market, equal to the excise (38.143 cents per litre).

Examining the proposed ultimate design for the fuel excise system the first question that arises is are there sound arguments for different excise rates based on energy content and for alternative fuels? First note that if the excise is being used to raise revenue then if the different fuels have different own-price elasticities this would be a ground for different excise rates. However, such a rationale is not cited in policy documents as a reason for different excise rates and there seems to be no evidence justifying such differentiation. The greater the substitutability between the expanded set of fuels, the greater the likely elasticity of demand for individual fuels would be. This provides a justification for lower excise rates in general. Econometric estimates of these elasticities would be valuable information.

Including exemptions for business uses, as argued earlier, contributes to a more efficient tax system. The exception of a user charge for large vehicles is supported by work discussed later in this report. A question that remains is why the exemption from fuel excise is not extended to all business transport, rather than just that in vehicles of 4.5 tonnes or more, as is applied with the GST. One possible justification is that there are concerns about distinguishing between private and business uses for smaller vehicles.

For negative externalities associated with transport, such as congestion and from accidents, which are related to distance travelled, an adjustment based on energy content is suitable if lower energy content means less distance travelled per litre of fuel. These externalities do not provide any justification for further discounts for alternative fuels.

As global pollution externalities can be handled through the proposed ETS, the remaining question is whether alternative fuels produce less local pollution than petrol and diesel and if so what is the value of the difference? What is the evidence that the alternative fuels have lower negative externalities? The most important alternative fuel is LPG. ALPGA (2008) claim that, compared with petrol, LPG results in a 9.3–13 per cent reduction in carbon dioxide emissions, a reduction of 71 per cent for carbon monoxide, an 89 per cent reduction for hydrocarbons, and unspecified reductions in particulate matter and nitrogen oxides.

The argument for biodiesel and ethanol blends, consumed in much smaller quantities, is less clear. Apart from a brief reference to reducing particulate emissions the Biofuels Association of Australia submission (BAA, 2008, p.2) does not refer to reducing local pollution. The Australian Government Biofuels Taskforce (2005) reviewed the environmental effects of ethanol and biodiesel building on the earlier review of the science in Department of Industry, Tourism and Resources (2003). The focus here is on tailpipe impacts because other impacts are best handled by other policy tools. The earlier report concludes that the ethanol blend E10 has negligible impact on particulate matter emissions, increases nitrogen oxide emissions and reduces emissions of carbon monoxide and NMVOC (non-methane volatile organic compounds). The later report, in its calculation of the health cost impact allows for a 40 per cent reduction, but states this is not a 'scientifically accepted value' (p.69) and 'this value should be viewed only as a sensitivity factor to examine the health cost impact …' (p.75). A CSIRO and Orbital Corporation (2008) report does find significant reductions in particulate matter, though in nearly all cases, these reductions are less than 50 per cent. If excise is used to tackle local pollution then a key question is the size of an appropriate discount for alternative fuels. Estimates of the optimal petrol excise are discussed below.

Efficiency costs of fuel excises. Fuel excise efficiency costs are computed in terms of their excess burdens (EBs). Denote by ε_D the uncompensated own-price elasticity of demand and ε_D^H the compensated elasticity. The compensated elasticity is related to the uncompensated elasticity by $\varepsilon_D^H = \varepsilon_D + \theta\varepsilon_Y$ where ε_Y is the income elasticity of demand and θ is the fuel's budget share. If demand is linear and fuel supply is perfectly elastic the excess burden (EB) of a specific fuel excise is given by:

$$EB = 0.5|\varepsilon_d|(Q_1/P_1)*t^2 \qquad (1)$$

where t is the specific tax rate and Q_1 and P_1 are the post-tax quantity and price.

The marginal excess burden indicates the excess burden created by raising an additional unit of revenue. Assuming that supply is perfectly elastic, the marginal excess burden formula used in Albon (1997) and discussed in more detail in Gabbitas and Eldridge (1998) is used:

$$MXSB = \frac{-\left(\frac{t}{P_1}\right)\varepsilon_d}{1+\left(\frac{t}{P_1}\right)\varepsilon_d}$$

The EB and MXSB from petrol and diesel are calculated using the data in **Tables 4 and 5** respectively.

Estimates of uncompensated own-price and income elasticities of demand are from Breunig and Gisz (2009) using data for Australia from 1966-2006. These authors conclude that the long run own-price elasticity is -0.20 with income elasticity 0.27. These estimates are low compared to other countries (see Litman, 2008). There is, however, considerable variation across countries, over time and by estimation technique. Litman (2008) argues that, over the sample period, the price of petrol is lower in Australia than other countries which may give rise to the low elasticities. Drawing on the same sources used by Litman we have determined Australian petrol prices were relatively low at least as far back as 1998. Another possible argument is that oil price shocks are, to a greater extent than in Europe, Japan and North America, are correlated with positive price shocks to fuels and other minerals that Australia exports, resulting in a partially offsetting positive income shock. It is also worth noting that estimates of running costs of motor vehicles provided by the RACV demonstrate that fuel is a relatively small component of total costs compared with depreciation, interest and registration costs. Finally note that earlier Australian studies, cited in Litman (2008), demonstrate a history of low estimated elasticities.

Table 4: Calculation of Excess Burdens – Petrol for 2005/2006

Item	**Value**	**Source**
Own-price Elasticity of Demand (Long Run)*	-0.23	Breunig and Gisz (2009)
Income Elasticity of Demand (Long Run)*	0.61	Breunig and Gisz (2009)
Budget Share	0.033287	Table 2, ABS Cat. No. 6535.0.55.001 (2003-04) (revised February 2006)
Compensated Elasticity	-0.2097	
Post-Tax Quantity	18792397661 litres	ABARE (2008), converted from Petajoules.
Post-tax Price	132.973 cents	Table 1, ABS Cat. No. 6403.0.55.001 June quarter 2006 for a litre of unleaded petrol. Aggregated using weights for Automotive fuel from Table 5 of ABS Cat. No. 6403.0 for CPI, 15th Series.
Tax	50.2314 cents	Sum of excise and implied GST.
Nominal Excess Burden	$374m dollars	
Marginal Excess Burden	9 cents per $ of revenue.	

Note: these estimates are partial equilibrium rather than general equilibrium losses.
*Elasticities from (Breunig and Gisz, 2007, Table 2) are used are used as these are more representative of the later period.

Estimating the EB from the fuel excise on diesel is complicated because there is no estimate of the own-price elasticity of demand for diesel in Australia and because there are three substantial groups of diesel consumers, each paying different rates of excise. Thus passenger vehicles pay both excise and GST; light commercial vehicles, light rigid trucks (4.5 tonne GVM or less) and small buses pay excise and, heavy rigid trucks, articulated trucks and large buses pay a lesser excise as a road usage charge rather than a tax.

An upper bound estimate of the EB on diesel can however be computed and is reported in **Table 5**. Estimates are for 2006/2007, the earliest comparable year to that for petrol, for which price data can be obtained.

Here the share of diesel consumed that is subject to excise is first estimated. The *Survey of Motor Use, Australia* (ABS, 9208.0) estimates the share of diesel consumed by passenger and light commercial vehicles to be 27 per cent – most of this is for light commercial vehicles. The share of diesel used by light rigid trucks is estimated by adjusting the reported share of diesel consumed by all rigid trucks by the share of the number of light rigid trucks consuming diesel of all rigid trucks consuming diesel using data from the Census of Motor Vehicles (ABS, 9309.0). Light rigid trucks consuming diesel make up about 25 per cent of rigid trucks. About 5 per cent of diesel consumed is by buses which may be greater or less than 4.5 tonnes GVM. This suggests that about 33 to 40 percent of diesel consumed is subject to excise – 33 per cent of 9,372 million litres is used here.

Because most diesel consumed is by users who can claim credits for GST the average retail price is adjusted to remove GST.

Furthermore, because diesel is used primarily for business rather than personal purposes an uncompensated elasticity of demand is used - there is no adjustment for income effects. As mentioned, however, there is no estimate of the elasticity of demand for diesel for Australia. Indeed, Litman (2008) reports very few estimates for any country. Litman cites a study by Bailly (1996) who reports elasticities for different fuels in Canada, including diesel used by trucks and buses. These elasticities are typically about 50 per cent less than those for automobiles. This suggests that estimates of DWLs from taxing diesel using the own-price elasticity of demand of petrol will be upper bound estimates. Because estimates of Australian elasticities tend to be low over time, probably because of low fuel prices, we choose to use an Australian estimate (Breunig and Gisz, 2009) of the own-price elasticity of demand for petrol rather than a Canadian estimate of the own-price elasticity of demand for diesel.

Table 5 demonstrates that the efficiency losses from taxing diesel are small. This is so because most consumers are effectively not taxed because of business exemptions. In addition, the demand for diesel is likely to be quite inelastic.

Given petrol's low own-price elasticity of demand it is possible to justify taxation of petrol on Ramsey grounds. Parry and Small (2005) provide a methodology for estimating Ramsey taxes which accounts in addition for externality taxes. Plausible optimal excises are provided for the US and the UK. This approach seeks excise taxes which maximise the utility of a representative consumer while meeting a fixed level of government spending. The study accounts for induced changes in travel behaviour as a consequence of the tax and for changes in labour taxes as a consequence of changed excises to keep the budget in balance. The same methodology can be applied to Australia. As the own price elasticity of demand is much lower in Australia than in the US, it can be anticipated that that the optimal Ramsey tax will be much larger than the US 26 cents per litre tax for year 2000 that was estimated by Parry and Small.

Table 5: Calculation of Excess Burdens - Diesel for 2006/2007

Item	**Value**	**Source**
Own-price Elasticity of Demand (Long Run)	-0.23	Breunig and Gisz (2009)
Share of Diesel subject to excise	0.33	October 2007 *ABS Survey of Motor Vehicle Use*, No. 9208.0; the *2008 Motor Vehicle Census*, No, 9309.0
Post-Tax Quantity	3092.8 million litres	October 2007 *ABS Survey of Motor Vehicle Use*, No. 9208.0
Post-tax Price	117.91 cents	Average price of diesel of 129.1 cents for 2006-2007, from the Australian Institute of Petroleum website, accessed April 27, 2009. Deflated to remove effect of GST.
Tax	38.143 cents	Excise
Nominal Excess Burden	43.89 million dollars	
Marginal Excess Burden	8 cents per $ of revenue raised	
Note: these estimates are partial equilibrium rather than general equilibrium losses.		

The methodology of Parry and Small (2005) is now used to estimate an optimal excise for petrol in Australia. A more detailed summary of the model is provided in an **Appendix** but the main features are summarised here. Their model derives an optimal tax on petrol which both internalises externalities from pollution, congestion and accidents, and which incorporates the efficiency trade-offs between commodity taxation and income taxation. The calculations of Parry and Small for the US and UK are recomputed for Australia using Australian estimates of many parameters. Results are reported in **Table 6**. The fourth column reports the estimated optimal tax. The estimates in the second and third decompose this tax into a component that account for externalities and a component which is an optimal Ramsey tax.

The simplifications in the model and the lack of some parameters mean the numbers should be treated as indicating a direction rather than prescribing a value. They consistently suggest that the excise on fuel should be considerably higher than the current rate.

With preferred Australian estimates the environmental component is $0.48 cents which, even ignoring revenue motives, is 10 cents per litre higher than the current excise. If global pollution is charged for separately under the ETS, this would reduce the environmental excise by approximately 4 to 5 cents per litre.

Table 6: The Parry and Small Model - Estimates for Australia

	Externalities Component	Ramsey Component	Optimal Tax
Australian estimates	$0.48	$1.51	$1.99
Australian estimates – high elasticity of demand	$0.47	$0.36	$0.83
Australian estimates – low share of government	$0.49	$0.51	$1.00
Australian estimates – higher labour supply elasticity	$0.46	2.82	$3.28

At this point we can also comment on the size of any discount for alternative fuels (ignoring any differences based on energy content). First, any fuel with zero contribution to carbon emissions would, under the assumptions in this model, be entitled to a discount of 4.6 cents per litre. Second, if a fuel eliminated all local pollution it would be entitled to a further discount of 12.1 cents per litre. More sophisticated calculations would be required to determine the optimal excise rates for each alternative fuel but these calculations are suggestive that some discount may be appropriate.

The second feature is that all scenarios predict a substantial role for a petrol excise as a source of revenue. Using parameters for Australian conditions the estimates suggest an optimal Ramsey tax of $1.51 per litre. However, this assumes that the own-price elasticity remains at -0.23 at all price levels. This is unlikely given the observation that other countries with high prices of petrol feature higher own-price elasticities. Hence the simulation is repeated using a higher own-price elasticity of -0.55 (the value used for the US). The Ramsey tax then drops to $0.36.

To further analyse the sensitivity of our results to our simulations the share of government expenditure and the labour supply elasticities are also varied. Since the preferred share estimate for government is higher than that used for the US the estimations are repeated using the share for the US (0.35, rather than 0.52). This lowers the Ramsey tax to $0.51. Finally the uncompensated labour supply elasticities for the US seem lower than the best estimates available for individuals in Australia

– this might be expected with a greater tax burden. Hence the simulation is repeated using a higher labour supply elasticity (0.35 instead of 0.2 with a similar adjustment to the compensated elasticity). Then the Ramsey component explodes to $2.82.

The primary implication of these results is that the current Australian excise on petrol is not too high but probably too low. Even if the excise is viewed as a tax designed to correct externalities, our analysis suggests that it could be increased by 10 cents per litre. Furthermore, because of the particularly low own-price elasticity of demand, these results also suggest a significant role for the excise for raising revenue. This move could be made revenue-neutral by cutting other taxes such as income taxes.

3.2 GST. A Goods and Services Tax (GST) is levied at 10 per cent of the value of all motor vehicles although to the extent goods are used for business purposes, a GST credit can be claimed. This is consistent with public economic arguments discussed earlier that inputs not be taxed. The GST is applied to a broad range of products so the product specific effects on vehicles and fuel is unlikely to be large.

Are there any efficiency consequences from imposing a GST on top of a fuel excise? First, note that as businesses receive a credit for GST paid for fuel used for business purposes this issue applies only to fuel consumed for personal use. Second, note that if the excise is set either as a road usage charge or to correct for negative externalities, it remains appropriate that the GST is applied. This is because the `correct' price for fuel includes charges for the negative externalities.

If the excise is used for revenue raising and set optimally according to Ramsey rule then introducing a GST on top of a set of optimal commodity taxes may distort the quantities consumed of each fuel and reduce economic efficiency. Whether this occurs depends on differences in the extent to which the GST is passed on to consumers. For example, if the GST was passed on fully on all products, then the relative prices of fuels would remain the same thus not introducing any further distortions. As the GST is not applied to all products, there may be distortions introduced, primarily, with respect to products not included under the GST. However, this is a broader issue related to the overall design of the GST.

Intuitively it seems unlikely that the GST would be passed on differently for different fuels as they are distributed in similar market structures. Confirming this is an empirical question for which there is insufficient evidence either way. However, as the demand for fuel is relatively inelastic any distortions due to placing a GST on an optimal excise are unlikely to be large. Furthermore, the results provided suggest that the current excise on fuel is likely to be too low. If the excise is too low then placing a low enough GST on top of it will improve efficiency.

3.3 Tariffs. The tariff on passenger motor vehicles is set on currently 10 per cent of the value of imports but is scheduled to fall to 5 per cent from January 1, 2010. This taxes new passenger vehicles, off-road vehicles, second hand cars and vehicle parts. Used vehicles are subject to an additional impost of $12,000. There is also a 5 per cent tariff on light commercial and four-wheel-drive vehicles (Productivity Commission, 2008). The actual tariff rate on a specific car can vary for two reasons. First, there are preferential trade agreements with Thailand and the United States which in 2005 were both sources of cars. Second, under ACIS (Australian Competitiveness and Investment Scheme), exporters of vehicles obtain credits that can be used to offset the import tariff on vehicles that the company imports. All manufacturers in Australia include imported vehicles in their product line. After allowing for ACIS the Productivity Commission estimates the trade-weighted average tariff for cars is 5.7 per cent.

For 2007-2008, $1400 million was collected from the customs duty on passenger motor vehicles. There is no specific information on the customs duties collected for other vehicles such as trucks.

In 2007, there were sales of 1,049,982 new motor vehicles of which 60.7 per cent were passenger vehicles, 35.8 were light trucks/SUVs and the remaining 3.5 per cent were heavy trucks. Of the passenger vehicles 75.3 per cent were imported. 44.7 per cent were fleet sales. Of the light trucks, 88.5 per cent were imported and of the heavy trucks 60.2 per cent were imported (Glass's, 2008).

Partial equilibrium estimates of the efficiency losses from tariffs (the so called 'costs of protection') are provided in Tcha and Kuriyama (2003). Examining the period 1984-1999 they estimate an average welfare loss of $75 million per year. This loss declines over time, and their estimate for 1999 is just $33 million.

General equilibrium estimates of the efficiency costs of tariffs have been estimated by the Productivity Commission (2008) for 2005-2006 using the Centre of Policy Studies MMRF model. Though the tariff is now lower than it has been, the share of imported cars is much greater than previously. All passenger vehicles except for a few large models produced by the three manufacturers are imported. This means that the market base for this tax is broad. This base is reduced by the ACIS scheme – though this may increase the potential for distortions between different models. The reduction in Gross National Expenditure as a consequence of maintaining protection is estimated to be $500m annually. Abolishing these measures would end a redistribution of about $1b of income to the automotive industry. These numbers are much greater than those implied by Tcha and Kuriyama (2003).

These estimates of losses by the Productivity Commission have been criticised. Dixon (2009) argues that the estimated small reduction in protection from 10 to 5 per cent and elimination of ACIS could not yield a benefit of $500m and that indeed reduced tariffs would cost $66m per year rather than providing an economy-wide gain. Gropp et al. (2009) countered that Dixon's conclusions stemmed from assumptions made which simultaneously limited the resource responses to reduced tariffs and heightened adverse terms of trade effects. Dixon has a point in claiming that gains from reducing tariffs are low when tariffs are relatively low - this is confirmed by the view that the cost of protection will be proportional to the square of the tariff rate. But it is difficult to conclude that reducing tariffs from 10 to 5 per cent will inflict a welfare loss. The source of Dixon's conclusions seem to reside in his view that there Australian resource exporters have untapped monopoly power and that, because these have not been subject to an export tax that there is an optimal tariff of about 10 per cent that can be levied on cars. This argument can be motivated by the Lerner symmetry condition of trade theory that shows an export tax is equivalent to an import tariff. Therefore if an optimal tariff is not levied on exports for which Australia is a price maker, this can be achieved instead by levying a tariff on imports. In a two good model it doesn't matter which traded good is taxed to exploit the optimal tariff argument. The argument is that restricting output in export markets will raise price sufficiently to increase a nation's advantage. Specifically levying a tariff on imports in a two good world will drag resources away from the export sector, reducing output there and potentially advantaging the economy from an optimal tariff viewpoint.

This seems implausible. If there is market power in an exported resource sector then placing an import tariff on car imports will draw resources away from all sectors, not just that export sector. The implications of the Lerner symmetry condition are less powerful in such circumstances. Indeed a tariff on car imports may not draw any resources at all from the export sector. Instead it will draw resources away from industries with no exporting market power at all. In this case the economy will be worse off with any non-zero tariff on car imports since the tariff will be distortionary. One cannot draw conclusions about a case for low level tariffs without paying attention to the complementarities and substitutabilities in input use across the whole economy.

Finally some mineral exporters might already be exploiting their market already by acting as monopolists. For those who don't it might be the case that government might seek to access these rents by an export tax. But a low import tariff will not substitute for such a tax.

3.4 Luxury car tax. The luxury car tax (LCT) is an additional tax imposed on cars with a retail price greater than a threshold of $57,180. It is additional to GST and other transfer taxes. In 2008, if the GST-inclusive value is greater than the threshold, the car is subject to a LCT of 33 per cent on the difference between the threshold and the GST-exclusive value of the luxury car. Using data on registrations and prices provided in Glasses Information Services (2008) it can be determined that of 637,109 cars registered, nearly 60,000 cars would have been subject to the tax in 2007. For 2007-2008, $464 million was collected for the LCT.

There is no obvious market failure that the luxury car tax addresses. Indeed, the rationale appears to be to introduce a type of progressivity into commodity taxation. However, this is dubious at best because only one luxury good among the many that are likely to be purchased by high-income earners is taxed. The LCT is likely to be to distort consumers' choices away from purchasing luxury cars and either towards less luxurious cars or purchasing other luxury items. The size of the induced distortions depends on the elasticity of demand. As this tax does not address any particular market failure, it could be removed, with the small amount of revenue recovered through increased progressivity of the income tax system.

To estimate the EB from the LCT four types of information are needed: a price elasticity of demand, an estimate of the tax and a post-tax price and quantity. **Table 7** summarises this information.

This suggests that excess burden from the LCT could range from a relatively small $4.2 million to a more considerable $40.9 million dollars. Similarly the marginal excess burden could range from 2.5 to 30.8 cents per dollar raised. These are small compared with the excess burden for petrol, but this is on a much narrower base. The argument that such LCTs have low EBs because luxury cars are 'snob goods' that are valued because they are expensive (Ng, 1987 analyses the case of diamonds) seems inapplicable given evidence that the elasticities of demand are significantly negative.

While there is no estimate of the own-price elasticity of demand for luxury cars in Australia, the estimate of Tcha and Kuriyama (2003) is used to compute the uncompensated own-price elasticity. The true elasticity of demand is likely to be somewhat higher than this. While estimates of the own-price elasticity of demand for individual high level models, in the United States car market, in Berry, Levinsohn and Pakes (1995) are lower than those for mid range cars, the individual model elasticities are highly elastic ranging from between -3 to -5. So -0.43 is likely to be an upper bound on the own-price elasticity and -3.5 a lower bound estimate of the own-price elasticity. For the post-tax quantity estimates of the number of cars registered with prices $57,500 and above for 2007 are taken from Glasses (2008). Prices are estimated by calculating a registration-weighted average price based on the registration categories which are arranged by price ranges. If there was a range of prices the mid-point was used. If there was a category based on a minimum price (e.g. $100,000 or more), the minimum price was used on the assumption that most sales were likely to be close to this minimum. To calculate the sale price, we included the GST, the luxury car tax and stamp duty (if in Victoria), but only analysed the effect of the LCT. Finally, note that although we used the price and quantity from 2007, we estimated the effect of the tax using the threshold of $57,180 and rate of 33 per cent.

Table 7: Calculation of Excess Burden – Luxury Car Tax for 2007

Item	Lower Bound Value	Upper Bound Value	Source
Own-price Elasticity of Demand (Long Run)	-0.43		Tcha and Kuriyama (2003)
Income Elasticity of Demand (Long Run)	1.27		Tcha and Kuriyama (2003)
Budget Share	0.053694	0.053694	Table 2, ABS Cat. No. 6535.0.55.001 (2003-04) (revised February 2006)
Compensated Elasticity	-0.36181	-3.5	Lower Bound Value calculated. Upper Bound Value taken from Berry et al (1995)
Post-Tax Quantity	59851	59851	2008 Black and White Data Book
Post-tax Price	$86121	$86121	Weighted Average (GST inclusive) price of Luxury cars from 2008 Black and White Data Book is $76,500. Estimates of GST ($7650) and Stamp Duty ($3825)
Luxury Car Tax	$5796	$5796	
Nominal Excess Burden	$4.2m dollars	$40.9m dollars	
MXSB	2.5 cents per $ raised	30.8 cents per $ raised	

As described in the Mid-Year Economic and Fiscal Outlook (2008-2009), the LCT has recently been modified to include a higher threshold of $75,000 for cars that are energy efficient i.e. with a fuel consumption of 7 litres per kilometre or less. This measure is estimated to reduce revenue collected by $8.5 million for 2008-2009. The motivation for this is presumably to encourage purchases of energy efficient cars. There are no estimates of the sensitivity of the demand for energy-efficient cars to a discount on tax (or even a model of the demand for luxury cars in general). There is, however, more limited evidence from a study by Prentice and Yin (2004). They estimate hedonic regressions of the price of cars on a set of characteristics, including fuel consumption for three sets of cars – small, medium and sports/luxury. For sports/luxury cars, fuel consumption is not a significant determinant of the price of the car which is suggestive that consumers of these types of cars are not interested in fuel consumption. If one is willing to pay $75,000 for a car, differences in fuel bills are unlikely to be of great concern. This suggests that this measure is unlikely to be effective.

3.5 State taxes. Each Australian state has charges relating to motor vehicles (NSW Treasury, 2007). First, there is the motor vehicle registration duty and transfer fee imposed whenever a vehicle is traded. Second, there are annual motor vehicle registration fees and taxes. Third, there are surcharges or levies on motor vehicle third party vehicle insurance. Finally, there are fees associated with gaining and holding a driver's license.

In **Table 8** revenues from these charges is reported for 2006-2007. This information was collected from the budget papers for each state and territory. These numbers are suggestive rather than definitive as for some states it is unclear where transfer fees are included. Driver licence revenues are not reported as several states do not provide separate data for this. Revenue from Drivers Licenses is not large though not negligible either – for example, for South Australia in 2006-2007, $26.9 million is collected from the sales of driver licenses).

The largest source of revenue is annual registration fees and other state taxes. As these other taxes are relatively small and surcharges on insurance are best discussed with the effects of car insurance in general, they are not discussed at length here. Insurance taxes can be thought of as proxies for charges covering accident externalities, as discussed in Section 5. Road tolls as part of a user-pays approach have the potential to internalise congestion externalities (as discussed in Section 4) but are not discussed here as they are mainly levied by private firms.

Table 8: Total State Taxes on Motor Vehicles

Tax	Revenue ($ million)
Motor Vehicle Registration Duty on Transfer	1989.7
Annual Motor Vehicle Registration Fees and Taxes	3806
Surcharges and Levies on Compulsory Third Party Insurance	222.6
Other (not including Drivers License fees)	64
Source: Budget Papers each state and territory.	

State tax efficiency costs. These taxes have a cost-recovery component and can also be viewed as contributing towards the capital costs of roads although there is no explicit hypothecation.

As the state taxes are fixed, they will affect car ownership but will have, at best, a blunt impact on externalities that are related to the amount a vehicle is driven. However, they will affect the extent of trade in vehicles, the rate of purchasing new vehicles and the rate of scrapping vehicles. These effects may indirectly affect the externalities from driving, as different types of cars may produce different quantities of pollution. The potential efficiency costs of annual taxes on motor vehicles and taxes on trading vehicles are discussed below.

All taxes on owning and trading cars raise the cost of owning a car which should reduce car ownership. Extensive ownership of cars suggests this, in general, is unlikely, to have large effects.

Taxes on vehicle trading will reduce the rate at which vehicles are traded, thereby creating EBs. For example, an older couple whose children have left home may delay getting a smaller car. Alternatively, a younger couple who purchased a SUV before fuel prices rose may delay selling it and buying a smaller car. Determining the size of these losses is an empirical question that remains to be undertaken.

The progressive nature of some of these taxes implies, *ceteris paribus*, that small cheap cars will be replaced more often than larger more expensive cars. If larger more expensive cars have greater fuel consumption per kilometre, and produce greater quantities of local and global pollution, then a progressive charge system hinders reduction of these externalities. The size of this effect is again an empirical question for which there seems to be limited evidence.

Description of State taxes. Duties on trading motor vehicles are typically calculated at around 3 per cent of market value, though this differs in small degrees across states. Separate transfer fees are usually small (around $20) and fixed.

Annual registration taxes vary more substantially across states. All states and territories have a fixed fee component. All states and territories except Victoria have a component that increases with some measure of vehicle size measured either as weight or number of cylinders. The charge for Victoria and the charges for cars up to 6 cylinders tend to be between $150 and $200, with a few exceptions (New South Wales Treasury, 2007)

Surcharges and levies on insurance are either 10 percent of the premium (in Victoria and Western Australia) or a fixed fee (Queensland, Tasmania and South Australia). New South Wales and the territories do not have a specific surcharge on insurance.

The charges for driving licenses and associated permits do not vary much across states and are typically $25-$40 annually for a license. Learner permits and testing fees are generally of a similar magnitude.

There are no known estimates of the efficiency effects of these charges though they are presumably small relative to the role of quantitatively much larger registration charges.

3.6 Fringe benefits tax. This tax enables income received in kind by an employee to be taxed as well as income in the form of cash payments. This removes a distortion that encourages employers to substitute non-cash benefits for cash payments. Efficiency costs arise because it is difficult to estimate income received in kind and the approximations used may distort choices made about activities associated with these approximations. An often-cited example of this is the incentives FBT creates that encourage driving.

FBT is calculated in two ways. There is the 'operating cost method' and the 'statutory formula method'. Each method calculates the total benefit of running the car and then calculates the portion of this benefit attributable to private use. Each method also deducts the value of any employee contributions to the vehicle.

The operating cost method calculates the total benefit of operating the car as being equal to the operating costs of the vehicle. The proportion of this benefit is determined by the share of use for private purposes as documented by log books.

The statutory formula method calculates the total benefit of operating the car as being equal to its base value that is the purchase price (including any accessories). The proportion of the benefit assigned to private use is the product of the share of the days the car was available for all uses that it was available for private use and a statutory percentage. The statutory percentage declines with the number of kilometres driven, from 26 per cent for less than 15,000 kilometres to 7 per cent for over 40,000 kilometres. It is estimated that the application of this formula may lead to an underestimation of the tax payable for 2007-2008 of $1490m.

Kraal et al (2008) provide evidence that the statutory formula creates a *moral hazard* problem. The firm can benefit itself by driving extra kilometres to lower the statutory percentage even if the value of the trip is less than the other costs of undertaking it. Kraal et al (2008) note that other methods of more directly recording private and work benefit use of the car are more costly so the relevant issue is how relatively large are the losses created by this system. Drawing on a large sample of public sector organizations and universities, they collect the mileage of each of the 1250 cars in the fleets of six of these organizations. After compiling a cumulative distribution function for mileage, they discover flat spots in the function around the thresholds. This is consistent with the cars being driven just enough to exceed the threshold. About 19 per cent of cars are just above the cut-off points for the statutory percentage, which is not an insignificant proportion. However, they do not test if these flat spots are statistically significant.

3.7 Fines and penalties. So far analysis has focussed on using taxes to correct market failures arising from legal activities as a way to collect revenue. The market failures addressed were usually negative externalities. Numerous illegal activities on the road, such as driving while influenced by alcohol or other drugs, speeding and driving through red lights, also involve negative externalities. Each of these activities may benefit the individual undertaking them, but they also increase the likelihood that other drivers will be in an accident. Violation of property rights, such as parking violations are another relevant illegal activity.

Ideally, the fines for these activities should be set such that only socially beneficial actions remain. Activities such as driving under the influence of alcohol imply huge externality costs – as argued in Section 5 those driving under the influence of alcohol in the US have 7 times the external accident risk of other drivers so there is a justification for very hefty fines and penalties on drink-driving Such fines are a source of revenue for local and state governments. For certain activities, such as parking, it may be best to just think of the fines as a parking price that has a steep gradient and treat such fines as a method of raising revenue. In more specific terms, if a driver wishes to stay for two hours in a one hour parking spot, in effect, the driver pays a much higher expected price equal to the probability that their illegal parking will be detected multiplied by the fine. The theory of how fines should be imposed is developed in Polinsky and Shavel (2000) but this is beyond the scope of the current study.

3.8 Summary. Several transport taxes have been reviewed - excise on fuels, import tariffs, the LCT, state charges on ownership and trading of cars, fines, and FBT. The main focus has been on the consequences of these taxes for economic efficiency rather than their distributional effects as redistribution is better handled through the income tax and transfer system.

The excises on fuel are the taxes that yield the largest revenue so these were analysed in considerable detail. A major feature of the liquid fuels market that shaped much of the analysis is that transport demand for petrol is highly inelastic. The immediate consequence of this is that the efficiency losses on petrol and diesel are unlikely to be large relative to the revenue raised. Furthermore, this suggests that there is a role for an excise on fuel in raising revenue.

In addition, if it is too costly or difficult to directly charge for activities generating a set of negative externalities from road transport, such as pollution, traffic accidents and congestion, there is also a role for the fuel excise in correcting these. Because some of these externalities are not specific to any particular fuel, all fuels should be subject to excise. As an environmental tax, the excise should vary with energy content and there is a potential case for setting a lower excise on alternative fuels. Any discount for the latter is likely to be small though. Furthermore, to avoid increasing inefficiency in production, fuel used for business purposes (on or off road) should be exempt from excise – as is already substantially the case – unless measuring this is highly problematic.

Similarly, as is currently the case, there is also an argument for using the excise as a proxy for user charges for road damage by heavy vehicles if it is too difficult to directly charge for road damage.

Calculations of optimal fuel excises for Australia indicated that there was a role for an excise to raise revenue as well correct for negative externalities. These calculations suggest that the current excise, nominally fixed since 2001, is likely to be too low. The excise could be raised and other taxes lowered.

Looking to the future, technological developments are likely to make direct charging for activities creating negative externalities easier to implement. This suggests a relatively greater role for the fuel excise as a source of revenue. Furthermore, with the development of hybrid cars and alternative fuels, it is likely that a broader range of fuels will be used more widely than at present. As the excise on fuel is substantially a tax on road transport, these new fuels should taxed within the same framework and subject to the same considerations as in the current system.

If the fuel excise is purely a tax to correct for negative externalities or a user charge, it is appropriate to apply a GST on top of it – on the externality-inclusive charge. If the excise is being used for revenue raising a GST on top of this will create further distortions. However, given the current excise is likely to be too low, the current practice increases rather than decreases economic welfare provided the GST is small enough.

It is recommended that tariffs on motor vehicle imports be repealed. They do not address any market failure, create substantial efficiency losses and do not raise much revenue.

Similarly, the luxury car tax should also be replaced on similar grounds. Furthermore, raising the threshold on energy efficient cars is unlikely to alter behaviour.

As state taxes and fees are substantial, there are potential efficiency costs. But their size is unknown. There may be some efficiency gains in increasing their uniformity across states.

Some fines, such as for parking, should be considered as prices and considered explicitly in terms of raising revenue for local government.

There is a potential moral hazard problem with the current design of the FBT as applied to cars. More analysis is needed to determine the costs here. Eliminating this moral hazard by more directly recording private and work-related use of vehicles would increase administration costs. Such additional costs would need to be compared with the benefits from eliminating the moral hazard problem. It is recommended that such an analysis be carried out.

Finally, more detailed demand estimation for fuels and motor vehicles should be carried out. Breunig and Gisz (2009) provided a valuable estimate of the own-price elasticity of demand for petrol. Ideally, similar work would be carried out on other fuels. In addition, while the older work of Tcha and Kuriyama (2003) provided an estimate for the Australian car industry, some of the questions considered here, such as on the LCT and the costs of industry protection would be best addressed by a car model-level analysis such as that provided in Berry et al (1995). Estimation of such a model for Australia would be a valuable input for policy.

4. Congestion, Parking, Greenhouse Gas and other Pollutions.

The efficiency costs associated with vehicle-induced congestion, parking externalities, greenhouse gas emissions, air pollution and noise externalities are now discussed. Traffic accident problems and road maintenance issues will be discussed in Sections 5 and 6 respectively.

Summary Section 4
Congestion costs impact on all Australian capital cities but are pronounced in Sydney and Melbourne. They will increase strongly over the next 20 years unless addressed with policy measures. Supply-oriented management of congestion will become increasingly infeasible so it makes sense to consider demand-oriented, user charges. .
There is almost no experience with congestion-based pricing in Australia and only rudimentary modelling of such costs. With the exception of the Sydney Harbour Bridge tolls current road pricing is geared toward cost-recovery and does therefore not assist in smoothing peak travel demands.
Choice of congestion pricing scheme can range from comprehensive electronic-based pricing to partial schemes which seek to price roads in only key parts of a city. The latter schemes impose considerable second-best spill-over costs. International experience suggests such schemes are expensive and require, as a prerequisite, an effective public transport backup.
There is an imperative to address congestion pricing issues before they place huge costs of travel on urban commuters. The case for using comprehensive electronic pricing of all urban vehicle travel in currently congested cities using telematic technologies is strong. Such technologies involve lower implementation costs than expensive intermediate schemes and their effectiveness is greater.
If intermediate policies are sought they should concentrate on cordon pricing of congested cities with traffic density dependent tolls on major ring roads and arterials. Parking policies provide an imperfect though useful additional intermediate way of addressing congestion.
Greenhouse emission costs at current carbon charges are conveniently addressed via petrol excises although at current carbon charges and with low fuel price demand elasticities they are negligible.
Other vehicle-caused pollutions and noise/vibration externalities are best addressed via

regulation rather than through user charges.
Important items in the Australian research agenda call for more research on congestion modelling along with techniques for assigning congestion charges. There is also a case for more research effort on devising satisfactory parking policies. Whereas on-street parking in Australia is typically underpriced, parking charges in airports seem excessive.

4.1 Traffic congestion externalities. As a general phenomenon congestion occurs when the quality of service provided by a facility depends on the intensity of its use. For transportation the key aspects of service quality are the times taken for journeys including the reliability of making a journey on time. With respect to urban road use some congestion is unavoidable and to some extent internalised into driver's travel plans. This type of internalised congestion is not of concern to economists. What are of concern are the congestion externalities that arise when road travellers do not consider the impact of their travel decisions on the travel times of *other* road users. This creates what is the most significant externality associated with road travel in urban areas. For the UK congestion is estimated by Samsom et al. (2001) to provide between 75-84 per cent of total estimated marginal external road costs. For the US, Parry et al. (2007, p. 384) estimate that congestion costs constitute about 50 per cent of all distance-related externality costs. There are no comparable estimates of the relative importance of congestion costs for Australia but the estimates of absolute size that are available (and which are subsequently discussed) suggest a substantial importance.

Australian per capita incomes should double over the next 20 years which will impact on transport demands and on the liveability of Australian cities. Our increasingly affluent capital city populations will grow by 3 million with car traffic forecast to increase by 33 per cent, light freight by 41 per cent and heavy traffic by 39 per cent. Growth in total traffic in already congested major cities will be considerable. In the absence of pricing Sydney's traffic will grow 47 per cent and Melbourne's by 40 per cent (Gargett and Cosgrove, 2004). Moreover, some key congestion impacts will emerge in state capitals such as Brisbane and Perth – indeed by 2020 congestion costs per kilometre in these cities will exceed those forecast to prevail in Sydney and Melbourne in 2009 though the aggregate congestion costs will remain somewhat lower (Garrett and Cosgrove, 2004, p. 109, p. 111).

These congestion impacts will be increasingly difficult to reverse using conventional supply measures because land supply constraints will increasingly bite. Pressure will fall on a more comprehensive reliance on public transport along with demand management by pricing congestion. As cross price elasticities of demand for car travel with respect to public transport prices are low (Button, 1993, chapter 3) the options for diverting road users by subsidising public transport are restricted by the high costs of such subsidies. There is a fundamental need to price road congestion.

Congestion theory. The background static speed/flow theory of congestion pricing that underlies much empirical work is exposited in Hau (1992). This theory deals with *density-dependent congestion* and abstracts from forms of congestion associated with, for example, traffic bottlenecks or what is called nodal congestion. Then in the simplest formulation, if motorists have the same value of time, charging motorists the dollar value of the marginal congestion costs they impose provides a social efficiency gain since losses to travellers as a consequence of higher commuting costs are exceeded by the revenues yielded by the congestion charges. This argument is set out diagrammatically in **Figure 2**.

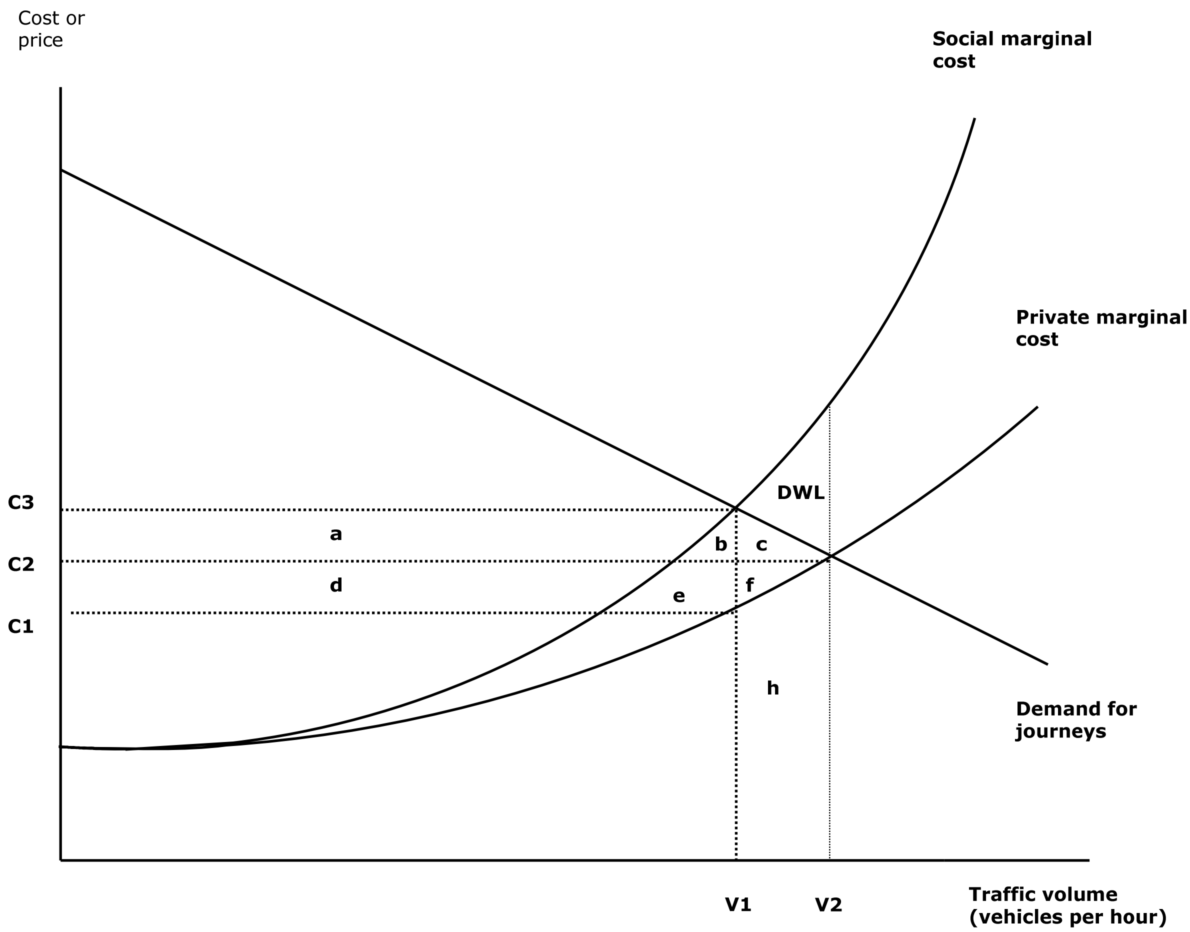


Figure 1: Congestion Pricing in the Speed/Flow Congestion Model.

Here without congestion charging traffic volumes are V2 and the cost of travel is C2 which creates a deadweight loss DWL The optimal user charge is C3-C1 which reduces traffic volumes to V1 and eliminates the deadweight loss DWL. Road users pay higher toll-inclusive costs C3 and lose gross consumer benefits c+f+h but experience reduced costs DWL+c+f+h provided that all revenues (a+d+b+e) are rebated to them. Hence there is a welfare gain with a move to pricing of DWL. Without compensation of the tax revenues however road users lose consumer surplus a+b+c and hence are worse off. Uncompensated gains therefore do not arise.

An important feature of this outcome is that there are no uncompensated gains to motorists. Road users face higher toll-inclusive costs of travel and are better-off only when appropriate redistributions of tax revenues are made to compensate them. This need creates substantial 'political economy' issues of implementing congestion pricing because there arise issues of trying to convince motorists that they are better-off. Uncompensated gains can arise if motorists attach different values to their travel since then it can be the case that those with a high value of travel time (these will generally be experienced by those on high incomes) derive net benefits that exceed the costs to those making lower-valued journeys. There can similarly be gains to individual motorists if they prioritise the same trip differently though time. Finally, if there is high congestion so that, for example, large queues form – this is hypercongestion – then uncompensated gains can arise even if motorists have a uniform value of time (Hau, 1992, p.16).

The main shortcomings of the speed/flow model are that it cannot adequately accommodate important bottleneck constraints that cause hypercongestion. Nor does it account for the dynamics of driving decisions - motorists can not only choose if they travel but also when they travel. They can avoid the worst congestion during peak periods by changing their departure time. The 'bottleneck congestion model' addresses these issues (Vickrey, 1969; Arnott et al, 1993). Here motorists have a preferred arrival time and incur increasing costs with departures from this time. These costs are traded-off against time savings costs of leaving before or after peak travel periods. With a single bottleneck, a queue forms at peak travel times and then declines. The optimal congestion toll then varies with time as an inverted U-shaped function which seeks to 'flatten out' the peak by inducing more drivers to leave earlier or later. Unlike the speed/flow model this toll eliminates congestion entirely by eliminating queuing at the bottleneck. Empirical estimation of this model has proven difficult but numerical simulations suggest that half the welfare gains yielded from congestion pricing can come from trip rescheduling rather than avoidance of peak travel altogether. This reflects the fact that the costs of congestion arise because people are forced to shift away from their desired departure times as well as because they incur extra travel time costs. This means that welfare gains from congestion pricing are much greater than in the speed/flow model and roughly of the order of the revenue collected.

Finally, it is worth emphasising that congestion can arise from non-recurring events such as accidents and bad weather which also cause severe congestion and reduced travel time reliability as well as a time cost of travel. The models discussed above do not directly address such concerns but, with congestion charging, such events should have less severe impacts (BITRE, 2008a) than they otherwise would.

Congestion empirics. There are various methods for estimating congestion costs – macro or aggregative approaches (an example is BTCE, 2007), network simulation-based (e.g. the Saturn model, Van Liet & Hall 1997) and most recently game-theoretic models that examine the strategic problem of whether to make a journey (Viauroux, 2006). Most empirically-oriented models use the speed/flow approach.

The most comprehensive and up-to-date study of congestion costs in Australia is BTCE (2007) and it too relies on the speed/flow model. This study provides estimates of the congestion costs in the eight Australian capital cities and base case (business as usual, 'bau') projections of these costs to 2020. The study estimates these correctly as deadweight loss (DWL) estimates. The methodology is aggregative and relies on broad indicators of a city's overall traffic. It is not based on network simulations in each city. The model is intended to be appropriate for use in national level studies. Comprehensive network modelling estimates are not yet available for Australia.

For 2005 the estimated DWL is $9.4b for the 8 Australian capital cities comprising private time costs ($3.5b), extra business time costs ($3.6b), extra vehicle operating costs ($1.2b) and extra pollution costs ($1.1 billion). This aggregate figure is subject to considerable estimation uncertainty – sensitivity analysis suggests the true figure lies between $5-$15b. The worst congestion is concentrated in Sydney and Melbourne (costs are $3.5 and $3.0b respectively) though it is growing strongly in smaller cities such as Brisbane and Perth. This analysis does not consider costs of introducing new congestion control regimes, it ignores consequences of congestion other than those mentioned and assumes a 1 per cent annual expansion in lane-kilometre road provision through to 2020. Under bau traffic is forecast to grow 37 per cent from 2005-2020 and congestion costs grow strongly to $20.4b over this interval.

The congestion costs identified are around 8 cents per km in Sydney, 7.5 cents in Melbourne, 6.5 cents in Brisbane, 5.4 cents in Perth and 5.2 cents in Adelaide. The (weighted by traffic) average for all 8 cities considered was 6.8 cents per km. These figures are mid-range compared to national estimates for the US and the UK. Specifically the year 2000 Australian weighted estimated average across all capital cities was 6 cents compared to an estimate of 6.6-7.2 cents US/km for the UK in that year and 1.5-3.3 cents US/km for the US (Parry and Small, 2005, p 1282).

It is worth emphasising that all of these studies use aggregative speed/flow models. This raises the question of whether the gains from introducing congestion pricing are understated because gains associated with smoothing out bottleneck issues are not considered.

The cities that would be eligible candidates for partial pricing schemes (major roads plus cordon schemes), assuming estimates from the aggregative BITRE (2007) study are plausible, are Sydney and Melbourne. Brisbane, Perth and Adelaide have quite high per km costs but much lower aggregate congestion costs and will be less immediately obvious candidates for partial pricing given the fixed costs of establishing a pricing scheme discussed below. There seems to be no current case for attempting to capture congestion costs using congestion tolls outside these major cities.

Current Australian congestion pricing. Most road pricing in Australia – certainly *CityLink* and *Eastlink* in Melbourne – are geared toward achieving cost-recovery and do not specifically address congestion. Such tolls do not achieve the objectives of efficient congestion pricing since tolls charged do not increase at peak travel times when traffic is most intense. Thus such tolls do not provide incentives to switch travel away from peak periods to 'smooth out the peak'. The inefficiencies here reflect the levying of charges on motorists when there is no congestion and hence when there are no congestion costs. Private firms operate these tollways under contract with government so that an appropriate reform would be to renegotiate these contracts so that short-term marginal cost rather than uniform charges were levied (Clarke and Hawkins, 2006). This move would eliminate DWLs stemming from the current inefficient charges. If private management of tolled roads is to be maintained then future contact designs for tolling should require efficient pricing perhaps along with, perhaps, compensatory transfers to operators from government.

One significant attempt to introduce 'time-of-day' pricing is tolling for use of the Sydney Harbour Bridge. This tolling came into operation on 27th January 2009. The explicit objective was to ease traffic congestion by encouraging motorists to travel outside peak periods if possible. On weekdays during the peak period 6-30am-9-30am and 4pm-7-00pm the maximum toll of $4 is charged. From 9-30am-4-30pm the toll is reduced to $3 while from 7pm-6-30am the toll is lower still at $2-50. On weekends lower tolls are levied. It is too early to make assessments on the impact on peak traffic flows since although the initial effects look favourable – peak traffic flows crossing the bridge have eased – the longer-term effects cannot yet be determined. The important implication is that traffic authorities have made a move towards specific 'time-of-day' pricing, a move which essentially endorses the logic of the congestion pricing model.

The Sydney Harbour Bridge experience should provide useful evidence on the effects of differential time-of-day pricing on traffic congestion.

Congestion and 'second-best'. The 'first best' case for comprehensive road pricing is immediate provided that the costs of implementing comprehensive pricing (analysed below) do not exceed the DWLs avoided. Two complications, however, limit the applicability of this conclusion. First, comprehensive pricing may in fact be impractical so that only pricing of a subset of roads (including perhaps a cordon around a city's CBD) may be feasible and, second, general equilibrium impacts of pricing may trigger additional distortions in such areas as labour markets. General equilibrium complications are raised in Section 7 but, given that practical road pricing almost always involves 'second-best' issues, it is important to discuss some 'partial pricing' second-best issues now.

Second-best 'partial pricing' issues are discussed in Choe and Clarke (2000), Clarke (2008). The main insight is that if congestion pricing is restricted to a city cordon or to major arterial or ring roads in a city that gains from congestion pricing can only be realised with auxiliary policies to address 'second-best' constraints and that, even with such side policies, gains may be substantially reduced.

If pricing is imposed around a cordon then congestion can develop on its boundary. This must be addressed through parking restrictions and other congestion policies imposed around the boundary. Pricing only major roads can lead to 'rat-running' along alternative unpriced routes that can create urban disamenities. Pricing and investment policies are altered by these constraints as well. Generally tolls should be set lower under incomplete pricing schemes so that lower DWLs are captured than would be without the constraints. In addition installed road capacity on the tolled roads should also be set lower. This inevitably means lower welfare gains from congestion pricing and from efficient road provision.

If major arterial roads and ring roads are to be priced into cities - there is a strong case for doing so in Melbourne at least given extensive congestion in the city periphery (Clarke and Hawkins, 2006) - then there is a need to restrict traffic follows onto minor unpriced roads by using traffic architecture and perhaps traffic constraints. These constraints again reduce the gains from congestion pricing.

An important issue in large Australian cities is the congestion arising on major arterial roads and cross town roads at considerable distances from city CBDs. These are complex issues since it is difficult to eliminate 'second-best' issues on roads that run through low-population density areas on a city's periphery and difficult to provide public transport infrastructure that will encourage modal shifts that are sought by pricing private vehicle use. The complication is that many journeys in periphery and periphery areas are not along roads directed radially towards the city CBD. Many journeys are cross-town to workplaces, schools and shops located elsewhere in the city outskirts. Clarke and Hawkins (2006) argue for liberalising provision of a wide range of bus and mini bus services as a palliative but there remain difficult issues of transport and urban planning in the periphery of congested cities.

Congestion pricing implementation costs. The feasibility of peak-load road pricing has improved recently with developments in electronic metering technology. Fees can be collected electronically by in-vehicle transponders or by direct billing with global positioning systems. The telematic technologies that can be used to price are discussed in Section6.

Nevertheless proposals to price congestion face cost obstacles and vary in accord with the extent and complexity of the pricing. Assessing these costs is difficult since congestion charging schemes are in their infancy and evolving technologically. Even providing ballpark estimates of the costs of introducing comprehensive or piecemeal congestion pricing in Australia is complicated by the distinctively lower population densities of Australian cities (BITRE, 2008a). It is not clear how transferable the cost estimates of other national experiences are. Congestion problems are often less severe in Australia but fixed transaction costs of observing and pricing traffic flows are spread over a smaller population base. There are also relatively fewer economies of providing public transport to encourage sought-after modal shifts.

The costs of comprehensive electronic pricing involving charging by location and time using on-board units are both large and uncertain. For Britain the Eddington report (DOT, 2006) forecast set-up costs in the wide range £10-62b with annual running costs £2-5b. This wide range reflected uncertainties over the scope of charges and technology costs. There were also important costs of compliance and enforcement.

In terms of partial approaches to congestion pricing much recent attention has focused on the London 'area pricing scheme'. The cost experience of this scheme has implications for those seeking to imitate it. Set-up and operational costs of the scheme were considerably higher than initially expected. Implementation costs over the first two years averaged twice what were expected during the planning phase partly because of much higher than expected compliance costs. The annual costs of the scheme are estimated to be £163m (£143 million if establishment costs are included) compared to total annual benefits of £230m (Leape, 2007). Thus costs comprise more than two-thirds of benefits. In addition there are the costs of providing enhanced public transport services to meet demand created if the costs of private vehicle use are increased.

An interesting aspect of the scheme of relevance to Australia is that the London area scheme might be seen as an intermediate policy in a longer-term move to full-scale electronic pricing of all roads in the UK. The success of the London scheme suggests that such a move may, in fact, be uneconomic since congestion pricing of London accounts for 80 per cent of the benefits from a national scheme (DOT, 2004). In fact, on interurban roads, Newbery (2005) estimates that national distance-based pricing would be uneconomic and that a better scheme would be to simply rely on existing fuel taxes which would adequately capture many of the congestion costs.

Reasons for the success of the London scheme include the existence of a well-functioning public transport system and the presence of very high congestion levels. Moreover, the existence of a ring road around London provided a convenient boundary. It cannot be assumed that Australian cities with milder traffic congestion, less clearly defined boundaries and an already overtaxed public transport system would have an analogous cost experience.

In Sydney, for example, in 2004 there were 15.8 million trips per day of which 70.5 per cent were by private vehicle, 17.2 per cent were walked and only 9.9 per cent were by public transport. Public transport trips are split about equally between bus and rail. Achieving substantial reductions in traffic congestion would involve huge costs and hefty road user charges. Reducing traffic volumes by one third would mean diverting 846,000 people from car to other modes which would place huge expansion pressures on the bus and rail system (Stopher and Fitzgerald, 2008).

Final remarks on congestion. The most frequently advocated congestion pricing solutions for Australia will involve specific cordon pricing cities for some of its major cities along with pricing of major arterials and ring roads. Most plausibly these would be Sydney and Melbourne. Other cities face high per km congestion costs but have limited aggregate congestion costs. This would mean that fixed costs of operating cordon pricing schemes would make them at best, only marginally viable. There are serious issues of providing extra public transport infrastructure to encourage modal shifts from the use of private vehicles.

The use of revenues yielded by congestion pricing has not been discussed. The emphasis in externality pricing work is on providing correct price signals to internalise externalities not on revenue raising. Economics is generally lukewarm on the issue of hypothecating such revenues to particular purposes such as transport infrastructure. But given the very substantial public opposition to pricing there could be 'political economy' benefits in making it clear that such revenues will be directed towards reducing other costs associated with transport such as statutory registration charges or public transport. There are also arguments – developed in Section 6 - for hypothecating such revenues toward road supply expansion and maintenance spending. The idea is to make supply decisions more response to demands.

Finally, the issue of phasing in programs of reform needs to be addressed. Broadly there are three stylised classes of candidate policy. First, there are piecemeal reforms (cordons, pricing of major roads) that could be introduced followed by a switch at some time in the future toward comprehensive electronic pricing that included assessment of road damage costs, distance-based insurance externality costs and which provided access to paid parking with low search costs and so on. Second, there is the possibility of maintaining piecemeal reforms for at least a considerable period into the future. Finally, third, there is the possibility of avoiding piecemeal reforms and making a switch to lower cost comprehensive electronic pricing schemes at a time in the future when they become more technologically viable and commercially feasible.

The cost of a program of piecemeal reform is high as evidenced by the cost of the London area pricing scheme and the effectiveness of selectively pricing major roads alone is lower than with comprehensive pricing. Thus there are sound arguments for delaying moves to act until comprehensive pricing can be introduced. The difficulty with this argument is political rather than economic. Offering politicians the chance to defer action in dealing with the severe problems of addressing congestion in major Australian cities, given that they are forecast to increase so strongly, is not something those seeking to provide better demand management of Australian urban roads will happily endorse. Australian governments have been slow to recognise the huge emerging costs of traffic congestion and advocating delays in charging might have perverse effects on stiffening political spines.

It is not sensible policy to avoid introducing any road demand management reforms at all in the lead-up to comprehensive pricing. At least some roads and access to CBD areas can be priced. Piecemeal pricing reforms will provide some relief from congestion and will also provide valuable information about likely traffic responses to pricing. Case studies of current commercial pricing schemes such as Melbourne's *Citylink* and *Eastlink* can add to this information base. Finally, correctly configured parking policies can, in addition, provide a useful partial means of reducing congestion.

4.2 Parking policies and parking-induced congestion. The congestion pricing models economists work with are often aggregative and downplay the issue of vehicle parking either by ignoring it (as in BTRE, 2007) or by treating parking costs as a fixed fee for taking a trip. Yet road travel is a derived demand from such things as the need to get to work, to visit friends or to go shopping. Almost all vehicle journeys involve the need to park a vehicle at some stage to implement the purposes of a journey. Parking policies provide a useful though imperfect piecemeal policy that can be used to reduce congestion.

Parking charges that exist at a destination influence the costs of travel which terminate at that destination but, to the extent they reduce such terminating traffic, such charges provide incentives for increased flows of 'through' traffic (and traffic doing 'drop-off' errands that does not require long-term parking) which will now face reduced congestion costs. If, on the other hand, all traffic terminates at the same destination, where it must park, then parking charges substitutes perfectly for congestion charges that relate to costs incurred in the neighbourhood of a destination. Note that only congestion costs in the neighbourhood of a destination are captured when, as will be usual, different vehicles have different points of journey origin.

Parking charges that target congestion – even specific peak period charges – are attractive to government since they do not impose substantial administrative difficulties. Typically some sort of charging is already in place and has widespread community acceptance as a 'reasonable' charge on a visible physical entity, namely a parking spot.

In principle 'first best' parking charges should not be directed at congestion costs associated with commuting at all if there is non-terminating traffic. Instead the traffic itself should be subject to a congestion charge. Parking charges should instead target the elimination of costs associated with the act of parking itself such as wasteful searches for a parking spot (including search-induced congestion costs) that stem from excess demands for limited parking spots.

Australian parking policies. In many Australian cities an attempt has been made to regulate levels of parking by controlling levels of on- and off-street parking. The dominant trend has been to heavily restrict on-street parking but to keep it priced relatively cheaply. The resulting excess demands are rationed primarily by restrictions on the length of time that a spot can be occupied, by means of restrictions on the type of vehicle that can be parked such as residency permits and by fines directed on parking over-stayers and other forms of illegal parking. Privately-owned off-street parking has been encouraged as a higher-priced alternative to on-street parking. A strongly-held, if somewhat confusing policy objective, is to discourage long-term parking. This might be motivated by retailers seeking to optimise sales but maximising the opportunities for short-term shopping visits has the perverse effect of increasing traffic volumes.

The effect of providing relatively cheap on-street parking is to create an excess demand for it resulting in high levels of congestion from attempts to search for and secure a cheap parking spot. The preference for providing short-term parking options provides incentives for greater traffic densities averaged over a day but possibly a shift away from travel during peak periods.

Around Australia attempts have also been made to adjust parking charges to influence traffic flows as a 'second-best' attempt to restrict congestion flows on roads. For example the Victorian Government, in 2006, introduced an $820 per parking spot levy on long-stay car parking spaces in Melbourne to ease traffic flow congestion and to reduce greenhouse gas emissions. It was also intended to encourage more short-stay, off-street parking although this will have, as mentioned, some counterproductive offsetting effects in increasing traffic flows. The parking levy is administered by Treasury (not the Department of Transport or *VicRoads*) and impacts on 52,000 parking spaces in the city. It provided about $40 million fiscal revenues in 2007 (Dowling, 2008).

In Sydney, NSW too a Parking Space Levy (PSL) has operated since 1992 to discourage car use in major commercial centres. The PSL is hypothecated to fund infrastructure projects that make it easier to access public transport. These include 'kiss and ride' facilities that allow temporary parking for those dropping off or picking up travellers, park-and-ride facilities, bus shelters, taxi stands, transport mode interchanges, passenger information and security services. The PSL is $950 in Category 1 areas (Sydney CBD, North Sydney and Milsons Point) and $470 per space annually in Category 2 areas (Bondi Junction, Chatswood, Parramatta, St Leonards). In 2008/09 PSL collections are estimated to be $47m and are collected by a branch of the NSW Treasury on behalf of the NSW Ministry of Transport (NSW, Ministry of Transport, 2009).

At the same time as inner city parking costs are being increased in Melbourne extra free parking spots are being provided in outer Melbourne on each of the five major train corridors into Melbourne City. This encourages 'park-and-ride' approaches towards city commuting. This is a 'second-best' attempt to deal with congestion without pricing it directly. The same policy is being pursued in Sydney under the umbrella of 'transport interchange policy'. If anything the cost of providing a parking place near a Sydney railway station would exceed that in Melbourne given higher land values there.

These measures will reduce city congestion by encouraging a modal shift to train use but at issue is whether this reduction is cost efficient. Land near railway stations has a high opportunity cost and could be used for homes, other buildings or for landscaping. Multi-level 'structured' parking stations involve, in addition, very substantial construction costs and will only ever be effective when land values are particularly high. The cost of providing a parking spot at a train station in Melbourne has been estimated by Green advocates at up to $17,000, an apparently expensive way of switching passengers from car to rail in order to reduce road congestion (Houston and Perkins, 2008). This substantial cost however is consistent with estimates for other countries. Shoup (2005) estimates that the cost of providing a US parking spot typically exceeds the value of the cars occupying it. Litman (2009, p.5, 4.2) estimates that, quite apart from the opportunity value of land, that parking structure construction costs in the US average $15,000US per parking spot.

Clearly parking spots in city areas are anything but costless. Despite this many 'park-and-ride' and other schemes leave parking unpriced. A parking spot is *not* a public good since its use is both excludable and rival. It should only be provided publicly if the costs of doing so are less than the external benefits that flow from reduced congestion. If purely private benefits are being delivered they should be recouped via metering. Otherwise land resources may be inappropriately converted into parking spaces and non-cost effective policies employed to address congestion.

It is straightforward to compute the scale of the daily external costs that must be eliminated to justify provision of a 'free' parking spot that costs $17,000 to provide. The minimum congestion cost that must be avoided at a discount rate of 4 per cent is $17,000*.04/1.04 or $653. Assuming that travellers use this spot 240 times annually, this means the avoidable daily cost must be $2-72. With a discount rate of 6 per cent the minimum avoidable daily cost that must be avoided is $4-01. At 4 per cent discount rates journeys which average greater than 40 km will deliver more external congestion costs at an average price of 6.8 cents per km in Australian capital cities (compare BTRE, 2007) than this discounted cost of the parking spot. The $17,000 capital cost figure might stop observers from thinking positively about the scope for 'park-and-ride' policies but the implied daily cost at low discount rates is not particularly high. Of course these costs along with metering costs should be recovered by those using these parking spots.

Finally, free parking *in* areas where congestion is an issue are a major source of excessive road demands which have an implied subsidy cost and which worsen congestion. For the United States Shoup (2005) estimates that provision of a free parking spot is equivalent to a 14.5 cents US per km (22 cents US per mile) subsidy to the average American making his or her journey to work. This subsidy reduces the cost of commutes by 71 per cent. In many cases this substantially exceeds the average marginal congestion cost of travel. Employer-paid parking reduces the cost of driving to work by more than double the average optimal congestion toll. Other authors (Litman, 2006) put the estimated subsidies of parking free at between 2-7 cents US per km (3-10 cents US per mile). There is controversy internationally about whether this is an external cost of parking *per se* or whether it results from other pricing distortions based on treating parking as a tax preferred fringe benefit.

In large Australian cities free on-street parking is almost non-existent with much growth in parking spots occurring in privately-operated parking stations. In addition free parking provided to an employee is normally subject to a fringe benefits tax of 46.5 per cent. This occurs if the parking spot provided to the employee is within a one km radius of a commercial parking station when the tax levied is the lowest daily charge levied by such a station. This helps eliminate distortions that arise on the basis of free employer-provided parking.

While much Australian parking is under-priced there are reasons for supposing at airports that parking is overpriced (ACCC, 2009). Airports can extract monopoly rents because they can control landside access. This is particularly the case for short-term parking since there is competition for longer-term parking from service providers removed from an airport. In 2002 *Southern Cross Airports Corporation Consortium* backed by *Macquarie Airports* purchased Sydney Airport for $5.6b and, from 2003/04-2007/08, increased short-term charges for 4 hour parking spots by 80 per cent.

These increases can be interpreted as 'monopoly' not 'locational' rents that come about because motorists seek a preferred location to park (Forsyth, 2004). If monopoly rents are being earned then deadweight losses are being incurred by the travelling public who face reduced supply and extra costs of parking as well as by airlines that lose business. The airport parking issue is not so much a tax as a regulatory issue that bears on the case for privatising airport.

In the United States, Shoup (2005) estimates for the United States, where drivers pay expressly for parking in only 1 per cent of their trips, that the cost of all parking spaces exceeds the value of all cars and may indeed exceed the value of all roads. Moreover, an average of 30 per cent of traffic in 11 large US cities that Shoup examines is cruising for a parking spot. The average motorist takes 8 minutes to find a spot. Motorists themselves attach high disutility to such searches – in Sydney they will pay up to 3.5 times their wage rate to avoid this searching (Henscher & King, 2001).

Given the suggested scale of such costs it is indeed surprising that Australian public transport authorities have paid so little attention to providing efficient levels of on-road and off-road parking in major Australian cities.

Parking creates congestion through its effects in creating search costs on motorists who seek a parking spot, particularly a cheap on-street parking spot. Where kerbside parking is permitted charges should be set so that parking markets readily clear. Cruising for parking is socially wasteful so that charges need to be set high enough so that anyone, anywhere can readily find a parking spot. If this proposal is implemented then there will be no search-related congestion costs. Traffic engineers normally recommend that about 15 per cent of parking places should be kept vacant to insure easy ingress and egress out of spots so setting charges to achieve this targeted vacancy rate will avoid socially wasteful 'cruising' (Shoup, 2005).

A US firm *Streetline Networks* has added a twist to this that is being trialled in 6,000 of San Francisco's 24,000 metered on street parking spots and in 11,500 of its off-street car parks. This uses a wireless sensor network that announces either by displays on street signs or on maps on screens of mobile phones which parking spots are vacant at any time. Drivers can also pay for parking using their phone and can top up the parking meter remotely using their phones without returning to their car. This minimises parking search costs. The San Francisco trial, costing $23m, is an attempt to find an alternative to congestion pricing of roads although a modification whereby congestion is also priced would be of interest. Either way the scheme uses pricing signals along with data on available parking spots to eliminate socially-wasteful searches for parking spots.

Another Firm, *VehicleSense*, is testing its wireless-sensor networks in parking areas along Interstate 95 in south-eastern Massachusetts. The idea is to give fatigued truckers better information on where they can pull off the road to get some sleep.

These innovative technologies could be potentially used in Australian cities such as Melbourne and Sydney. Either as an accompaniment to congestion pricing or a substitute for it, such schemes would dramatically reduce parking search costs and consequent traffic congestion. Already public displays of available parking spots are provided electronically in certain Australian shopping centres such as Westfield in Melbourne. These applications do not involve telematics but such technologies could be incorporated into the telematic devices discussed in Section 6.

To sum up parking charges should ideally not be used to target commuting congestion. They should be set to achieve equilibrium in parking markets so that excess demands for parking are eliminated as well as socially wasteful search costs. But parking charges can proxy usefully for more general measures of congestion at a destination provided that most traffic is terminating traffic at that destination.

4.3 Greenhouse gas emission costs. Vehicles using carbon-based fuels add significantly to greenhouse gas emissions. For every litre of fuel consumed about 2.3 kilograms of CO_2 is generated which accounts for 76 million tons annually or 13.5 per cent of Australia's total emissions (DEWHA, 2009). The Commonwealth has acted on the suggestion by the Garnaut Review (2008, p. 328-329) to include the transport sector in an emissions trading scheme. The resulting charges will be imposed on upstream suppliers of fuels who would receive credits if fuels were used in a non-polluting way – for example to produce plastics.

BTRE (2006) estimate the direct fuel-burning related output of CO_2-equivalent (CO_2E) in 2004 and forecast such levels through to 2020. With a business-as-usual base case assumption ('base case plus measures consistent with hitting then GGE targets') total emissions across all transport sectors grow from 82.8 million tonnes of CO_2E in 2004 to 106.3 million tonnes in 2020. The split-up of these emissions by transport mode is 55 per cent private cars, 31 per cent road freight vehicles, 7 per cent aviation with the remaining 7 per cent being in coastal shipping, rail and other categories. Most future growth in emissions will be in road freight and aviation but passenger vehicles will remain the major source of forecast emissions over this period.

What is the implied emissions tax on various fuels if a tonne of CO_2E (CO_2 equivalent) is taxed at say \$20 which is the Garnaut Review's transitional carbon price is \$20 per tonne? DCC (2008, p. 15-16) claim that each litre of gasoline, emits (1/1000)*34.2*(66.7 /1000) tonnes of CO_2E carbon dioxide or

2.28 kilograms of CO_2E equivalent. Thus it takes 438.6 litres of gasoline to produce a ton of CO_2E, so, ignoring demand shifts, a $20 per tonne tax would imply a tax per litre of about 4.6 cents. Accounting for CH_4 and N_20 emissions raises this implied tax though negligibly. If all CO_2E emissions in the transport sector had been priced at $20 per tonne in 2004 then, again ignoring demand shifts, total revenues yielded are $1.7b. Effects on demand would be negligible given the small impacts such charges have on prices. A tax of $100 per tonne CO_2E corresponds to something less than 23 cents per litre which is around 60 per cent of the current fuel excise. It is less than 23 cents because it is now implausible to neglect demand shifts entirely. But given the relatively price inelastic demands discussed in Section 3 the implied tax would not be much less than 23 cents and the revenues yielded would be something less, not greatly less, than $8.5b. At this type of scale carbon charges would impact significantly on vehicle-based carbon emissions in Australia particularly if such charges were levied along with an undiscounted fuel excise charge.

4.4 Other vehicle-caused pollutions and noise/vibration externalities. Gasoline-using vehicles emit carbon monoxide (CO), nitrogen oxides (NOx) and hydrocarbons (HC) (sometimes called volatile compounds). All of these compounds have significant adverse health consequences for humans. The extent of these pollutions is linked to distance travelled, fuel consumed and average emission performance.

Epidemiological studies in the 1990s suggest greater sensitivity of human health to such pollutants than was previously believed. Litman (2003) argues that such pollutants cause as many deaths as motor vehicle accidents although, because these deaths are concentrated among older people, years of life lost are lower. Litman remarks 'Automobile emissions continue to be a major pollution source, and reductions in vehicle traffic can provide measurable respiratory health benefits'.

In many countries, including Australia, vehicle kilometres travelled (VKT) have been strongly increasing through time. Cosgrove (2003) estimates that these will grow 46 per cent from 2000-2020. Accounting for economic growth, continuing urbanisation, growing congestion and an increasing fraction of the vehicle fleet being heavier commercial vehicles, Cosgrove estimates that, even with continuing improvements in fuel use efficiency, total fuel use will grow at 2.2 per cent per annum from 2000-2020. However improvements in average emission performance are projected to deliver overall *reductions* in pollution emissions. It is expected that metropolitan emissions of CO will decline 38 per cent through to 2020, NO_x emissions by 23 per cent and HCs by 21 per cent. Thus the situation with respect to these pollutants is improving due to technology improvements. This, incidentally, implies a reduced need for offering discounts on alternative fuels as discussed in Section 3.

BITRE estimates of congestion costs in Australia are calculated inclusive of extra air pollution costs generated by the congestion. For 2005 the estimated total congestion DWL was $9.4b for the Australian capital cities which included congestion-generated pollution costs of $1.1 billion (BTCE, 2007). This extra pollution cost due to congestion comprises 12 per cent of total congestion costs. The total air pollution cost due to vehicular travel in Australia is estimated by BTCE (2005) as $2.7b for 2005 comprising a premature mortality cost of $1.8b, taking the value of an individual life to be $1.3m, and an estimated morbidity cost of $0.8b where a healthy year of life lost due to disability is valued at $50,000.

The total figure for estimated heath costs due to car travel is 36 per cent of total congestion costs in 2000 as reported in BTRE (2007, p.109). If this same percentage held in 2005 then, taking the per kilometre congestion cost from 1.4.1 as 6.8 cents, the cost of air pollution externalities in Australia in 2005 would be 2.4 cents per kilometre in that year. Small and Kazimi (1995) came up with a year 2000 figure for Los Angeles of 1.6 cents US per km with a range of 0.6-5.3 cents US. Samson et al (2001) provide figures for UK air pollution costs for 1998 of between 1 to 5 cents Australian.

The costs of travel related to noise and vibration have long been discussed in the engineering road planning literature (Meyer and Miller, 2001, 120-122). Exposure to high levels of noise can have detrimental effects on the physical and mental health of humans. Specific damage to hearing is rare since high levels of noise are needed for sustained periods. As a rule-of-thumb noise levels have to exceed 85 decibels (dBA) on a fairly continual basis to cause hearing problems. The impact of noise in terms of hearing is proportional to the square of distance from the source so that the major concern in regulating noise levels is for land uses close to highways. However even here the damages are difficult to assess since homes and businesses can be insulated to protect against noise or retrofitted with such insulation.

The economic cost of noise has been estimated by looking at the value of property in situations of different noise exposure. Nelson (1978) estimated that residential property values decreased about 0.4 per cent per dBA above a daily average of 55 dBA. Halig and Cohen (1996) used this approximation and estimated the cost of noise to be $34-61US per dBA per household in 1993 dollars. Delucchi and Hsu (1998) estimate costs of 0-0.4 US cents per mile for passenger vehicles which is small relative to total external costs.

While these costs are low compared to other external costs they are much higher in specific areas. Given their locational specificity they are probably best addressed by regulation rather than by taxes and charges. Regulation is necessary since although quiet engines are not difficult to design, car makers have low incentives to do so given that individual vehicles generate only a small fraction of noise costs.

4.5 Miscellaneous external costs. Much higher health costs associated with sedentary lifestyles are claimed to lead to a broader range of health costs up to $58 billion annually (PTUA (2008), Access Economics (2008) and Giles-Corti (2008)). The $58b figure seems to come from the Access Economics (2008) study. It comprises the total disease cost netting out health costs incurred by individuals. 90 per cent of these costs vanish if loss of well-being - a cost to individuals - is included as a private cost. For this reason such costs are not analysed further.

Others have drawn attention to the externalities that arise from urban sprawl. Sprawl it is claimed arises because road travel is underpriced. This is by no means a clear-cut unpriced social cost since the inefficiency here lies in the failure to price road use. As Bruegmann (2005) point out the preference for living in large homes on a city's periphery can reflect informed market choices. There can be distortion-based preferences for such housing if tax concessions are provided towards capital gains on housing or if the external and infrastructure costs of new development are underpriced but these are features separate from transport issues.

Finally thinking has developed which analyses interactions between agglomeration economies and urban traffic congestion. As Arnott et al (2005) point out, there are likely to be agglomeration benefits in business and in personal life that accrue from living in concentrated cities. Such benefits provide a rationale for clustering. These benefits are difficult to quantify but, to the extent they are present, suggest an offset to the social costs induced by congestion and hence to setting congestion charges below marginal congestion costs to encourage interactions. The suggestion however ignores the fact that while agglomeration externalities result in land use being insufficiently concentrated so too do externalities. In the absence of data on agglomeration economies and on a clear theory of how such economies interact with congestion the issues are not discussed further here. Potentially they can change the way congestion modelling is interpreted and examined.

5. Traffic Accident and Insurance Issues

Summary Section 5
Traffic accidents generate very large private costs of road travel through deaths, injuries and property damages. To the extent that adding extra vehicles to traffic flows adds to accident probabilities there are also external costs of traffic accidents analogous to congestion costs.
There is little economic research on the impact of traffic accidents in Australia and almost none on traffic accident externalities. Thus most knowledge on the likely role of such costs

needs to be inferred from studies for other countries.
The sensible way of addressing traffic accident externalities is via distance-related insurance policies. This is gradually developing among private insurers. Contracts for compulsory third party insurance and private cover could be designed using these principles and telematic technology used to facilitate this further.

Traffic accident costs are a significant component of total road transport costs. Such costs bear heavily on Australian road supply design issues but have largely been ignored in assessing road use costs.

Traffic accidents can impose significant potential private costs on road users. Road users can die, suffer injuries or incur property damage costs as a consequence of traffic accidents. As a response to such costs a motorist can refrain from driving, exercise greater care while driving or insure to cover themselves against possible damages that occur as a consequence of driving. Such costs are then internalised by the motorist and, provided they can make informed travel choices, also internalised by passengers travelling in the motorist's vehicle.

Some traffic accident costs however are not internalised. When an extra car joins a traffic stream the accident probabilities of all other motorists in that traffic stream change because of the extra possibility of colliding with the additional motorist. While, for the most part, it is reasonable to expect the possibility of collisions would increase – the evidence supports this view – traffic might slow as densities increase and driver care may increase with increased densities thereby reducing the rate of *serious* traffic accidents and deaths. The empirical issue on this latter issue is inconclusive and since the respective effects have until recently not been measured the opposing effects are sometimes assumed to net out to zero so that the issue of accident externalities can be ignored. This is bad practise since a range of studies now confirm that accident externality costs lie somewhere in the region of between 52 and 74 per cent of the private costs of accidents (Small and Verhoef, 2007, p. 102).

Apart from density-related causes there are other potential traffic accident externalities as well. For example a pedestrian struck by a vehicle is an instance of external cost. In addition it is known that those driving under the influence of alcohol in the US have 7 times the external accident risk of other drivers providing a justification for setting high penalties on drink-driving (Levitt and Porter, 2001). Finally, those motorists who drive 'light trucks' (vans, pickup trucks or four-wheel drive utilities) considerably raise the level of external costs in motor accidents while improving the safety of occupants of the light truck (White, 2004).

These issues nuance the way the issue of accident externalities needs to be addressed using tax and fines but their discussion is well beyond the scope of this study which concentrates on traffic accident externalities based on traffic density issues alone.

To the extent that there are externalities these are analogous to standard traffic congestion externalities. These externalities need to be internalised to realise road use efficiency. If negative traffic accident externalities are unpriced individuals will undertake a socially excessive number of journeys and will generate a socially excessive number of traffic accidents.

There are no careful estimates of traffic accident externalities for Australia. The estimates that have been made are typically arbitrarily assumed to simply be some fixed proportion of total accident costs - for example, 10-50 per cent (Martin, 2005). These total costs themselves are subject to controversy because of intrinsic difficulties in valuing a human life. The lack of Australian evidence on the extent of traffic accident externalities is a gap in Australian transport economics research and inhibits informed policy discussion. Inferences need to be drawn on the basis of international experience that may not reflect local conditions. Moreover, the international evidence on such costs is mixed although numerous studies suggest that accident externalities in congested settings are large.

Unlike congestion externalities when time and place of travel mainly condition the scale of social costs, accident externality costs are partly driver-specific. For example, young men are disproportionately represented in traffic accident collisions.

One approach to pricing traffic accident externalities - and a much-discussed potential policy reform – is to set a fixed charge for car registration that reflects the person-specific expected costs of an accident and then add to this a variable charge that depends on how far the motorist travels. This proposal is discussed below.

5.1 Accident empirics. Traffic accident costs are a significant cost of vehicle use. In Australia, in 2007, 1,616 persons were killed in 1,466 road crashes. The absolute number of deaths is less than half the figure that prevailed in 1981 so there has been a long-term absolute decline. This decline, however, was concentrated in the late 1970s and early 1980s. Total deaths have not changed much since 2003 although deaths as a proportion of population have decreased. The road crash death rate during 2007 was 7.7 deaths per 100,000 population compared to 22.3 deaths per 100,000 in 1980 (DITRELG, 2008). In 2005 comparable figures on deaths per 100,000 were 5.5 for the UK and 14.7 in the US (BITRE, 2008c) so that Australia's traffic accident mortality experience is somewhere between that of these two countries. Apart from a secular decline of about 65 per cent in Australian deaths *per capita* from 1980 to 2007 there has also been an even greater proportionate decline in deaths per hundred million vehicle kilometre travelled. This has fallen from 3.55 in 1976 to 0.76 in 2006 (DITRELG, 2008). Thus, even though road users are driving further, they are experiencing much fewer fatal accidents per kilometre of distance travelled.

Fatal traffic accidents in Australia peaked in the 1970s and have declined steadily since that time as have serious traffic accidents generally. The fall in accident rates is due to seatbelt use, to reduced drink-driving and improved vehicle and road technology. Pedestrian deaths have fallen partly because fewer people walk. In addition, as mentioned, accident costs depend on the frequency and severity of accidents with higher traffic densities increasing the number of accidents but plausibly reducing the severity of accidents due to decreased average speeds and increased driver caution.

Putting dollar values on the costs of traffic accidents is important if sensible road safety investments are to be made. The value of human lives lost can be quantified using 'human capital' and 'willingness-to-pay' methodologies. Willingness-to-pay methodologies yield higher estimated values of life.

There were also many injuries, property damages, net losses of production as well as pain and grief (BITRE, 2008c) which can be costed if, in some cases, only very approximately. There is Australian information on such issues although it is dated. In 2000 the then Bureau of Transport Economics published an Australian study (BTE, 2000) that provided comprehensive information for 1996. The estimated value of total traffic accident costs for that year was around \$15b. This aggregate split into human costs (about 55 per cent), vehicle costs (27 per cent) and traffic delay costs (10 per cent). A human capital approach was used to value human lives lost.

Connelly and Supangan (2006) provide more up-to-date estimates of the total costs of road traffic crashes in Australia which, for 2003, they estimated as \$17b. This is \$47 million per day or 2.3 per cent of that year's GDP. They find substantial intra-national variations in accident costs by state with costs varying from between 0.62-3.63 per cent of Gross State/Territory Product. Death rates are particularly high in the Northern Territory where, until 2006, speed limits were not imposed on highways outside metropolitan areas. The average Australian accident cost as a proportion of GDP is lower than US estimates which put costs there at 4.3 per cent of GDP (Parry et al., 2007). A new set of cost estimates for Australia will be provided by the Bureau of Transport and Regional Economics in 2009. These will provide the first comprehensive official estimates since 1996.

Traffic accident frequency is known to be related to the age and gender of drivers (as mentioned, young males have high accident rates), to alcohol consumption and other drug consumption per capita, use of mobile phones and other distracting devices and to other influences such as weather conditions. A somewhat surprising empirical regularity is the simple, strong positive dependence of accident costs on traffic densities. Indeed the work of numerous authors (e.g. Litman, 2008) suggests that accident rates increase strongly with density.

In principle one might expect congestion, the effects of density in encouraging greater care in driving and other such phenomena to potentially reduce accidents. In fact however such effects do not seem to be strong enough to offset the link between increased density and the accident rate. Note, however, that the accident rate only partially determines aggregate accident costs because average accident severity also needs to be accounted for. It remains to be determined how accident severity is related to traffic density. As mentioned the intuition is that at higher densities since traffic speeds are reduced that accident severity might fall because of the density and because drivers are induced to take more driving care. This is an important empirical issue for which there is almost no Australian data.

5.2 Accident externalities. Injury risks in single vehicle crashes to the driver and car occupants are internalised if those travelling make rational transport choices. The bulk of crashes however are multi-vehicle. In the US multi-vehicle crashes as a fraction of the total exceed 70 per cent (Edlin and Karaca-Mandic, 2006, p. 933) (hereafter EM). Thus there is an issue of whether such costs are internalised. As mentioned above, if motorists drive more carefully or are inhibited in driving at speed by more congested conditions then the extra risks of driving under conditions of greater traffic density are offset to some extent by behavioural changes. This reduces the severity if not the incidence of accidents.

In important work EM argue that, when two cars crash, although only one party may be negligent in causing the accident, the accident would not have occurred had either driver not travelled. In this sense *both* drivers cause the accident. Motorists however pay for and internalise only the average cost of the accident, not its marginal cost, so there is an auto accident externality**.** Motorists pay too little for driving and hence, in the absence of a requirement to pay the accident externality cost, drive too far**.**

EM emphasise what they see as the vast scale of automobile externality costs in the US economy. They estimate accident externalities using panel data on state average insurance premiums and loss costs which are intended to capture the possible effects of reduced accident severity in denser traffic. These external costs are substantial in traffic-dense states though negligible in states where densities are low. In traffic-dense California an increase in traffic density due to a single extra driver raises total state-wide insurance costs by $1725-$3239 depending on the car model. This adds to the

$744 in premiums the average driver paid for insurance in 1996. A Pigovian tax to internalize this externality would raise $44 billion annually in California which is more than all state taxes combined. A national corrective tax would raise $113 billion (Edlin & Karaca-Mandic, 2007 correct a numerical error in EM).

Moreover, EM externality cost estimates plausibly underestimate since damages are ignored in accidents where parties are uninsured and costs of delays due to accidents are ignored. If uninsured costs behave as do insured costs then EM estimate that accident externalities could be 3.5 times those estimated or around $10,000 per motorist annually in California.

While building more roads to reduce US congestion would reduce the externality this is cost-ineffective because of the scale of the required expenditures involved to reduce densities to those prevailing in low traffic density US states.

5.3 Insurance and other reforms. While various Pigovian tax bases (per mile, per driver, per litre of fuel) might deal with the accident externality issues identified by EM their preferred solution is to tax car insurance premiums and to supplement this with moves that will force motorists to be fully insured. This is a heterogeneous tax base reflecting the accident and skill experience of drivers. Implementing this tax proposal in California would require a 200-400 per cent levy on insurance premiums a solution EM recognizes will probably not work politically. Without restrictions requiring motorists to fully insure such a premium also has the undesirable feature of encouraging drivers not to insure.

EM suggest a second-best compromise which leaves overall driving costs the same but increases the marginal cost of driving with insurance premiums rising with distance travelled as per kilometre premiums. People would then have an incentive to cut insurance costs by driving less which is the outcome sought. Per kilometre premiums are fair since they impose lower charges on those (like women and senior citizens) who drive less and who cause fewer accidents. The charges can be made driver-specific with high per-km premiums on high accident risk drivers who live in high traffic density areas. Edlin (2003) has estimated US gains from 'per km' premiums of $12.7b per year.

One difficulty with this proposal is that the chance of having an accident depends on when travel occurs as well as how far travel occurs. If driving at certain times involves encountering few cars the probability of an accident involving another vehicle is low. The ideal solution would be to seek congestion pricing of travel and to add to congestion tolls a charge that reflects the contemporaneous accident externality. Such a charge would be much higher in peak periods than a simple congestion toll. This is currently seen as infeasible but might become more feasible with new developments in telematic technology as discussed in Section 6.

Parry et al. (2007) criticise EM on the grounds that the externality evidence is based on insurance data which mainly covers property damage. While this captures some of the effects of accident severity property damage costs are only 14 per cent of what Parry et al. (2007) estimate to be the total social costs of accidents. EM in fact only provide inconclusive evidence on whether fatal traffic accidents – which account for 33 per cent of the Parry et al. (2007) estimated social costs – increase with traffic density.

Parry et al. (2007) estimate marginal external costs inclusive of pedestrian and cyclist injuries and come up with a figure of 1.2-4.8 cents US per kilometre for the year 2000. This turns out to be between 13-44 per cent of average accident costs. Samson et al. (2001) provide estimates for 1998 UK marginal external costs of from 0.82-1.40 pence per kilometre, or 1.2-2.8 cents per kilometre US. These figures may provide some clues as the likely scale of Australian costs.

Alternatively the 200-400 per cent premium figure provided by EM provides an alternative method of estimating the implied accident externality costs in Australia ignoring the issue of uninsured motorists and such things as time delay costs caused by accidents. Accepting the Connelly and Supangan (2006) estimate of the costs of accidents in Australia as 2.3 per cent of GDP this suggests a tax on insurance costs of 4.6-6.9 per cent of GDP, an enormous figure. This is obviously a rough ballpark figure only and ignores reductions in driving that occur as a consequence of the tax. Indeed there may also be generally less high-density driving in Australia and fewer multi-vehicle accidents. There are a variety of important empirical issues here which have not been - but should be - analysed for Australia.

5.4 Distance-based vehicle Insurance. This proposal for distance-related insurance charges can be seen as part of a package of reforms that private insurance companies might seek, or might be induced to seek (Litman (2008), Parry et al. (2007)). This is a 'second-best' policy that forgoes the ideal of seeking to charge the marginal accident cost by taxing distance travelled at relatively low transaction cost.

A charge levied on distance alone will be more effective than an increased excise on fuels since the primary behavioural response to it involves less driving. Litman (2007) estimates the desired charge as around 6 cents US per mile for the average US motorist or about 7.5 cents Australian per kilometre. If this figure has any relevance for Australia it is strikingly large and of the same order of magnitude as unit congestion costs in major Australian cities as discussed in Section 4. The actual figure charged to a motorist would depend upon the motorist (and possibly the vehicle) relative risk factor which would need to be determined by an insurance company.

The basic idea is that reduced travel as a consequence of distance-related insurance charging implies reduced accident risks. Distance-based insurance options give motorists the incentive to reduce their travel and hence to reduce accident costs and insurance premiums. This also provides side benefits of reducing fuel usage and congestion.

Moreover, while people who drive long-distances are likely to be relatively capable drivers who drive relatively safer vehicles still evidence supports the claim that a 10 per cent reduction in mileage will reduce crashes by 17 per cent. Thus those who drive only short distance pay too much with fixed insurance charges.

There are various pricing options such as using self-declarations backed by penalties for false declarations, using estimated mileage as a rating factor, paying a surcharge at the petrol pump to fund basic vehicle insurance, prepaying for a certain mileage cover, per minute premiums and using GPS-based pricing. There are implementation costs of such schemes although all seem to satisfy basic cost-benefit tests even if estimated transaction costs of inspection per vehicle are $10-$150 annually (Litman, 2008). Private insurance firms have adopted specific schemes already and can be expected to increasingly offer such products as technologies for monitoring vehicle mileage improve.

EM argue that this solution might need to be regulated since individual insurers may not adopt per kilometre policies on their own since gains are external - they accrue to other insurers - while the monitoring costs are internal. However, as Litman (2008) shows, some firms are already developing such policies and there is limited endorsement of them in Australia by firms such as Apia (2009) and Hollard (2009) who now advertise such policies in the mass media and on the web. Apia has adopted what is effectively a distance-related premium by charging those over 50 less on the grounds that they ‘drive less’. Hollard offer comprehensive insurance policies on a direct pay-as-you-go basis.

The possibility of linking third-party insurance with distances travelled by imposing a ‘second-best’ compulsory excise levy on petrol has the advantage of simplicity and helps bring the uninsured into the payment system. Disadvantages of this proposal are that it fails to reflect driver heterogeneity. In addition fuel-efficient vehicles pay lower charges even if they impose the same accident costs. Fuel surcharges are most effective in targeting reduced petrol consumption while pay-as-you-drive insurance better targets distance travelled. Parry (2005) shows that distance-based charges outperform excises on fuels once congestion, local accident and accident reduction benefits are accounted for.

5.5 Summary on insurance reforms. There are arguments for utilising per kilometre insurance charges rather than lump-sum annual fees. This proposal is consistent with the principal that prices should reflect costs. Such charges more accurately reflect the risks of traffic accidents than do risk-adjusted fixed charges since they directly limit distances travelled. The spinoff benefits of such measures include reduced congestion and pollution. Specifics of this policy proposal are set out in Litman (2008).

Per kilometre charges could be imposed in states such as Victoria by modifying the Transport Accident Charge (TAC) that is levied as a compulsory component of the annual vehicle registration charge and which covers third party personal damages. The overall registration charge could be based on a per kilometre charge that is both driver and vehicle specific. The motorist could select scope of cover and insurance company to cover additional non-third party damages. Political objections to these types of schemes could be eliminated by offering motorists the chance to stick with a higher fixed charge or utilise per kilometre charging.

For example the standard registration fee for a private motor vehicle in Victoria is around $593-80 which includes a TAC of $378. If the per distance accident charge to cover third party personal damages was, for illustration, 6 cents per kilometre for the average motorist driving a typical motor vehicle this fee would cover 10,080 km annually. Higher risk individuals would receive this insurance coverage by paying a higher fee as would motorists seeking to drive further. If motorists reacted to the higher marginal cost of travel by cutting back their distances travelled by 10 per cent then they would drive 1008 kilometres less and traffic accident costs, using the estimates of Litman (2008) would fall by 14-18 per cent. There would also be reduced traffic congestion and local pollution.

Since this insurance covers only third party person accident costs the appropriate per kilometre charge might be a good deal less than 6 cents. Other forms of insurance such as comprehensive policies covering personal accident cover and property damage cover could be taken out by a public insurer or a private firm. As mentioned while the Hollard Insurance Company offers 'pay-as-you-drive' (PAYD) insurance policies in Australia many large insurance firms, such as GIO and RACV, do not.

While distances travelled can be assessed by self-declarations with appropriate penalties for false declarations the telematic technologies discussed in Section 6 can also be adapted to measure distances travelled.

6. Road Capital and Maintenance Expenditures

Summary Section 6
Public spending on roads is a major item in Commonwealth Government budgets. Expenditure is split between various levels of Australian government. While revenues collected by road use taxes and charges more than balance road costs, the charges levied reflect the average not the specific cost of road use.
Road supply decisions are currently not related to demands but are often engineering-based and politically driven. One proposed reform is to relate road supply decisions to forecast demands based on user charges – particularly user charges related to the road damages caused by heavy vehicles.
User charges that reflected the actual costs of using roads would also help provide better usage decisions that reflected the value of different freight tasks.
Correctly levied user charges, under certain conditions, provide revenues that enable the recovery of capital and maintenance costs on roads. They will signal when roads are correctly priced and when roads should be expanded or upgraded.
Telematic technologies are currently used by trucking fleet operators to manage vehicle fleets. They can also be used for a range of regulatory purposes including for mass-location-distance charging. They are now being used for these purposes in the eastern states of Australia. Such devices can be used specifically to assess the loaded mass of a vehicle.
There is a deficiency of Australian research that links road durability to road thickness and traffic volumes. International studies suggest that such research has a potentially large payoff. There is also a deficiency of research on how road user charges might be provided to road supply agencies, on the conditions under which cost-recovery might be expected and how such information might be married with needs to meet community service obligations and regulatory requirements related to restricting monopoly power in a comprehensive user-charge based system.
Commercialisation of the Australian road system will not be as simple as commercialising former public utilities such as power generation. Much more attention needs to be directed at practical issues of implementing such arrangements.

The Australian road network provides different road services to various road users - local passenger transport services, long distance passenger transport services, local freight services and long distance freight services. The network therefore delivers multiple outputs. A key input in the production of road services is the presence of an extensive road network in good working order. The appropriate size and structure of this network will vary with both population size and its geographic distribution. Nonetheless, in the absence of significant changes to these factors, there will be little variation in the size of the road network. As such, at least in the short to medium term, the road network is a fixed input in the production of road services. This means that many of the costs associated with the construction of roads will be fixed costs some of which may be sunk.

There are variable costs. In the absence of congestion, a major variable cost associated with the production of road services are those incurred to repair the portion of road wear caused by the use of the road by vehicles. Road wear associated with vehicle use is predominantly caused by heavy vehicles.

Roads therefore involve significant capital and ongoing maintenance and operational costs. A significant fraction of road damage can be attributed to road freight transport ('trucks') although this damage can be reduced by investing in more durable roads. Road user charges can be designed as two-part tariffs or tolls to capture such capital and maintenance costs. The fixed component of the charge should capture the costs of providing access to roads, a cost that will be shared by non-freight vehicles plus a specific charge that reflects any additional investment in durability to reduce road damages. The variable part of the toll should reflect ongoing maintenance costs that can be attributed to heavy vehicles – defined here to be vehicles with weight exceeding 4.5 tonnes.

Cost recovery is a desirable feature of charging for road capital and maintenance costs but, in itself, is insufficient to ensure efficient use of roads by trucks since such charging will be averaged over roads with different durabilities and operational costs. What is most important is that freight vehicles bear the specific costs of using particular types of roads so that they are induced to make cost-efficient choices in the sense of making efficient value-of-travel versus road damage tradeoffs.

While economic theory typically opposes hypothecation arguments that favour spending taxes and charges related to road transport on roads alone, there are road supply-side efficiency arguments for doing just this. Road supplies and road capacity and durability investments need to be related to the economic benefits that such roads deliver can be anticipated to deliver. There should be incentives to deliver roads of appropriate capacity and durability where they are highly-valued so that valuable road supplies are directed towards road demands. A useful signal for this is the aggregated user charges such roads can be expected to generate compared to the costs of providing such a service.

6.1 Background on roads. Roads are among Australia's most important capital assets. Their capital value is high – if unmeasured - given their role in enabling light vehicle traffic and freight transportation over Australia's vast surface area. Australia has low population and low road use densities but relies heavily on trucking for the transport of raw material and agricultural outputs to markets and ports. The costs of building roads and maintaining roads are a substantial part of public sector budgets. Total Australian public expenditure on roads in 2005/06 was $9.3b of which Commonwealth spending was $4.2b, State spending was $2.6b and local government spending was $2b. A residual of $0.5b came from non-public contributions.

Revenues associated with road use are even larger than these costs. Thus expenditures on roads were more than met by fuel excises of $9.6b, fringe benefits tax of $1.8b, GST of $4b, Vehicle registration charges of $3.5b, Stamp Duty of $1.9b, licence fees of $0.3b and tolls of $0.8b. Total taxes and charges for 2005/06 were $16.3b which exceeded costs by 75 per cent (BITRE, 2008).

Split-ups by expenditure type - capital, maintenance and other operational costs – an economically interesting split – suggest that more than half of total road expenditures in Australia are devoted to maintenance (Naidu, 2009).

Ownership of Australian roads is spread across state, territory and local governments but their provision is partly financed by the Commonwealth.

Road freight transport is of particular importance in the Australian economy now and is expected to continue to grow strongly. Inter-regional freight movements between major intercity origin-destination pairs is expected to grow at 3.3 per cent annually over the next 25 years (BITRE, 2009) which is faster than forecast general vehicle traffic growth.

As is well known road use involves incurring congestion externalities because motorists do not account for the effects of their travels on the travel times of other motorists. Road use also involves road maintenance externalities if motorists do not pay a user charge that reflects the damages their vehicle causes to roads.

6.2 Heavy vehicles and road damage. Roads are capital investments which deteriorate over time and which require maintenance. The weather and climate contribute to road damage but deterioration due to heavy vehicle use is often emphasised. In fact, Paterson (1986) estimates that as much as 60 per cent of UK road damage is due to the weather.

With respect to heavy vehicles, carried out in the 1950s by the American Association of State Highway and Transportation Officials (the AASHO Road Test, Bridle and Porter, 2002) it was claimed that the effective damage done to a road, as assessed by road 'roughness', was proportional to the 4^{th} power of a vehicle's *axle weight*. The gross axle weight rating is the maximum distributed weight that may be supported by an axle – the central shaft that connects rotating wheels of a road vehicle. Gross axle weights can be distinguished by the location of an axle on a vehicle – the vehicle front or rear for example.

The AASHO results are subject to important subsequent qualifications, particularly in an Australian setting where roads have lower durabilities because they are low construction cost, sealed and unbound flexible pavements that use local materials and which carry relatively low traffic volumes:

See Mitchell (2008). The AASHO results were site-specific with cold winters and with spring thaws where pavements were weakened by the high moisture levels. These results however remain a highly cited work on the incidence of road damages. The study has led to an extensive literature that links road damages to road use and which, at core, emphasizes the role of heavy vehicles. On the basis of the 4^{th} power law a tractor-trailer weighing 36.3t with 3.6t on the steer axle and 16.3t on both of the tandem axle groups can be expected to do 7,800 times more damage than a passenger vehicle with 0.9t on each axle. Thus, to a good approximation, almost all damage done to roads by vehicle use is caused by heavy vehicles.

Australia has the largest and heaviest road-legal vehicles in the world, with some configurations topping out at close to 200 tonnes and with many between 80-120 tonnes. Two-trailer road trains or 'doubles' are allowed in most of Australia outside of urban areas. Three-trailer road trains ('triples') and ABQuads operate in western NSW and Queensland, South Australia, Western Australia and the Northern Territory with the last three states also allowing AB-Quads (3.5 trailers). For the most part these vehicles are restricted to non-urban areas. Darwin is the only capital city in the world that will allow triples and quads to within 1 kilometre of its CBD. Victoria and Tasmania do not allow the operation of road trains on any of their roads, with the exception of one operator in Victoria which has permission to run triples between the Ford Plant in Geelong and a plant in Broadmeadows.

Road trains are used for transporting livestock, fuel, mineral ores and general freight. Because of the economies of scale they deliver they are a cost-effective mode of freight transport which plays a significant part in the economic development of remote areas. Strict regulations on licensing, registration, weights and experience apply to all operators of road trains throughout Australia.

On the basis of the 4^{th} power law type of reasoning the issues of determining the appropriate durability of Australian roads - specifically the thickness and form of pavements - and the use of roads by heavy vehicles is an important one. Road pavements are designed with a certain durability and forecast maintenance schedule in mind. In some countries the standard design life is 40 years for new bitumen and concrete pavement but the lifetime of roads is conditional on initial investments in durability. For most roads maintenance is a cost concern over the entire forecast life of a road.

Roads can be and are designed for lifetimes that vary between 10-100 years. A road can be made very durable in the sense of investing intensely in initial thickness but this is expensive and for some low utilisation roads high expense is unwarranted. Similarly there can be underinvestment in durability for roads used intensively by heavy vehicles with resulting excessively large and frequent costs of maintenance. There are design tradeoffs between durability costs and maintenance costs.

Most roads will involve some maintenance and the costs of such maintenance are a significant component of total road operating costs. Road managers need to monitor roads and use preventive maintenance to best manage their life-spans. Attention focuses on the surface ‘roughness’ of roads which can be measured using specialised equipment that suggests appropriate preventative maintenance scheduling.

6.3 Road pricing and investment. In competitive markets individual producers adjust their outputs so that short-run marginal production costs equal market price. Total revenues cover total costs and provide a rent to cover the cost of fixed factors such as machines and buildings. If rents exceed the costs of providing fixed input services then entrepreneurs have incentives to acquire more fixed inputs. If enough entrepreneurs do this then price will fall until rents just cover fixed input costs. The market is then in long-run equilibrium and no firm will have a unilateral incentive to expand.

A long-run optimal road network can be described in an analogous way. The appropriate congestion toll is the difference between the social marginal cost of a trip and the variable cost born by a marginal traveller. If charges to all travellers are kept by a road authority this congestion toll serves as a rent on society’s fixed investment in road capacity. The ‘economies of scale’ indicator (s) for roads is often taken to be the ratio of average to marginal road capacity cost. Then, as originally pointed out by Mohring and Harwitz (1962), with constant returns to scale in the congestion technology – so congestion costs during any period depend only on the ratio of traffic volumes to road capacity, with constant returns to scale (s=1) and infinitely durable roads that are not subject to any indivisibility issues, congestion toll revenues will exactly cover capital costs for a road network of long-run optimal size, one for which the cost of the last unit of capacity just equals the present value of the user benefits it will afford by reducing present and future congestion levels. This is the situation of *exact self-financing*. With economies of scale (s>1) a deficit arises and with diseconomies of scale (s<1) a surplus will emerge.

The self-financing result is remarkable. If it applies it provides a necessary – though not sufficient - condition for optimal capacities and for optimal pricing. Thus whether or not it is met provides a check on the efficiency of roads. It isn’t a sufficient condition for efficiency since there are many combinations of tolls and road capacity that will deliver cost-recovery but only one of these will be optimal. The result also suggests that taxes are not necessary to support a road system - it can self-fund if appropriately designed and priced. It also encourages public acceptance of road pricing since it is consistent with a ‘user pays’ principal and the cost recovery process is transparent and observable. Finally the result provides a measure of when a road should be expanded – just as in a competitive firm expansion should occur when a road makes a pure profit. Small and Verhoef (2007,

p. 166-170) discuss this result in detail and include a broader range of complicating issues – discreteness in capacity, bottleneck congestion dynamics, network issues and user heterogeneity.

This insight has been extended in various ways. First Keeler and Small (1977) showed that optimal congestion tolls would equal costs of land acquisition, periodic replacement of roads and non-traffic related repair costs if there were constant returns to scale in each of these component costs.

This does not however address the issue of maintenance costs that depend on usage. This raises complications because congestion and road damage are caused by different vehicle characteristics. Congestion is proportional to the area a vehicle occupies, measured in PCUs (passenger car units) whereas damages are related to the axle load measured in ESAs (equivalent standard axles). Maintenance costs depend on cumulative ESAs while congestion costs depend on road capacity and traffic flow.

In a seminal paper Newbery (1989) considered congestion and road damage costs in a road investment and pricing model where road designers can invest in pavement strength ('durability') to reduce the damages that heavy vehicles cause on roads. The analysis shows that all capital and a large fraction of maintenance costs should be allocated as congestion costs on a PCU basis.

With constant returns to scale in road construction for roads of given durability and with strictly constant returns to road use - in the specific sense that heavy vehicles distribute themselves uniformly over a road's width - Newbery shows that the optimal road user charge (congestion plus road damage charge) will recover all road costs (maintenance and interest on capital) irrespective of economies of scale in road construction.

Even with constant returns to scale in road construction heavy vehicles spend a higher fraction of their time in the slow lane compared to other lanes. In this case the optimal road user charges will recover more than the total road costs. In the extreme case where heavy vehicles cause all road damage, and only use the slow lane, the charges will recover all overheads (including interest on capital) plus exactly twice the total costs of road maintenance.

The interesting general point made in this theoretical literature is the link that can be drawn between revenues and the costs incurred in supplying an optimally-designed road.

These self-financing results break down if roads of minimum scale need to be provided to meet community service obligations or if roads are sub-optimally priced. In the latter case interest centres on the case where no toll is charged. Then there is no self-financing since revenues are zero. Wilson

(1983) shows that in this case the optimal road capacity without pricing will need to be higher than that with pricing. Thus having efficient pricing in place saves on capital resources.

6.4 Road durability. Other authors have examined the issue of investing in road durability carefully using an economic rather than engineering approach (Small and Winston, 1988). With higher capital cost investment in road durability, typically measured by thickness, roads last longer. There are, moreover, long-run economies of scale to investing in greater durability. For example they need costly resurfacing less frequently. On typical high volume interstate highways in the US Small and Winston show that net savings from reduced resurfacings lead to a possible saving of 40 per cent of the present value of resurfacing costs. Crucially road user charges that are related to damage caused will be lower the greater is investment in road durability.

Small and Winston reject the AASHO estimates of the relation between damages and axle load and the 'fourth power' law in favour of a 'third power' law. They also confirm a less sensitive relationship between pavement life and pavement thickness. They claim AASHO have overstated the lifetimes of thick pavements. Moreover, optimal pavement durability seems higher than that computed using AASHO damage relationships. Equivalently, many roads designed using default thicknesses undersupply durability partly because of specification difficulties in the AASHO approach and partly simply because of overreliance on engineering models.

With the correctly installed durability Small and Winston show that user costs fall substantially. Indeed there is even dramatic confirmation of the trucking industry claim that, at least on high-volume roads, trucks would not be particularly damaging if pavements were designed optimally. Charges on six lane urban interstate roads in the US were less than one cent per ESA mile. It is important to emphasise here that with optimal durability trucks still pay most for most road damage costs since the enhanced durability costs are attributable to them though these payments are for capital rather than maintenance costs and paid more from fixed rather than variable user charges.

Indeed, according to Small and Winston, installing the optimal durability means that efficient damage-related road charges will not cover the long-run costs of pavement construction and maintenance because of economies of scale. Thus there is a strengthened role for fixed fees such as license and registration charges in addition to lower variable charges. If marginal cost pricing was accompanied by investment in optimal durability then high-volume roads would have user charges much lower than current fuel taxes.

It is important to note that this finding is contingent on roads having optimally installed durability. If durability is undersupplied, as it may be on substantial parts of the Australian road network, then variable user charges will still have a more important role to play in cost recovery. Work on these issues has been initiated in Australia, see Martin (1996), (2008) and offers significant payoffs. Weather and traffic conditions in Australia are distinctive so that roads are constructed distinctively so it cannot be assumed that findings for other countries will necessarily be immediately applicable here.

6.5 Road pricing and road supply reforms. In Australia policies governing charging for vehicle usage of roads have been part of a continuing reform process since 1991 when the *National Road Transport Commission* (NTC) was set up by the Commonwealth to implement a reform program and to determine pricing regimes for heavy vehicles. Following a request from the Council of Australian Governments (COAG) the Productivity Commission (2006) (PC) presented a report which dealt with road and rail freight pricing in Australia. This has led to a recent round of proposed pricing reforms as discussed in Section 8.2. Although set up partly to address competitive neutrality concerns arising from the fact that rail freight services alone pay on a commercial basis for their infrastructure, the PC determined that such neutrality concerns were insignificant. Indeed road and rail were seen more as complements than substitutes which meant that, to a substantial degree, their efficient provision could be analysed separately. There were however inefficiencies in road pricing that needed to be resolved and inefficiencies in the way capital and maintenance investments in roads were managed.

The PC argued that heavy vehicles were paying the road damage and access costs that could reasonably be attributed to them so that cost-recovery was not an issue. Moreover, with recent NTC reforms, cross-subsidies between vehicles were subsequently eliminated. Indeed the levies that are imposed are derived on a PAYGO basis (pay-as-you-go) with costs recouped via registration charges and a fuel excise that reflected their weight on the basis of historical costs imposed. The common levies across Australia are imposed only on heavy vehicles – for light vehicles charges vary by jurisdiction. Concern was that these PAYGO costs attributed to heavy vehicles were averaged over different types of roads and hence did not reflect the actual costs incurred when journeys were made on particular roads. The averaging across road types suppressed an essential factor influencing how vehicles do damage to roads. What is needed are charges related to distances travelled on roads of differing durability and the mass carried, namely, mass-distance-location charges.

One specific efficiency-promoting reform has been the proposal to admit heavy vehicles to less durable roads provided they pay an ‘incremental price’ that reflects the additional damage to the road caused by the incremental mass above current maximum weight limits. This intended reform will be effected by GPS technology currently used by trucking companies to monitor vehicle movements for fleet management purposes. These make it possible to charge on the basis of time, distance and location of travel as well as tare weight although currently it is not feasible to charge on the basis of loaded weight.

Vehicle telematic technologies, based on GPS principles, are becoming available which will enable road managers to price road use on the basis of time of journey, distance travelled, type of road and loaded 'axle-load' weight. These are discussed further below. These technologies can potentially be developed to capture all of the externalities generated by both light and heavy transport usage of roads of varying durability and which are subject to differential substance and congestion-based externality costs (Ochieng et al, 2008). With plausible technological optimism and with an adequate data base determining how road damages can be related to types of heavy vehicle use, pricing of vehicle-induced road damages on a mass-distance-location basis should become feasible over the next few years.

What remains to be determined is how such revenues should be disbursed to road construction authorities in different jurisdictions so that there are efficient road supply responses in terms of constructing new roads or expanding old ones by investing appropriately in their capacity and durability characteristics.

6.6 Road transport and telematics. Mobile phones have revolutionised our lives. Analogous communication devices in vehicles can change and improve the way we travel. Economy-wide efficiencies can result from adopting these technologies. In-vehicle (telematic) units (IVU) units can be installed in motor vehicles to meet a variety of regulatory and commercial needs. They can provide information about journeys to external agencies such as regulators or vehicle-fleet managers and receive information from such agencies in a form accessible to a vehicle's driver.

For regulation IVU devices can be used for congestion pricing of roads, for charging by mass and location of travel in order to assess road damage costs, for charging for local vehicle pollution emissions, for tracking the delivery of dangerous goods and to maintain driver-specific information on number of rest breaks, distance travelled and to ensure road safety standards. There are also various potential commercial applications. The devices can be used for fleet management for tracking/tracing vehicles, for pay-as-you drive insurance, as anti-theft devices, to provide vehicle-to-vehicle communications and navigation services and for providing emergency help in the event of an accident. Potentially they could be used to provide information about and the ability to manage parking spots in a congested city to eliminate search costs for parking spots and the accompanying congestion.

In Australia today these devices are widely used for commercial trucking fleet management purposes. There is increasing pressure by some groups to encourage the use of such devices for regulatory purposes. As discussed below IVU are being used to manage access of vehicles onto the Higher Mass Limits (HML) roads in NSW and Queensland and there has been an application to heavy mobile cranes in Victoria. Hence experience with regulatory applications is developing rapidly in Australia. The devices would be necessary if the 'incremental pricing' reform discussed by COAG were to be implemented - this is the scheme by which heavy vehicles are permitted to drive on less durable roads - from which they are currently banned - by paying an appropriate extra fee.

Vehicle telematic services are delivered through IVU that rely on *Global Positioning System* (GPS) and *General Packet Radio Service* (GPRS) technologies. These technologies have been widely employed in Europe for a range of applications (Rapp Trans, 2008). The COAG agenda in Australia is very much focused on issues of heavy vehicle charging so this is examined here. Essentially COAG wants to encourage cost-minimising use of roads by heavy vehicles and the right sorts of supply decisions for road providers.

What can Australia learn from the European experience?

Heavy vehicle charging in Europe occurs in Austria, Germany, Czech Republic and Switzerland. The objective in the main is to recover the costs of road use by heavy vehicles and sometimes to provide competitive neutrality with respect to other transport modes such as rail. The charging principle variously depends on distance, the number of axles on a vehicle, emission values and, in the case of Switzerland, a weight limit. None of the technologies specifically determine the weight of a laden vehicle as a basis for charging. Drivers are required to indicate if they are not operating as prime movers without load (when they are subject to a low charge) or whether they are carrying a trailer (when they are subjected to a substantially higher charge). If the vehicle is carrying a trailer it is assumed the vehicle is fully laden and the passage of the vehicle is priced accordingly. Triangulation of load carrying is encouraged by this practice so a vehicle taking a heavy load from point A to point B will seek to take some sort of load in returning to A perhaps by detouring to another point C to reduce the costs they would bear by having a heavily-charged vehicle that carries no load. Distances where vehicles with trailers carry no load are only around 25 per cent of the total so it is not a substantial issue.

The IVU (in Europe, 'on board units', OBUs) costs in 2007 are from around $65 for the DSRC IVUs used in Austria and the Czech Republic and around $800 for the GPS and CGSM technologies in Germany and the tachograph- DSRC technology of Switzerland. The Austrian and Czech devices can be self-installed by being attached to the vehicle windscreen while the German and Swiss devices would require 2-4 hours installation in an approved garage. Overall the IVU installation costs are therefore not substantial (Rapp Trans, 2008, p. 14).

Costs of implementation and operational costs are more considerable but not very clearly documented or categorised into fixed and variable charges. These costs depend on whether the organisation operating the scheme is established or needs to be set up, on the extent of outsourcing of tasks, on the legal constraints for servicing frequent and occasional users, on the procedural and technical complexity of the schemes and the model of remuneration of the operator. For example many of the European schemes need to provide a number of ways to levy charges because some road users may be based in other countries.

Some published estimates of cost value the 'cost of implementing' the scheme in Austria at $586m with revenues in 2007 of $1.5b. In the Czech Republic costs were $1.3b (including operational costs for 10 years) with revenues collected in the first year about $352m. In Germany rough estimates suggest an implementation cost of $1.7b with revenues for 2007 being $5.7b. Finally, the Swiss scheme cost $300m yielding revenues in 2007 of $1.5b. ((Rapp Trans, 2008, p16). Operational costs as a fraction of revenue have been estimated as 8-10 per cent for Austria, 20 per cent for Germany and 6-8 per cent for Switzerland (Rapp Trans, 2008, p. 16).

Many of the European costs are high because of the need to accommodate traffic flows from other countries – an issue that would not arise in Australia.

In Australia the *intelligent Access Program* (IAP) is a voluntary program which provides heavy vehicles with access, or improved access, to the Australian road network in return for monitoring of compliance with specific access conditions using vehicle telematic solutions. The IVU are supported in Australia by the *Transport Certification Authority* (TCA) a public company with directors drawn largely from state and territory road agencies and the Commonwealth Department of Transport and Regional Services. The TCA was established to administer and implement all aspects of the (IAP) including policy and legislation, and to certify suppliers of IVU. There are currently three certified commercial providers in Australia.

IAP currently operates in Queensland and NSW, Australia already has IVUs that provide evidentiary data on location, speed and time - distance can be calculated from the same records - and these are now used in an application that monitors compliance. If Australia were to decide to have heavy vehicle charging schemes based on those parameters already monitored by IAP, then it would be merely a back-office software addition on implementation.

A crucial issue in Australia is that many trucks shift heavy but variable freight loads across large parts of the country. Many journeys by heavy vehicles in Australia involve taking mineral products to ports so that almost 50 per cent of the times such large vehicles will be travelling without load because the possibility for triangulating freight tasks is low. In Australia a vehicle of a particular size can therefore carry widely differing tare loads. This is a distinctive feature of Australian as opposed to European conditions and means that inferences about the mass of a load cannot be readily inferred from the size of a vehicle. Self declarations will be subject to deliberate and inadvertent error if self-declared. It is therefore necessary to determine directly this loaded weight. This is a crucial issue since it is this tare weight which determines the appropriate user charge that should be levied to manage road damage costs.

Recent experimental testing of on-board mass monitoring devices (OBM) carried out by TCA is positive about the feasibility of such technology. Using 12 OBM systems from 8 Australian OBM suppliers across 5 Australian states over a period of 7 months showed that mass could be estimated to within a 2 per cent error of the true mass as estimated by a weighbridge. Static measures of mass were more accurate than dynamic (time series) measures though the dynamic data provided useful evidence on the issue of tampering (TCA, 2009).

The costs of OBM devices depend on the specific technology used in the sensors – load cell or APT – and on the type of truck. Load cell technologies provide greater accuracy than APT systems but have much higher installation costs. Across a variety of truck types and load cell/APT configurations total costs ranged between $3,200-$13,500 per vehicle with installation costs varying between $200-$2500 (TCA, 2009, p. 43-44).

Crucial issues involved in commercialising these technologies are the potential for tampering in order to understate weight measurement and the issue of evidentiality – the provision of information that verifies that the mass of a vehicle was what the OBM indicated. TCA believes it can now address the critical issue in mass tampering through the use of dynamic data from the sensors as a quality indicator to the declared mass outputs from the systems. This is detailed in the OBM report (TCA, 2009, p55) and the specifications for doing this are being compiled now.

Finally there are issues of privacy that to some extent bear on the evidentially issue. These are important but surmountable. Disaggregated information on where travel occurs could be kept private and only revealed if a challenge was made to a pricing claim.

Developments in telematics offer the opportunity for a transport-dependent country such as Australia to develop an additional source of national advantage.

6.7 The COAG agenda. COAG is committed to a *Road Reform Plan* designed to improve the effectiveness of Australian road planning procedures. The general intention is to link revenues from road use with better decision-making procedures by road providers. The core issue is that road planning issues in Australia are frequently undertaken on the basis of engineering and political considerations alone given some exogenous public budget.

Ideally road providers should face incentives to provide roads with optimal durability and capacity which provides a competitive rate of return on capital invested. This will be the case if road providers can feasibly design a road which recovers its capital and maintenance costs together with a competitive return on capital invested by charging road users the capital costs of the roads used as well as maintenance, congestion and operational costs incurred. Provided providers know that this will happen they can draw on local and international capital markets to supply desired road funding for efficient road designs.

This type of proposal is analogous to a commercialised 'road fund' proposals (Gwilliam and Shaizi, 1999). Essential national or regional road agencies are set up as regulated monopolistic public utilities. These institutions would ultimately derive their revenues from road user charges and would be responsible for maintenance and capital investments in their segment of the market whether it was national highways or regional. Regulation would be essential both to restrict the exercise of monopoly power and to encourage the development of projects with high social value that might require cross subsidies or direct funding by government. The experience of other countries can be drawn on in coming up with specific road agency designs. For example, an instance of such arrangements is Transit New Zealand (subsequently the NZ Transport Agency) (NZTA, 2009) which monopolistically manages New Zealand's roads subject to regulation.

6.8 The future of road supplies. Longer-term efficiency in road use requires pricing of road use by all vehicles to recover the costs they impose. Mass-distance-location pricing might capture the major issues for freight transport but time of travel might be of major concern in addressing road use by passenger motor vehicles in congested urban areas. The types of technologies developed to account for efficient pricing of roads by trucks can be adapted to deal with specific congestion concerns in urban areas.

The issue of selling such technological fixes to politicians and ultimately, via politicians, to road users has not been discussed here. Ignoring cross subsidies the attractiveness of all such schemes is that they potentially reduce costs of road usage by delivering efficiency gains. Incremental pricing schemes make this transparent since they offer trucking operators additional freedom of choice to select road transport options at a price.

7. General Equilibrium Issues, Double Dividends and Public Transport Subsidies

Summary Section 7
Partial equilibrium analyses of the case for levying revenue-yielding excises on certain goods and for levying Pigovian taxes on activities that deliver negative externalities are subject to significant general equilibrium qualifications. These qualifications bear particularly on the impacts of these taxes on labour markets.
The strong results obtained in Section 3 on the Ramsey case for hefty excises are strengthened further if, as seems likely, fuel use and untaxed leisure are consumption complements.
Double dividend arguments that suggest externality taxes provide secondary benefits by facilitating the reduction of distorting taxes in other markets are questionable. The distortionary effects of such taxes in labour markets may overwhelm any efficiency effects that arise from cutting other taxes.
A key empirical issue is the extent of separability between goods subject to taxes and leisure demands. With separability the case for differentiated Ramey excises disappears but with weak separability the partial equilibrium analyses justifying Pigovian taxes become justified.

7.1 Fuel excises in general equilibrium. Much of the analysis in this report is based on standard partial equilibrium analyses of market inefficiencies. Such approaches have been criticised. Specifically standard 'Harberger triangle' measures of excess burdens (Harburger, 1964) have been shown to substantially underestimate the excess burdens of commodity taxes in certain situations. The traditional formula performs poorly because it ignores general equilibrium interactions – particularly with labour markets where work effort is taxed but leisure is not. These interaction effects have traditionally been assumed to be of 'second-order' importance and ignored. Goulder and Williams (2003) argue that this neglect is unjustified under what they see as a reasonable assumption for many commodities – that they have average *substitutability* with leisure. With this property the bias in using conventional excess burden measures is claimed to be large. Indeed a new tax on a commodity like gasoline creates far more excess burden through general equilibrium interactions than through additional distortions in the market for the taxed good itself. The substitutability hypothesis suggests that an increased tax on the commodity will encourage increased consumption of untaxed leisure which will increase distortions in labour markets.

In this case, optimal excises on fuels and car use charges should be set low to avoid efficiency losses. A general implication is that broad-based commodity taxes are a more efficient way of raising revenue than taxes on particular commodities.

It is known that broad-based taxes such as excises on fuel implicitly tax factors of production such as labour. This is also true even for more narrowly defined taxes on such things as luxury vehicles or car registration and car licence charges. In the latter case even though the effects on income are small, even such small additional distortions generate a significant excess burden in labour markets because of extensive pre-existing labour market distortions.

Goulder and Williams (2003) provide a tractable formula for computing such effects on the assumption that the taxed commodity is average in terms of its substitutability with labour. This assumption is an important proviso. If the commodity is only weakly substitutable with leisure or strongly complementary with leisure then the formula does not work. For example if leisure is a complement with gasoline an increased gasoline excise will reduce the demand for untaxed leisure and reduce distortions in labour markets. If there is neither substitutability nor complementarity then the traditional partial equilibrium formulation is accurate.

In fact, West and Williams (2007) provide evidence that gasoline is a relative complement to leisure and compute optimal excises on fuel that are much larger than those suggested in earlier work – indeed their work justifies the current scale of US fuel taxes and deduces that the optimal excise should exceed the marginal pollution and other costs associated with fuel use. Driving is a relatively time-intensive good and time-intensive goods tend to be leisure complements. Alternatively it might be that the demand for leisure driving is much more price-elastic with respect to fuel prices than is the demand for commuting. Thus a higher fuel tax leads to less leisure-based travel. An important issue here is to estimate the cross price elasticity of demand for leisure with respect to fuel prices.

In Section 3 high optimal excises for fuel were motivated by partial equilibrium Ramsey arguments and by arguments for using such excises as a proxy for environmental externality charges. In the absence of strong arguments that fuel use and leisure are substitutes these arguments seem robust to a general equilibrium critique that examines the effect of such taxes on labour markets.

7.2 Double dividends from congestion taxes. General equilibrium arguments of the type just discussed have important implications for 'double dividend' debates (Schöb, 2003). Imposing a congestion tax will reduce deadweight losses in the market for road transport (the 'environment') but can impose them elsewhere in the economy on 'non-environmental' welfare. Particular concern has been addressed to effects on distorted labour markets although one could also question the impact on tax-distorted fuel markets as well.

Schöb (2003) identifies two 'double dividend' hypotheses. A *weak* hypothesis asserts that tax revenue from a congestion tax can lower the excess burdens associated with other taxes and thus offset any efficiency cost of the tax. The *strong* hypothesis asserts that a congestion tax reform improves both environmental and non-environmental welfare so that a 'green tax' provides 'no regret' benefits even if the overall environmental benefits are in doubt.

This literature is technical but a key concern is that raising a narrow congestion tax and using this revenue to cut a broad-based tax, like a labour tax, might increase overall distortions in a tax system. Clearly the nature of the tax relief provided will influence judgements about double dividend efficiencies. A simple approach to selecting a tax base in which to focus the effects of reform would be to select that base where current marginal excess burdens are highest. These are likely to lie outside the transport sector and to involve taxes on such things as labour. Parry and Bento (2001) have shown that channelling revenues from a congestion tax into reducing labour taxes does provide net benefits. But this type of switch might be politically unsatisfactory if congestion taxes are seen as local taxes where the support of local residents needs to be achieved to make a switch toward congestion pricing feasible. It might be plausible to expect that such support is likely to be greater if tax revenues are used to improve the local public transport system as analysed by Kidokoro (2005). If there are external benefits from funding extra public transport then the optimal congestion tax is higher than it otherwise would be.

In Australia the main expenditure and tax cut options associated with introducing congestion taxes would be (a) to hypothecate revenues for investment in public transport or in increased mass transport subsidies; (b) to cut fuel excises or registration charges or (c) to cut income taxes.

- **Mass transport**. This is a politically attractive option since those 'tolled-off' roads might see the improved provision of mass transport as compensation. Hypothecating revenues in this way might involve some efficiency losses but these will not be great if mass transport infrastructure needs to be expanded to accommodate those induced to limit use of private vehicles by congestion charges.

- **Reducing fuel taxes**. Imposing a congestion tax will have some effect in reducing the demand for fuel since traffic will flow more easily. This in itself would reduce the excess burdens that prevail in tax-distorted fuel markets. If revenue from a congestion tax was used in a revenue neutral way to cut fuel excises then the tax burden would have shifted from a relatively broad base to a narrower one so some efficiency losses would prevail.

- **Income tax cuts.** The general equilibrium costs of a congestion tax are likely to fall heavily on labour markets. Shifting the tax burden from a broad-based income tax to a narrower congestion tax would result in some efficiency losses so the issue is whether the gains in the environmental market exceed such costs. Empirical evidence from Parry and Bento (2001) and some simulations conducted by the UK Department for Transport (2004) suggest there will be a net gain overall.

The important general character of these results is that attention needs to be paid to how the proceeds of something like a congestion tax are used.

7.3 Irrelevance of excises? It is finally worth noting that 'second-best' issues limit the relevance of Ramsey case for concentrating high taxes on goods, such as fuel, that are in relatively inelastic demand and that the empirical issues here are much the same as those determining the applicability of standard partial equilibrium efficiency measures and the role of double dividend arguments.

The standard partial equilibrium expression for the deadweight loss $D_i(t_i)$ of a small *ad valorem* tax t_i levied on good i demanded in quantity x_i at price p_i with compensated elasticity of demand ε_{di} and elasticity of supply ε_{si} is:

$$D_i(t_i) = \frac{\varepsilon_{di}\varepsilon_{si}}{\varepsilon_{di} + \varepsilon_{si}} t_i^2 \frac{p_i x_i}{2} .$$

With i = 1,2,...n commodities, a tax system $(t_1,t_2,...t_n)$ which minimises the sum of these deadweight losses subject to the constraint of raising government revenue $R = \sum_{i=1}^{n} p_i t_i x_i$, assuming expenditure on each good $p_i x_i$ is fixed, is given by the inverse elasticities rule

$$t_i = k(\varepsilon_{di}^{-1} + \varepsilon_{si}^{-1}) \text{ for } i = 1,...n$$

where k is the constant Lagrange multiplier associated with the government's budget. This is the *Ramsey rule* (after Ramsey, 1927). Since elasticities of demand and supply clearly vary across commodities implanting this rule involves non-uniform excises across commodities. If suppliers are price takers then the standard result, that the size of an excise is inversely proportional to the price elasticity of demand obtains (Salanié, 2003, p. 63-64).

The Ramsey rule sets relatively high excises on goods in inelastic demand on the assumption that consumers are identical, demands are not interdependent and that there is no income tax which can be optimally set at the same time as excise taxes are being optimised. Ramsey restricts the government's objective to raising a fixed amount of revenue and deduces an optimal pattern of excises that minimises the aggregated deadweight losses reflecting behavioural adjustments contingent of the excises. It ignores all income effects.

Diamond and Mirrlees (1971) extended the analysis of optimal excises to a production economy under the limiting assumption that the economy displays constant returns to scale. This is an important extension since inputs such as fuels are used both as consumer goods and as productive inputs. The key result is that the production sector should not be distorted by excise taxes. There is therefore an *a priori* case against taxes on intermediate goods which are produced by some firms and used as inputs by others.

Diamond (1975) showed that accounting for heterogeneous individuals the Ramsey rule needs to be modified to reflect both efficiency (lower tax rates on elastically-demanded goods) and distributional objectives (goods purchased by wealthy individuals) should be taxed more. Thus both price and the income elasticities of demand were seen as specifically important.

That non-uniform excise taxes are optimal in this setting is shown by Corlett and Hague (1953-54) to stem from the fact that leisure cannot be taxed. As a second-best approximation given this inability the optimal Ramsey rule entails levying heavier taxes on goods and services that are complementary with leisure (e.g. yachts and sports cars) rather than goods complementary to labour such as urban transportation. The intuition is that a uniform excise is equivalent to a proportional tax on labour which discourages effort. This distortion can be countered by discouraging leisure which occurs if goods complementary with leisure are taxed.

Modern tax theory (Kaplow, 2009) suggests that, to a first approximation, redistribution should be confined to income taxes and transfer programs whereas other government policies, such as excise taxes, should be assessed solely on efficiency grounds. Distributional concerns are not relevant since these can and should be addressed via income taxes.

In addition, as Atkinson and Stiglitz (1976) have shown, provided there is weak labour separability in the utility function – so again the labour/leisure choice is independent of purchasing decisions – and provided that an optimal income tax can be selected as well as optimal excises - uniform excises are preferable on all goods and services irrespective of price (or income) elasticities. Since uniform excises amount to an increased tax on incomes this suggests that income taxes can pursue both efficiency and redistributive goals. Excises are redundant and can be set at a uniform level of zero.

Kaplow suggests the need to integrate income tax determination with excise modelling and does this by considering 'distribution-neutral' (and 'revenue-neutral') reform packages whereby income taxes are adjusted to offset the effects of any policy change under consideration such as an excise or externality tax change. Then there are no distributional impacts of the policy change. Moreover, with weak labour separability there will also be no effects on labour supply so that the standard tradeoffs in the optimal income tax literature – between efficiency and distribution – can be set to one side.

With some qualifications this greatly simplifies the economic analysis of various issues since first-best policy prescriptions can now be used. Pollution and congestion externalities can be addressed by setting Pigouvian taxes equal to marginal social costs, public sector pricing can be set at marginal cost and so on.

Moreover in this setting, with the assumption of weak labour separability, the Atkinson-Stiglitz result on the inefficiency of differential taxes can be generalised to arbitrary rather than optimal income taxes. Furthermore, any measure which eliminates proportionately excise differentials across commodities will also produce an efficiency gain (Kaplow, 2008, p. 133-134).

An immediate implication is that luxury good taxes as well as exemptions from tax liability for necessity goods are inefficient. Precisely these propositions were argued earlier in this report.

These are powerful results that limit the case for excise taxes. Of course these arguments do not detract from the use of specifically high taxes to address externalities (as addressed in Section 3) or indeed goods with specific harmful effects that are not external. They do however reduce the case for using discriminatory excises as revenue-gathering policies.

The crucial empirical issue is whether or not leisure is weakly-separable in the utilities of consumers. There is relatively little empirical evidence on this. Browning and Meghir (1991) reject the hypothesis while other evidence is cited in Salanié (2003, p. 117-119). As noted in section 7.1, West and Williams (2007) provide evidence that gasoline and leisure *are* sufficiently complementary to generate substantial differentiated optimal fuel excises. A specific study of the separability between leisure and environmental goods for Australia would be a valuable contribution for policy making.

Despite the strong theoretical arguments supporting relying from income taxes or a uniform GST it is worthwhile continuing considering excise on fuel for raising revenue. First, the conditions required for the uniform excise result are neither intuitively obvious nor supported by extensive empirical evidence. Second, issues such as administrative costs of taxes and risks of evasion are also important issues determining choice of taxes. Income taxes have high collection costs and evasion is relatively easy compared to excises or the GST. Indeed a uniform GST without exemptions satisfies the Atkinson-Stiglitz prescription which is probably the core of the reason that 29 of the 30 OECD countries have such a tax (Mankiw et al. , 2009).

8. Rail, Air Services, Shipping and Taxis

Summary
The failure to set precise user charges on road freight does not seem to raise significant competitive neutrality issues with respect to rail.
The lessons of rail sector experience for the road sector rest in the difficulties of using

mandated access regimes in settings where there is intrinsically substantially natural monopoly power both 'above' and 'below' rail.
Ships engaged in coastal shipping, should, in principle, pay customs duty on fuel consumed doing this. However, the difficulties of calculating the fuel consumed this for ships engaged in international voyages commenced and concluding overseas (and currently not paying customs duty) makes this impractical. The size of any cost advantage from this is unlikely to be large.
There is no case for introducing a tonnage tax that effectively reduces the tax on income paid in shipping. There is no argument that such a tax would improve economic efficiency. Indeed, while introducing such a tax might benefit the coastal shipping industry, it would reduce the overall economic efficiency of the economy.
Low fuel excises on airlines can be partly rationalised on the grounds that airlines pay directly their infrastructure costs. More seriously the monopoly rents that are implied by restrictive Air Service Agreements on international flights are an implicit tax on international travellers which accrues to the airlines. It imposes significant costs on Australians making international flights and on downstream tourism and travel firms.
Developing an efficient taxi industry is a significant component of road sector reform. There are no significant direct tax issues bearing on the taxi industry though the restrictive licensing structure does possibly increase costs and reduce service quality. Deregulation will be expensive and should not be complete – fare and service-quality issues should continue to be monitored.

The main concern in this report is with the road sector. Inter-modal choice issues have largely been suppressed. Some brief comments here are made about some alternative transport modes that are affected by reform of road charging and the road supply system or which have their own tax implications. Certain modal choices – for example – bus services involve significant regulatory issues but not substantial tax and transfer policy issues.

An important issue here is the extent to which levying user charges on road transport will increase demands for other transport modes. As a generalisation the demands for many particular forms of transport are fairly price inelastic. This is certainly true for coastal shipping where there are few substitutes but is even true for roads and mass transit (Button, 2003, p. 40-46). Moreover, cross price elasticities generally tend to be even lower than 'own' price elasticities particularly for the effects of mass transit fares on urban vehicle demands. There are greater shifts between alternative mass transit modes as a consequence of relative price shifts (Button, 1993, 46-50).

Roads are in a sense the sole remaining sector of the Australian transport system that has not yet been commercialised but instead operate almost exclusively on the basis of public funding. Revenues associated with road use do not elicit road supplies whereas revenues from other transport sectors determine supply responses.

8.1 Rail. The road network faces potential competition from the rail network for the custom of at least some forms of freight. The presence of this competition has implications, for example, for the optimal charges that are levied for the use of the road network by vehicles that carry freight.

The rail network can be usefully divided into two components. The first component is ‘below rail’, which consists of the rail tracks, stations and other fixed equipment that constitutes the rail network which is generally regarded as a natural monopoly. The second component is ‘above rail’, which consists of the moving stock such as train engines and train carriages which might seem to be potentially competitive but where natural monopoly elements again are important. The ‘below rail’ network is now in the hands of corporatized, government-owned or funded entities – for example the Australian Rail Track Corporation (ARTC) runs the standard interstate rail system - so that, unlike road, rail now operates within a commercial structure. The ‘above rail’ operations are predominantly, although not exclusively, provided by the private sector and by Queensland’s corporatized railroad, QR.

Australian rail services split into passenger and freight services. Most passenger services are provided to urban commuters as an alternative to vehicle use – intercity passenger commutes are a small market segment. The main competitors for rail freight are trucking services and, to a less extent, shipping.

Australia has pursued a policy of mandated free access to use of rail lines by its railway freight sector which draws on the ‘below rail’ assets. Potentially multiple operators can offer services to shippers over the same infrastructure. Competition is intended to encourage innovation and reduce costs although given the natural monopoly character of ‘above rail’ services the extent of competition is often limited (Fagan, 2008; Wills-Johnson, 2008). The states have moved to reduce subsidies but these are still a major part of urban passenger rail provision where they can be partly justified as ‘second-best’ attempts to address unpriced road congestion. There are also still major expenditures by state governments on rail infrastructure so that it is difficult to assess the extent of additional implicit subsidies. While there are complicated access pricing issues here the main issue in relation to competition with respect to road freight is whether or not competitive neutrality exists given that many road use costs are not charged for.

Policy makers have always struggled when they have sought to introduce competition into natural monopoly enterprises. The main lessons for the commercialisation of rail are the manifest monopolies that still exist even in a range of ‘above rail’ services and the difficulties of coordinating the provision of infrastructure for ‘above rail’ service providers. The fact that entry to the rail freight industry has been so low partly reflects these monopoly issues.

A useful Productivity Commission report deals partly with rail (PC, 2006) and there is also a useful submission by BTRE (2006) to that inquiry. The PC contend that there are inefficiencies in road use pricing but that still there is substantial competitive neutrality across road and rail sectors. The main freight routes in Australia run East-West from Sydney or Adelaide to Perth and rail has a natural dominance over trucking here given the vast distances. On the shorter north-south corridors between Sydney and Brisbane trucks have a competitive advantage (BITRE, 2008b). The movements of coal for export from the Hunter Valley in NSW and the Bowen Basin in Queensland to ports are best carried out by rail. The same is true for the private railroads running from the Pilbara in Western Australia (BITRE, 2008).

8.2 Air Services. The role of taxes in the domestic and international aviation markets are of limited importance in Australia. Aircraft are privately-owned and as such involve costs of aircraft purchase, costs of variable inputs many of which are taxed and the use of airport facilities.

Aviation gasoline and turbine fuel used for domestic trips are subject to an excise though at a much lower rate than automotive fuels. Revenues generated are hypothecated to recover costs for the Civil Aviation Authority rather than to raise revenue. While some claim that fuel used in aviation is primarily a business input and should not be taxed to secure revenue the deadweight losses of such taxes will be very low because the taxes themselves are low. There is also a claim that, unlike motorists who pay for the free roads they use through petrol excises, that aviation providers pay directly for the infrastructure they use and for air traffic control services so that they should be subject to lower charges (Forsyth, 2008).

There is also a claim that existing lower taxes on aviation fuels and perhaps user charges generally on aviation involve cross subsidies because fuel is fully taxed for private car use and user charges on rail fully meet costs. These cross subsidies distort choices between road, rail and air travel by making air travel relatively cheaper. At issue here is the extent of substitutability between these different modes of transport although this would seem to be low for most medium to long distance journeys in Australia.

Not taxing fuel used on international flights biases travel decisions against domestic journeys but the decision to tax flights to or from Australia reduces the competitiveness of Australia as a destination. Again given that the local fuel taxes are low it is difficult to believe that the DWLs here are substantial.

Of greater significance with respect to international flights is the view that restrictive Air Service Agreements (ASAs) effectively impose an export tax on international journeys on international flights to and from Australia though it is a tax that is collected by the airlines (Clarke, 1992; Clarke 1998). According to this view restrictive ASAs particularly to the United States and Japan enable Australia to bid up the price of air-services on these routes to extract an export tax on passengers. This ‘tax’ has efficiency costs because it impacts on Australian as well as international passengers, because of impacts it imposes on other sectors of the economy who service international travellers such as hotels and restaurants and because it induces x-inefficiency losses on the part of airlines. Various reports such Productivity Commission (2008) have sought reforms to liberalise restrictive ASAs and this program has achieved some successes over recent years.

8.3 Shipping. Maritime Transportation can be thought of playing three roles in transport in Australia. These roles are summarised in **Table 9** below

Table 9: Comparing Shipping with Other forms of Transport	
International Maritime Transport – million tons loaded (discharged)	656 (78)
International Maritime Transport – average kilometres shipped	8342
International Maritime Transport – Passengers Carried (thousands	283
Domestic Maritime Transport – million tons loaded (discharged)	56 (6)
Domestic Maritime Transport – Average Kilometres shipped	2239
Domestic Road Transport – Tonnes Carried (millions)	1844
Domestic Rail Transport – Tonnes Carried	641.2
Domestic Road Transport – average kilometres shipped	91
Domestic Rail Transport – average kilometres shipped	295
Source: Data for 2006-2007 from Tables 7 and 15 BITRE *Australian Transport Statistics*, June 2008.	

There are several points to be drawn from **Table 9.** First note that the quantity shipped for export is much larger relative to that shipped for domestic freight. Second, note that the quantity shipped is much smaller for domestic maritime transport than for rail or road. However, note that on average commodities that are shipped by coastal shipping go much longer distances than those for the other modes. Both containers and bulk commodities such as bauxite, cement, sugar and refined petroleum are shipped using coastal shipping.

We will focus on taxation issues related to domestic maritime transport (or as it is often referred to, coastal shipping) as this is the area where the main concerns about taxation have been raised.

All vehicles engaged in coastal shipping must either be licensed or have received a permit (DITRDLG, 2009) but these fees are negligible – an annual license costs $22. A ship, irrespective of its nationality, can receive a license if the crew receive Australian wages while engaged in coastal shipping, the crew have access to the ship's library and if the ship does not receive a subsidy or bonus from a foreign government.

Alternatively, a ship can receive a permit to engage in coastal shipping, at a cost of $22 for a single voyage (carrying passengers), $200 for a single voyage carrying cargo, or a cost of $400 for voyages between designated ports for up to three months. A license will be issued if there are no suitable licensed ships or licensed ships provide inadequate service, and if it is in the public interest.

Two issues around taxation as related to shipping arise. First is the exemption from certain taxes of fuel used by vessels engaged in coastal shipping as part of an international voyage. Secondly there are issues related to tonnage taxation. An optional tonnage tax, linked to mandatory training requirements, is recommended in the recent report by the House of Representatives Standing Committee on Infrastructure, Transport, Regional Development & Local Government (2008) (hereafter RACSI, 2008).

The MUA (2008) claim there are two ways in which vessels engaged in coastal shipping as part of an international voyage receive a tax advantage over vessels engaged solely in coastal shipping. First, they are exempt from GST for fuel purchased in Australia. However, any coastal shipping for business purposes (which presumably is all of it) would receive a tax credit to cover the GST so there is no apparent advantage. Second, the MUA refers to advice from the Australian Customs Service that ships engaged in international voyages do not pay customs duty on the fuel unlike that paid for by local ships. This would provide a tax advantage to such ships. In theory the fuel used in coastal shipping by ships engaged in international voyages should be taxed (either through customs duty or the equivalent excise). However, an example demonstrates the complexities in calculating this. A ship begins its voyage in Singapore, picks up a cargo in Perth, unloads it in Melbourne and continues to Auckland to unload its initial cargo. Using the fuel consumed between Perth and Melbourne would be an over-estimate as some distance like this would need to be covered on the trip to Auckland anyway. Furthermore in discussions of why costs are higher in Australian coastal shipping, attention focuses on labour costs rather than fuel costs (RACSI, 2008, page 31).

A tonnage tax system is a system where a ship operator can chose to be taxed on the tonnage of their fleet rather than the income earned. In the DITRDLG (2008) submission to RACSI the claim was made that this tended to reduce the effective tax rate on income from coastal shipping. RACSI (2008) recommends a tonnage tax as part of a set of measures to encourage local coastal shipping, although no rate is recommended, a rate that would reduce the effective income tax is presumably what they have in mind. However, they do not provide a justification in terms of correcting a market failure, for a lower rate. If the current tax rates are otherwise optimal, introducing a reduced tax rate for coastal shipping would create economic inefficiencies by encouraging extra resources into this sector. Hence, we recommend against the introduction of a tonnage tax regime.

8.4 Taxis*. Increased user charges on vehicles and increases in carbon-based fuel prices might have long-term effects of reducing private car ownership and use - there are tentative signs that this has

* An author of this report, Harry Clarke, has provided consulting services to the Victorian Taxi Association Inc.

already happened in the US in response to the now-ended oil price boom. This might encourage some commuters to shift towards mass transit for many trips and to the increased use of taxis for specific short journeys. An efficient taxi service, and indeed, efficient car rental services, are an increasingly important adjunct to overall transportation sector reform.

It goes without saying that user charges on motorists that reflect travel related externalities should apply to the externalities generated by taxi services.

The supply of taxi licences in all states of Australia is set by State and Territory Governments. The resulting limitation in supply can create monopoly power in the hands of the taxi industry which potentially creates inefficiency costs in the form of deadweight losses. The difficulty for governments is that taxi licences they have issued acquire a scarcity value and are held as legal, income-earning assets.

Victorian taxi licences are, for example, traded on the National Stock Exchange. In February 2009 they traded for $430,000 per licence.

If governments sought to respect the asset values created by the licence system they could deal equitably with licence holders, and eliminate the deadweight losses associated with the alleged monopoly power in this industry, by buying back the licences at their market value. Victoria has 4,652 metropolitan, urban and country taxis so that buying these licences back at the quoted figure would cost $2b. The comparable cost in Sydney with 6,420 taxis and at market values around $375,000 would be worth $2.4b. Comparable costs in Brisbane would be $1.3b, in SA $0.3b, in WA $0.4b and in the ACT $0.1b. Achieving this type of reform throughout Australia would be an expensive once-and-for-all exercise that would cost in excess of $6.5b (private industry sources). If the buyback was seen as a payment to eliminate the present value of annual deadweight losses then, at a 5 per cent interest rate, these gains from reform and the eliminated deadweight losses would need to be more than $309m annually across Australia to make the buyback worthwhile.

The buyback is clearly a substantial cost. It represents the present value of the profit stream associated with the current licence system and this will exceed the value of the present value of the deadweight losses. Government, in law, may even be able to abolish licences *without* compensating licence holders though there are moral and equity arguments against doing this. The issue here is whether a licence is a property right or not. In Ireland compensation was seen not to be a legal requirement because taxi licences were issued subject to the proviso that government policy might change in the future (Seibert, 2006). The law has not been tested in Australia.

There are persistent concerns by politicians and regulators with 'low' driver incomes in the taxi industry and these too limit the possibilities for reform. Thus, although the industry is seen as having monopoly power, drivers are seen as being employed in competitive markets for relatively unskilled labour so that wages are pegged in these markets. These incomes are typically determined by bailment arrangements between licence holders, operators and drivers with the latter receiving as income 50 per cent of all revenues and owners paying all operational costs such as petrol and taxi maintenance costs. Driver incomes are therefore determined in these markets at competitive levels leaving any monopoly rents accruing to licence holders and to a less extent taxi operators. Drivers can boost their incomes primarily by working longer hours. There is evidence in some jurisdictions (such as New York) that drivers 'target' certain income levels by adjusting their working hours (Köszegi & Rabin, 2006). In this case pressure on incomes due to entry into the industry would be met by increased working times and perhaps by extra demand for services due to reduced waiting times.

Taxi industry deregulation is often advanced as a way of removing the deadweight losses although the empirical effects of deregulation of the taxi industry in other countries are fairly ambiguous (Small and Verhoef, 2007, 213-214). Loosening entry requirements and price controls has led to significantly more taxis operating although fares have often not declined as expected. Service quality in terms of access times has sometimes improved but has also sometimes deteriorated in terms of no shows and refusals. Productivity often declined as cabs spent more time waiting at ranks or cruising for business. Overall a disappointing finding in centres where the taxi service has been deregulated is that little strategic innovation has occurred. Developments in telematics might eventually make such innovation more likely.

It seems plausible to suppose that although the industry acting cohesively as a whole does have monopoly power that there is enough competition within the industry to keep prices at reasonable levels. Under the bailment arrangements currently in place drivers have incentives to act as sales-maximisers and will generally favour prices lower than a monopolist would seek to negotiate with regulators. These arrangements seem inefficient since the alternative of renting a taxi for a particular period and paying petrol costs reduces wasteful fuel-usage through cruising.

Overall there is some differentiation in the market and the structure appears more like regulated monopolistic competition than a regulated monopoly. There are existing problems with no shows and with slow provision of services but it seems these sorts of service issues are best addressed in a regulated setting.

The way forward in Australia is to either buyback the taxi licences currently issued and to accept a huge cost of doing so or live with the current system. If licences *are* bought back, and the industry deregulated, then the precise nature of the deregulatory reforms needs to be thought through carefully. Issues of service quality and pricing should remain regulatory concerns.

9. Conclusions

A key issue in the Australian transport sector today is whether, in the medium term, governments should move away from collecting revenues via fixed charges (such as vehicle registration) and variable charges (such as taxes based primarily on fuels) toward a tax system based on user charges that account more directly for the specific costs that road users impose.

A case for excises on fuel can be based purely on their revenue gaining potential independently of their role in muting externalities. This argument depends crucially on two basic assumptions: (i) That arguments supporting the standard Ramsey case for discriminatory high excises on goods with low price elasticities can be sustained and (ii) that elasticities of demand for transport fuels are in fact low. There is strong evidence that elasticities are low but conventional Ramsey arguments can be questioned if leisure and fuels are weakly separable items in consumer utilities since then the case for differentiation in excises disappears. If the relation between leisure and fuel demands is one of substitutability the case for such taxes is particularly weak while if the relation is one of complementarity the case is strengthened with high fuel taxes proxying for the role of untaxed leisure. The character of this relationship is partly an empirical issue and the applied economics literature is not definitive on it. On *a priori grounds* if leisure activities are linked to increased use of motor fuels then the hypothesis of complementarity seems more plausible than that of substitutability so the Ramsey case for high excises is sustained.

The revenue case for excises on fuel is strengthened by their low collection costs and by the limited opportunities agents have to waste resources in seeking to evade them. It should be emphasised that this case has nothing to do with capturing externality costs. Indeed the optimal Ramsey-based fuel excise that is calculated which allows for a possible independent role of excises in mitigating congestion is considerably in excess of that currently charged.

Arguments for hefty fuel excises also do include the role such taxes can play in substituting for more efficient road use charges that target road use costs and externalities more effectively but which are not currently in use because they currently have higher collection costs. In addition, the capital costs of using roads should also be collected from road users on the basis of the ‘benefits principle’ of public taxation and, again, fuel use can surrogate for road use.

This surrogate role for fuel taxes involves no approximation when it comes to dealing with externalities associated with greenhouse gas emissions although no such specific tax is required if the consumption use of fuels is covered by an ETS of the type currently proposed. For other substance, noise and vibration-based externalities the use of fuels as a proxy for the underlying costs becomes highly imperfect because the location of travel then becomes the crucial determinant of the scale of the external costs. Outside major cities such costs will be less important than in densely-populated urban and city areas where traffic flows have more pronounced local impacts. Plausibly substance, noise and vibration-based externalities will be tackled more directly by regulations than by externality-correcting user charges.

The other major externalities (traffic accident, road damages and congestion) are only very imperfectly linked to fuel usage. For example although fuel usage does increase under congested conditions it does not increase enough to mirror the scale of increased congestion costs. There are strong arguments for addressing the levying of specific congestion charges in large cities.

There is also imperfect evidence that the incidence of traffic accident externalities increases under congested conditions. Traffic densities can be reduced if the extent of driving can be reduced so that reducing the extent of driving reduces the frequency of traffic accidents; indeed it falls more than proportionately. The imperfection in this evidence is that while the number of accidents increases with increased traffic accidents it is unclear that the number of serious traffic accidents increases to the same extent. Under congested conditions it could be that, because drivers are forced to drive more slowly due to the congestion and because drivers may exhibit greater care that, while the incident of accidents may increase, their average seriousness may decline. If it is true that significant accident externalities can be cut by reducing driving, then charges on petrol will prove helpful. This might suggest a case for excises on fuel to reduce accident externalities.

This case seems to us unconvincing since these externalities can be far better addressed using direct distance-based insurance charges. Fuel use can be reduced by investing in fuel efficient cars as well as by driving less. Moreover accident probabilities reflect characteristics of the driver (age, gender) as well as their residential address (urban or country). All these factors can be incorporated into personalised two-part insurance tariffs levied by the insurance industry that reflect distance travelled and personal characteristics of the driver. Taxes can be appended by government to such tariffs – or to the fixed component of registration charges - to capture any residual external costs. There may be a role for government policy here to promote, by competition from public insurers, policies which are distance based.

Another significant source of external cost is vehicle-caused road damage. Fuel use in some ways reflects road damage costs since the heavier trucks that impose most damage consume much fuel. Moreover, current policy gives these heavier vehicles gain lower relief from fuel excises to capture the road damage costs they imply which amplifies this effect. In addition heavy vehicles are prohibited from using certain low durability roads.

Road damage costs however depend on the character of roads being driven on and distances driven on these roads as well as vehicle mass. The technology for measuring the mass, distance and location of travel now seems to be close to being viable as part of standard fleet management practice and will mean that such road damage costs can be accurately monitored at low cost. This would seem to be an important, low cost innovation.

As a prelude to such an innovation, 'incremental pricing', whereby heavy vehicle users can access roads currently not accessible with the voluntary payment of an additional fee, should confirm the efficiency gains that can accrue to the trucking industry as well as to public budgets from a more direct approach to charging for road user costs. This can be an effective interim move prior to more comprehensive reform. It also illustrates the fact that pricing relaxes usage constraints on road users. In fact, given that heavy vehicles already pay their way, the efficiency dividend from better overall pricing of freight can and should be returned in part to heavy vehicle operators.

The dominant road externality in urban areas is congestion. This is also only imperfectly captured by excises on fuels because the increases in fuel use that occur under congested conditions do not nearly match congestion costs. The most plausible role for congestion pricing is in the east coast Australian state capital cities, Melbourne and Sydney. Here severe congestion externality costs occur. There is a straightforward strong case for moving toward congestion pricing schema based on: (i) Partial pricing of major arterial and ring roads with cordon pricing of the CBD, or, (ii) comprehensive electronic pricing of all the congested roads in the city. Partial pricing schemes are more-or-less immediately implementable although at substantial cost and have only moderate effectiveness. Comprehensive pricing schemes should shortly become available at more modest cost but with far greater effectiveness. The policy choices are to either adopt (1) permanently, or to adopt (i) and then switch to (ii) or, finally, to make only very partial reforms and to then and adopt (ii) permanently. There are some economic reasons for thinking seriously about this last approach. Specifically it might be best to congestion price a few major roads and to cordon price the CBD of large cities, perhaps in accompaniment with much more cohesive and imaginative parking policies, before a really substantial step toward comprehensive electronic parking of all the externalities associated with road travel are internalised.

A further reason from switching away for substituting user charges as a source of road capital is that such charges provide signals that help ensure efficient road supply decisions. Hypothecation arguments are unpopular among economists but there are efficiency reasons for considering them here. Road supply decisions should reflect road demands and actual or forecast road user charges. Economic theory shows, provide useful signals that guide how roads should be built, upgraded, expanded and maintained. Constructing a road provides a community with a long-lived community asset which should be efficiently used, managed and possibly expanded through time. Such assets should have capacities and durabilities which provide competitive returns on capital employed, after accounting for maintenance costs that are comparable to other long-lived public and private sector assets.

Levying effective user charges on heavy vehicles around Australia and levying appropriate congestion and damage charges on all vehicles in urban areas provides information that will encourage the construction of roads that optimise economic rather than pure engineering advantage. The difficulty here is not so much to devise an effective system of charging but to come up with appropriate institutions to forecast and respond to such signals. There would seem to remain a role for some form of central direction in providing forecasts and for constructing major interstate roads. The regulatory issues that arise in governance of decentralised service providers to prevent inefficient strategic behaviours and to meet community service obligations are difficult and have not been adequately thought though.

This paper has also drawn several conclusions about the way fuel excises operate independently of their revenue-gathering characteristics. There are several positive features of the current system of excises. As currently implemented such taxes sensibly do not impact on business inputs. Moreover, the excise system has become simpler and included a broader range of fuels. If hybrid cars become more popular, electricity used for transportation may also be considered for inclusion as a fuel. Generally there need be no implication that excises on fuels invariably mean excises on liquid carbon-based fuels alone.

One criticism of the current excises is that lower rates of excises are proposed for alternative fuels, such as those based on ethanol as well as LPG, when the environmental grounds for giving ethanol fuels, in particular, lower excise rates are not strong. This will be even truer when an ETS operates.

This report has also provided views on the efficiency effects of other taxes and charges in the economy. While the EBs associated with 10 per cent tariffs are the subject of dispute there is no convincing efficiency case for retaining them. Similarly while the luxury car tax causes only numerically small absolute EBs there is no sound distributional or efficiency-based reason for retaining it. On the various state taxes further study is required to reach firm welfare consequences. However, making charges uniform across states would save some transaction costs. It would also be simpler to remove the transaction taxes and replace income foregone with a larger annual registration fee. Tax expenditures from application of the statutory formula to motor vehicles probably create a moral hazard problem resulting in excess driving. However, the application of the statutory formula reduces the collection and administration costs of the FBT. Further study would be useful to determine if the savings in costs are greater than the welfare losses from induced excess driving.

Transport is a crucial intermediate input that impacts on all aspects of the Australian economy. Australia is a large country with a dispersed population distant from many key international centres. Transport in Australia involves large public costs and transport activities are quite heavily taxed. Transport yields a significant range of external costs that impact on all. The more efficient are transport taxes and investments in transport infrastructure the better will be Australia’s productivity and overall quality of life. Australia intensifies its advantages as an economy as it moves toward a transport sector with greater overall efficiency.

Appendix: The Parry and Small Model - Estimates for Australia

Parry and Small (2005) derive a second best optimal tax on petrol that accounts for environmental externalities from petrol consumption and the relative efficiency of using a tax on petrol compared with a tax on labour income. They estimate optimal taxes for the UK and USA and conclude that the tax in the USA is too low and in the UK too high. In this Appendix this model is outlined and estimated for Australia. The model is a sophisticated treatment of adjustment mechanisms to changes in fuel taxes allowing consumers to not only vary fuel consumption, but time and distance travelled and the fuel efficiency of their vehicles.

The analysis begins with a representative consumer for whom utility depends on consumption, distance travelled, time spent travelling, leisure and government spending. Travel requires purchasing petrol and incurring other costs of travel. Four external effects of driving are included: global pollution (such as greenhouse gases) which is proportional to fuel consumed; local pollution (such as carbon monoxide); external costs of congestion and, finally, traffic accidents, each of which is proportional to distance travelled. The government is supposed to raise taxes from two sources, namely, a per litre tax on petrol and a proportional tax on labour income. The government runs a balanced budget. The consumer is modelled as choosing consumption and travel plans subject to budget and time constraints. Petrol and labour taxes are then derived which maximise household utility subject to the constraints on individuals and government. The resulting expression for the fuel tax is expressed as the sum of an adjustment for externalities and an optimal Ramsey tax.

With estimates of each of the parameters and exogenous variables the optimal tax and its components can be computed. This requires simultaneously solving three sets of equations (one non-linear) which was done in GAUSS using the NLSYS module. Note that, as a check, the Parry Small model was re-estimated using this procedure using the US and UK data and the earlier results replicated. The data requirements for the estimations are now discussed.

There are three sets of data required to estimate the model. The first are estimates of each externality cost. The second are parameters summarizing the responsiveness of travel and fuel to changes in the price of fuel and income. The third are parameters summarising other relevant features of the economy. Our general approach is to use Australian data unless no data exists when values employed by Parry and Small for the USA are used.

The estimates of the externalities for global pollution (4.6 cents per litre), local pollution (2.4 cents a kilometre) and congestion (6.8 cents a kilometre) are taken from the text of this report. For externalities from accidents no local estimate exists so the estimate of Parry and Small (3.4 cents a kilometre) is used.

The Breunig and Gisz (2009) estimates for the own-price elasticity of fuel (-0.21) are used. Since local estimates of the elasticity of kilometres travelled with respect to the price of fuel and income are unavailable the estimates of Parry and Small are used. Thus the income elasticity is assumed to be 0.6 and the price elasticity was, as in Parry and Small, assumed to be 0.4 of the own-price elasticity of fuel.

The estimates of Parry and Small for the uncompensated and compensated labour supply elasticities (0.2 and 0.35) are used. Although there are many estimates of the labour supply elasticity for Australia, modern work tends to apply a single data set to estimate a labour supply elasticity for a single group of workers such as single women (Dandie and Mercante, 2007). Buddelmeyer et al (2007) do report, in their Table 1.1, one set of consistently-generated elasticities. A weighted (by numbers in the labour force) estimate of the labour supply was used using three of the four groups in Buddelmeyer. This yielded an estimate for the uncompensated elasticity of 0.35. This is slightly higher than that used by Parry and Small. However, as a matching compensated elasticity of demand was unavailable the estimates of Parry and Small were used.

The values used by Parry and Small were in $US for 2000, so the year 2000 values were converted to Australian dollars using PPP exchange rates (Heston et al, 2006) and then converted to 2008 dollars using the CPI.

Our base estimate of fuel economy is for a 2000 Holden Commodore from www.drive.com.au. We chose this model as being typical of an older car on the road. Parameter estimates are summarised in the **Table**.

Table: US and Australian Data for the Parry and Small model

Parameter	US Estimate	Australian Estimate	Source of Australian Estimate
Producer price petrol	94 cents per gallon	60 cents per litre	Average Terminal Gate Price, less fuel excise for December, 2008. Australian Institute of Petroleum.
Base fuel tax on petrol	40 cents per gallon	38.143 cents per litre	Fuel Excise value.
Base fuel efficiency.	20 miles per gallon.	9.09 kilometres per litre	Fuel efficiency of a 2000 Holden Commodore, reported on www.drive.com.au
Government expenditure as share of labour income	0.35	0.52	Share of individual and indirect taxes (from *Budget Papers* no. 1, 2008-09) in total compensation of employees (ABS 5206.0 Table 34) for 2006/07
Share of expenditure on petrol	0.012	0.0156	Annual sales of automotive gasoline (Table 3A of *Australian Petroleum Statistics*, January 2009) for 2008, multiplied by average producer price for 2008 less the excise, divided by the Gross National Expenditure for 2008 (Table 3, ABS 5206.0)

Results of the analysis are provided in the text, Section 3.

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