Exploring the Impacts of Fuel Price Increases on Public Transport Use in Melbourne

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1   Introduction

> "Public transport the ticket as petrol goes crazy - Melbourne is facing what could become its greatest petrol crisis as prices surged towards $1.40 this week and motorists, governments and transport experts scrambled to respond. Transport Minister Peter Batchelor yesterday confirmed that petrol prices were causing a jump in public transport use, leading to questions about whether the system could cope with an influx of commuters."
>
> <div align="center">The Age (September 10, 2005)</div>

There is widespread concern about the increasing price of petrol and how it is affecting the economy. Much media interest has focused on how increasing fuel prices have acted to increase public transport demand although these reports are not based on any robust analysis. This paper undertakes a statistical analysis of the relationship between recent fuel price changes and increases in public transport demand through an analysis of data collected for the Melbourne public transport system. It starts with a review of evidence on impacts through a review of international studies in this area and a compilation on measures of cross elasticity of demand i.e. the demand for public transport as affected by the price of fuel for auto travel. Section 3 describes the context for the study, the public transport system and market in Melbourne, Australia. Section 4 outlines the methodology for the analysis of the Melbourne data and section 5 describes the main findings of this analysis. The paper concludes with a discussion of the implications of these findings and some suggestions for further research.

2   Previous Research

The impact of auto fuel price on public transport demand has most commonly been measured in terms of the cross elasticity of demand (e). The most recent Australasian work in this area was by Wallis and Schmidt (2003) who recommended the following values:

- A typical value of 0.15 should be assumed (with a range of between 0.07 and 0.30)
- Values in the peak are two to three times of off peak values and broadly double all day values
- Values tend to be higher where public transport has a low base (e.g. Australian and the US) whilst they are lower where there is a higher mode share base (e.g. Europe).

The value of e = 0.15 recommended by Wallis and Schmidt suggests that broadly speaking a 10% increase in fuel price will increase public transport demand by 1.5%. Their suggestion that peak values may be considerably higher is significant since this is the time when capacity on many Australian urban rail systems is most stressed.

Table 1 presents a summary of auto fuel price and public transport demand cross elasticity evidence. It is clear that there is a wide range of evidence and experience. The contention that e values in countries with lower mode shares are higher is not well supported in this data. Rather a mixed picture is apparent. The only specific values for the Melbourne context are 0.70 for rail (Booz Allen Hamilton, 1999). This is at the higher end of the evidence range.

Table 1 : Fuel Price – Transit Demand Cross Elasticity Evidence

Source/ Context	Trip Type	Cross Elasticity Values		
		Short Run	Long Run	Not Stated
Australian/New Zealand (Low Transit Mode Share)				
Wallis and Schmidt (2003) Australasia	Typical Range	0.15 0.07-0.30		
Booz Allen Hamilton (1999)[1] Melbourne – Time Series 1978/79-1995-96)	Rail			0.70
Taplin et al (1999)[1] Sydney – Stated/Revealed Preference surveys		0.17		
Willis (1994)[1] Adelaide – Time Series (1985-1993)	Linear model Log model			0.44 0.35
Bray (1995)[1] Australia – literature review		0.07		
Luk and Hepburn (1993)		0.10		
Booz Allen Hamilton (2001)[1] Wellington – Time series (1998-2000)	All Day Peak Off Peak	0.18 0.29 0.11		
Travers Morgan (1990)[1] New Zealand – Time Series(1974/5-1988/9)		0.07		
Other Low Transit Mode Share Countries				
Wang and Skinner (1984)[1] USA				0.08-0.80
Kocur et al (1982)[1] USA – Mode Choice Modelling		0.25-0.45		
High Transit Share Conditions				
Dargay and Hanley (2001) UK – Bus Motoring Costs	Metropolitan Areas	0.34		
Hanley et al (2002) UK	Urban Rail Urban Bus	0.35 0.72		
Rail Industry Forecasting Framework UK Rail	Rail			0.22
TRACE (1999) Europe	Commuting Business Education Total			0.20 0.24 0.01 0.13
De Jong and Gunn (2001)[1] Europe – many studies (1985-2001)	Overall Commuter HB Business Education Other	0.33 - 0.17 - 0.48	0.07 0.12 0.03 0.14 0.07	
Goodwin (1992)[1] UK – 5 studies pre 1992	Overall			0.34 (0.08-0.80)
Boulahbal and Madre (2000)[1] France – Time series 1975-1995	Overall	0.10	0.19	
Storchmann (2001)[1] Germany – modelling 1980-1998	Overall	0.07		
Algers et al (1995)[1] Sweden – transport model	All Trips Work Trips			0.06 0.09
Bovy et al (1991)[1] Netherlands	All Transit Rail	0.14 0.26		

Note: [1]These values quoted from Booz Allen Hamilton (2003)

In general the contention that peak values are higher than off peak is supported by this data. There is some suggestion that bus values may be higher than rail (from the UK evidence of Hanley et al, 2002) although it is unclear if this will be relevant to Australian/lower mode share contexts. Litman (2004) suggests that modal variations in elasticities are largely the

result of the different markets which they serve. There is evidence that groups who are more dependent on transit are less price sensitive than those who have a car available for trips.

There is also a mixed picture of e values for short run and long run conditions. As Wallis and Schmidt (2003) note: "the weight of international evidence indicates that , for most variables, elasticities over the longer term are 1.5 to 3.0 times larger than the short term responses". However as Table 1 suggests it is unclear if this will apply to *e* as in some cases *e* increases in the longer term and in others it declines.

Overall this evidence suggests *e* probably lies in the range of 0.07 to 0.80 and that peak values could be two to three times higher than this. Other evidence is unclear and/or may vary considerably by the conditions where fuel prices are increasing. This is an inordinately wide range for scoping market responses. It suggests that the market response to a fuel price increase of 30% will range from between 2.1% and 24%!

3   Context

Melbourne Australia has a residential population of 3.6M (ABS, 2003) with a low urban density (462 people per km^2). The city has an extensive heavy rail, light rail and bus network. Heavy rail services cover some 372 kms of track on 15 lines and 209 stations. Light rail services, primarily streetcars, have 250 route kms of service over 40 routes. Some 230 bus routes cover the majority of the suburban residential catchment. An unusual feature of the Melbourne system is its light rail/tram service which is one of the largest in the world. Together with heavy rail, light rail acts to provide the primary CBD radial access function. Bus services provide suburban access and cross corridor service in low density areas.

Table 2 shows reported transit usage in Melbourne between 2002 and 2005 and the relative level of fuel price over this period. Total transit boardings have increased by 5.2% but rail has been particularly high (at 9% for heavy rail and 7.9% for light rail/tram). Bus declined during this period by 4% (although there has been some recalibration of demand estimation methods during this period).

Table 2 : Transit Usage and Auto Fuel Price – Melbourne, Australia

Demand/Price	Year		
	2002-3	**2003-4**	**2004-5**
Total Transit Boardings (M p.a.)	362.4	364.4	381.3
Heavy Rail Transit Boardings (M p.a.)	133.8	134.9	146.0
Light Rail/Tram Boardings (M p.a.)	134.7	135.9	145.3
Bus Boardings (M p.a.)	93.9	93.6	90.0
Average Fuel Price (Cents, nominal)	89.40	91.10	100.90

Source: Department of Infrastructure Annual Reports 2002-3 to 2004-5. Note these indicate a different methodology for calculating patronage in the 2004/5 data
Australian Automobile Association (2006) – Melbourne average auto fuel price.

These changes occurred during a period where annualised auto fuel prices increased by 7.5% (in nominal terms). This is suggestive of a broad (shrinkage ratio point) cross-elasticity for total demand (*e*) of around 0.7 with values of 1.2 for heavy rail and 1.0 for light rail. However none of these estimates include an allowance for 'real' (inflation adjusted) changes in fuel costs and other factors affecting patronage such as population growth.

The decline in bus boardings during this period is interesting since it contrasts with expectations and also with changes in rail based demands. Bus markets in Melbourne are dominated by 'captive' riders i.e. those with no choice to travel but by bus. Some 69% of

bus users have no driving licence available; 83% have incomes under $10,000 p.a. (DoI, 2005b). Rail markets are dominated by 'choice' passengers who tend to have cars available; 60% of heavy rail and 64% of light rail passengers have incomes above $10,000 p.a. (DoI, 2005b). It can be theorised that people who own cars are more likely to be directly sensitive to changes in fuel price. These findings tend to support such a hypothesis. However even captive markets can be influenced by auto fuel prices changes if it causes a reduction in lift giving. Clearly these are issues of interest in the data analysis.

4   Methodology

The approach adopted examined direct impacts of fuel price on transit usage. This approach simplifies the real world influences on transit demand. In practice the level of fares, changes in service levels and other factors such as traffic congestion affect transit usage. The simplified approach assumes these other factors are generally constant and that auto fuel price is the major driver of demand. This approach also omits consideration of feedback issues such as any raising of fares associated with higher fuel costs and any follow on impacts which this may have on demand. These were considered minor issues since fare changes in Melbourne are tied to CPI increases. Nevertheless the omission of these influences could act to inflate values for cross elasticities obtained.

4.1   Source Data

Market demand source data was kindly provided from Metlink, Melbournes agency responsible for collecting ticketing information and marketing. The data was monthly usage of public transport by mode between the period January 2002 to December 2005. The data is ticketing system validations which is only a representative sample of total demand. Longer term periodical tickets do not require validation although these are only a small share of patronage. Ticketing validations are only a small proportion of tram boardings (possibly as low as 30%) due to fare evasion hence validation rates may be sensitive to changes in ticket checking policies. Heavy rail and bus validation data is known to be a more reliable representation of patronage.

Fuel price data was obtained by month for the Australian Automobile Association representing Melbourne Average prices.

A number of adjustments to the demand and price data series were made to represent wider market and price influences over the period:
- Market demand data (validations) were adjusted for changes in residential population during this period. Annualised residential population estimates were sourced from the Australian Bureau of Statistics (2005a). During this period residential population increased by 4.7%
- Average auto fuel prices were adjusted for inflation through the application of the Consumer Price Index for Melbourne (ABS, 2005b).

The outcome values are real auto fuel price changes and per capita validations. Figure 1 shows the values for the data series.

A number of observations regarding this figure are:
- All transit demand values are highly seasonal. Clearly analysis will have to account for seasonality.
- Bus and tram demand figures suggest either a flat trend or an average decline over the series
- Fuel price is not consistently increasing. Rather there are peaks and troughs. Although there is trend for growth this growth is modest for the early half of the series (part A) and greater in the later half of the series (part B)

- Although seasonality obscures the relationship between demand and fuel price; heavy rail in particular appears to have a close relationship based on visual inspection.
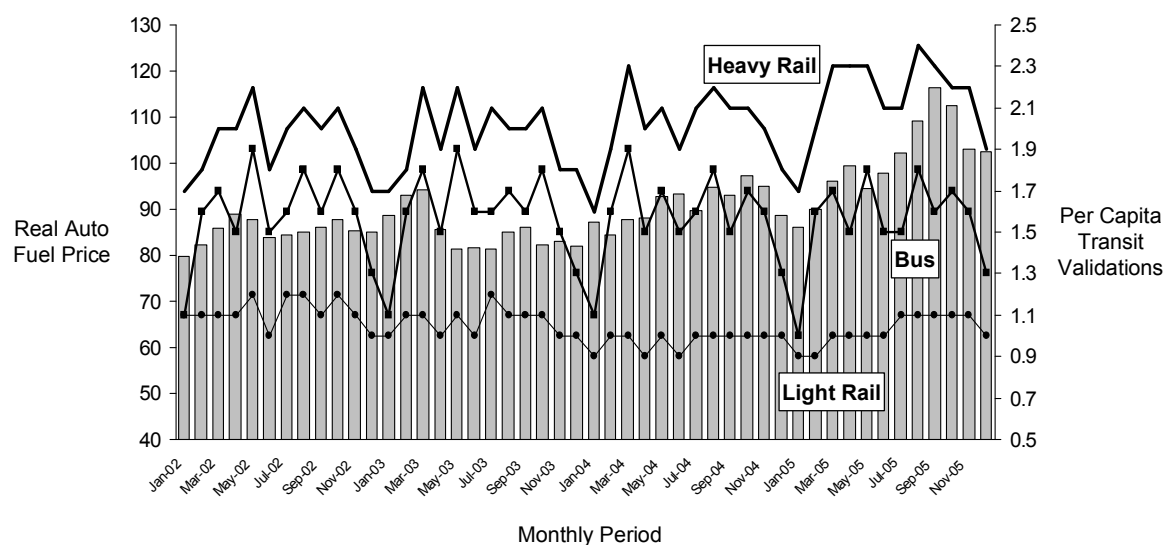

Figure 1 : Real Auto Fuel Price and per capita Transit Validations - Melbourne

4.2 Analysis Aims

The aim of the analysis is to explore and quantify cross elasticities of public transport demand with respect to auto fuel price. Five separate types of analysis were undertaken:
1. <u>Transit Mode Disaggregation</u> – Cross elasticities were to be identified :
    i. Aggregate – for all transit modes
    ii. Aggregate minus Tram – for all transit modes excluding tram because tram validations were known to be a potentially unreliable representation of demand
    iii. Heavy Rail
    iv. Tram
    v. Bus
2. <u>Fare Disaggregation</u> – validation data could be readily separated into type of fare. The following were selected for analysis:
    i. Full Fare – since these are known to be more closely representative of higher income 'choice' riders
    ii. Concession Fare – since these are known to be more representative of lower income 'captive' riders.
3. <u>Short-Medium Term Analysis</u> – Because the fuel price changes were higher in the second half of the analysis period cross elasticities were separately analysed for:
    i. Period A – Short Term - Jan 2002 to Dec 2003
    ii. Period B – Short Term – Jan 2004 to Dec 2005
    iii. Medium Term – Jan 2002 to Dec 2005.

In addition two other areas were investigated as part of the analysis:
4. <u>Time Lag Effects</u> – Analysis aimed to explore if fuel price affected demand with some element of time lag. Notionally this appears a reasonable hypothesis since a car owner may take some time to adjust travel habits in response to fuel price changes.
5. <u>The Dollar Threshold Effect</u> – The nominal price of fuel increased over the $1.00 a litre level during the analysis period. Much media attention surrounded the occasion when this threshold was broken. Analysis explored if the market impacts of fuel price changes around this level were significantly different from other periods.

4.3   Analytical Approach

The aim of the analysis was to establish elasticity values hence a log log model form was adopted. Arc elasticities were calculated as follows:

$$e = \frac{\partial Q}{\partial P} \times \frac{P}{Q} = \frac{\partial \ln(Q)}{\partial \ln(P)} \qquad \textbf{[Formula 1]}$$

Where:
    e = elasticity
    P   = real auto fuel price
    Q   = per capita validations

A regression elasticity model was developed with the following form:

$$\ln(Q_t) = \alpha + e\ln(P_t) + \sum_{i=1}^{11} \beta_i M_i + \varepsilon_t \qquad \textbf{[Formula 2]}$$

Where:
    α = Intercept parameter – estimated in the model
    β = Parameter for each monthly dummy variable
    M   = Monthly dummies, takes a value of 1 in the corresponding month and 0 otherwise. Base month is December, where it takes values of 0 for all dummies.
    ε = Error term
    i = Month index – 1 to 11, December is excluded as it is the base month i.e. all monthly estimates are relative to December.
    t = Time index

The monthly dummy variables enable seasonality to be modelled.

The following tests/measures were used to check model validity and parameter significance. All statistical tests were performed at the 5% level of significance. :
- Logic test : this checked whether the estimated coefficients were consistent with expectations i.e. positive or negative values
- Coefficient of Determination (R^2) : This measures the percentage of variation in the response (dependent) variable by the group of explanatory (independent) variables. Models with R^2 closer to 1.0 represent a better fit. When comparing models with a different number of parameters, the adjusted R^2 is used instead, as it takes into account the number of parameters.
- F-statistic: a statistical measure used to test whether the estimated coefficients as a whole is statistically different from zero. The cut-off mark depends on the degrees of freedom
- T-statistic: a statistical measure used to test whether the estimated coefficients individually are statistically different from zero. The cut-off mark is 1.96 at the 5% level of significance, i.e. a coefficient with a t-stat less than 1.96 is said to be statistically insignificant or statistically indifferent from zero

Tests also considered auto correlation which can tend to inflate R squared values in time series analysis. This was considered a minor issue since seasonality was the major factor involved in the data series. Fuel prices were not related to seasonality.

5   Results

5.1   Mode, Fare Type and Short/Medium Term Analysis

Table 3 shows the results of the modelling for Mode, Fare Type and Short/Medium term analysis. This indicates that:

For Transit Modal Analysis (medium term):
* Over the medium term, only the 'heavy rail' and 'aggregate no tram' models were significant with cross-elasticity estimates of 0.475 and 0.217 respectively. R^2 values were also high at 0.87 and 0.93 respectively.

For Fare Type Analysis (medium term)
* All cross elasticity estimates for full fare paying passengers were higher than those for concession fare paying passengers. For the 'aggregate no tram' model cross elasticities for full fare paying passengers were 0.319 and concessions 0.126 suggesting full fare paying passengers are 2.5 times more sensitive to fuel price increases than those on concessions.
* There was only a slightly higher cross elasticity for full fare paying heavy rail passengers compared to those with concessions
* Some negative cross elasticity estimates emerged, these were clearly due to data inaccuracies. They particularly affect tram and hence might be reasonably related to known problems in associating ticket validations with demand on trams.

Table 3 : Cross-Elasticity Results – Mode, Fare and Short/Medium Term Analysis
(Note : Significant Values Indicated in Bold
***t* statistics in parenthesis)**

Model Type	Short/Medium Term Analysis		
	Medium Term	**Short Term (A)**	**Short Term (B)**
i. Aggregate (All Transit Modes)			
Total	0.089 (1.478)	0.026 (0.153)	**0.353 (3.267)**
Full Fare	0.024 (0.313)	0.101 (0.595)	**0.430 (3.432)**
Concession	0.060 (1.055)	0.051 (0.289)	**0.279 (2.614)**
ii. Aggregate No Tram (Train and Bus Only)			
Total	**0.217 (3.891)**	0.121 (0.703)	**0.319 (2.839)**
Full Fare	**0.319 (5.066)**	0.260 (1.616)	**0.432 (3.139)**
Concession	**0.126 (2.368)**	0.062 (0.343)	**0.225 (2.154)**
iii. Heavy Rail			
Total	**0.475 (7.023)**	0.156 (0.920)	**0.537 (3.528)**
Full Fare	**0.479 (6.855)**	0.242 (1.462)	**0.539 (3.333)**
Concession	**0.464 (6.703)**	0.041 (0.224)	**0.525 (3.268)**
iv. Bus			
Total	-0.116 (-1.952)	0.091 (0.500)	0.028 (0.226)
Full Fare	**-0.224 (-2.851)**	**0.327 (1.961)**	0.055 (0.377)
Concession	-0.069 (-1.193)	0.089 (0.464)	0.044 (0.375)
iv. Tram			
Total	-0.225 (-1.809)	-0.088 (-0.310)	**0.542 (5.763)**
Full Fare	**-0.602 (-3.536)**	-0.010 (-0.033)	**0.484 (4.418)**
Concession	-0.126 (-0.976)	-0.046 (-0.154)	**0.663 (6.049)**

For the Short/Medium Term Analysis:
- Almost all the values for the Short Term (A) (early half of the data series) were not statistically significant.
- The estimates for the period Short Term (B), where considerably higher increases in fuel price occurred, had significant and high cross elasticity values. 'Heavy rail' values (total) for Short Term (B) were 0.537 and 0.319 for the 'aggregate no tram' model.
- Medium term measures were all below this short term figure, however this is almost entirely due to the lower increases in fuel prices in the earlier part of the data series combined with the higher values in the later parts of the data series. The medium term values in this case are representative of medium term values relative to the Short Term (A) series. They cannot be compared as medium term extensions of the Short Term (B) series since Medium term values relative to this set will occur after 2005.

5.2   Time Lag Analysis

Time lag analysis aimed to explore if fuel price affected demand with some element of time lag or offset in terms of months of effect between fuel price change and change in demand. Two sets of analysis were undertaken:
- Discrete Monthly Time Lag Analysis - estimation of cross-elasticities including a separate variable time lag off-set for each month of month 1 to month 12
- Multiple Monthly Time-Lag Effects – separate modelling of multiple time lags were undertaken to establish which combination of time-lags would produce a more accurate model outcome.

Figure 2 shows the results of the discrete monthly time lag analysis for the 'heavy rail' and 'aggregate no tram' models:
- All estimated values were significantly different from zero at the 5% level of significance
- In general elasticities are highest with a 7 month time lag for rail and 12 month for 'aggregate no tram' (although the 7 month value was also high for this model).
- The range of cross-elasticity outcomes is about 10-20% of the mean. It is unclear if any particular time lag is significant given the potential variability of the source data
- A separate analysis of these models for the full fare and concession fare sub-groups showed similar results for each.
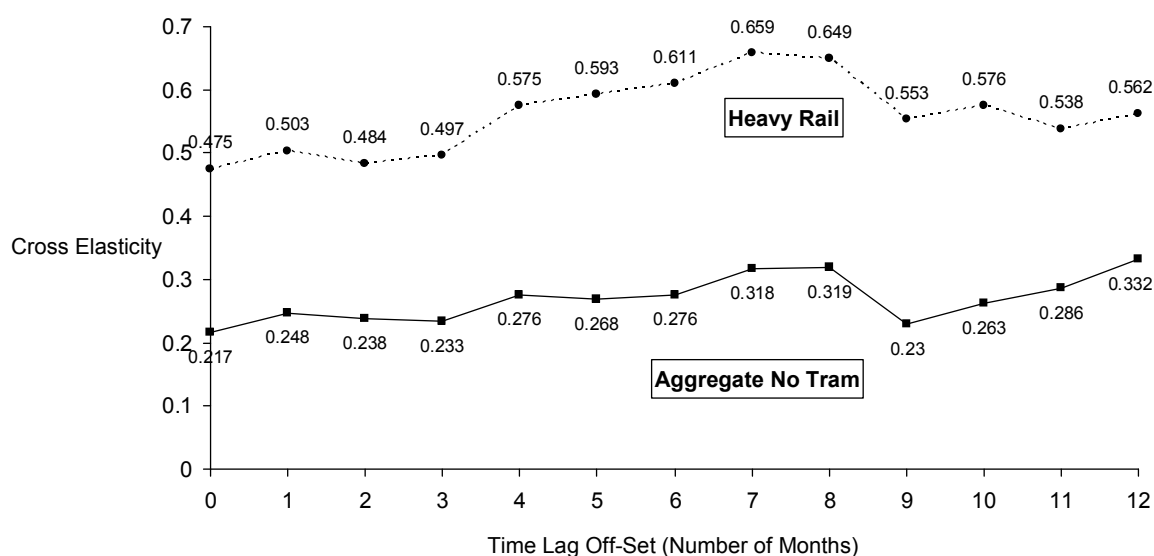

Figure 2 : Elasticity Estimates Based on a Discrete Monthly Time Lag

Analysis also considered multiple combinations of time lag effects by combining parameters in the model which represented monthly offsets. Multiple combinations of offsets were tested to see which provided the best model fit. The following models provided the best fit:

For the Heavy Rail Model

- A model including a 1 month, 4 month and 7 month time lag. This provided an adjusted R^2 value of 0.9 which compared to 0.87 for the total heavy rail model without offsets. It was also higher than the adjusted R^2 of any of the individual time lag analysis.

For the Aggregate No Tram Model

- A model including both a 1 month and an 8 month time lag. This provided an adjusted R^2 value of 0.94 which compared to 0.93 for the 'aggregate no tram' model without offsets. Again this adjusted R^2 value is the highest of any of the individual time lag analysis.

5.3 The $1 a Litre Threshold

When the fuel price, measured in cents per litre, reached a dollar there was much concern in the media that this represented an important threshold for car owners. The general sentiment was that this was the point at which 'serious' decisions needed to be made regarding the affordability of driving. This analysis aims to explore if the theoretical 'dollar threshold effect' has caused any particularly higher changes in public transport demand.

Figure 3 shows both the nominal (actual) price of auto fuel and also point cross elasticities measured for public transport demand around each monthly change in fuel price. The fuel price 'wavered' around a dollar on three occasions. It crossed the dollar mark on August 2004, October 2004 and (on a more consistent basis) from March 2005. In each case, point cross elasticities are not particularly different than for any other month. Certainly there is no obvious rush of demand to public transport around these points even allowing for a time lag.

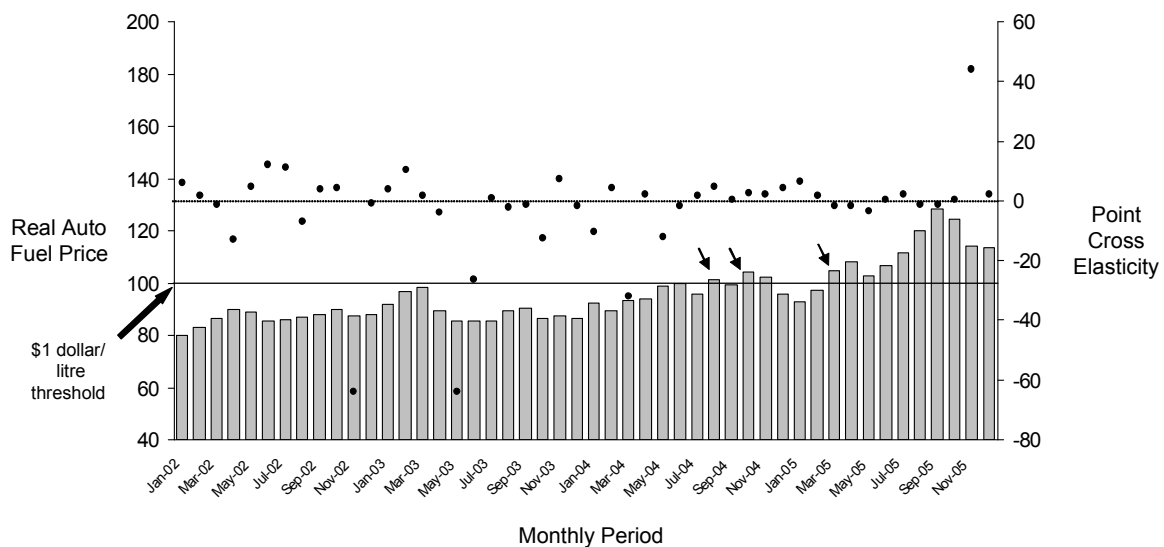Overall this analysis seems to disprove the $1 threshold effect theory.

Figure 3 : Exploring the $1/Litre Threshold Effect

6   Discussion

Medium term cross elasticities of public transport demand in Melbourne with respect to auto fuel prices have been measured at 0.45 for heavy rail and at 0.217 for bus and rail in aggregate. These values are higher than proposed by Wallis and Schmidt (2003) and other Australian sources but are consistent with the work of Willis (1994). This suggests that heavy rail demand might be expected to increase by 4.5% for every 10% increase in auto fuel price.

Short term (B) values are higher than medium term estimates with values at 0.537 for 'heavy rail' and 0.319 for 'aggregate no tram'. These are at the higher end of secondary research experience and more consistent with the high value for rail reported in Melbourne (0.7, Booz Allen Hamilton, 1999).

An interesting implication of these relatively high cross elasticity estimates for rail is the repercussions this may have for peak rail services. Wallis and Schmidt (2003) have suggested peak values are often twice those of all day values. This suggests that peak rail demand may be increasing by the same size of any fuel price increase i.e. *e* = 1.0. Clearly closer examination of peak and off peak market impacts will be worthwhile.

Tram and bus market analysis provided estimates of cross elasticities which were largely statistically insignificant. Reported values for bus were low. This is consistent with the market composition of bus which has a significant majority of passengers without access to a car. Reported tram cross elasticity values were somewhere between rail and bus. This is again consistent with tram patronage car ownership (which lies between bus and heavy rail).

Analysis of the full fare/concession fare data is also suggestive that passengers with access to a car (typical of full fare paying passengers) are more sensitive to fuel prices than those who are dependent on transit (the concession fares market). This supports the contention that those who own a car are more directly concerned with fuel costs. However it is interesting that this effect is less important for heavy rail; cross elasticities for full fare and concession fares on heavy rail were very similar. One might theorise that a car owners capacity to provide lifts to those without access to a car is less when fuel prices increase. This might be explained by less kiss and ride behaviour to rail in periods of higher fuel prices. Certainly park and ride and kiss and ride are major access modes to heavy rail in Melbourne (representing 20% and 15% respectively of all station access from home, DoI, 2005b). This suggests there is much capacity for behaviour changes of this type. In contrast park and ride and kiss and ride access to bus is some 2% and 5% respectively. This would suggest less of a capacity for these access modes to influence bus. This is partly supported by the substantially lower cross elasticities reported for concession vs full fare bus passengers. Clearly there is much scope to explore the market dynamics of fuel price impacts on rail and bus access behaviours through further research in this area.

Short term (B) cross elasticities were consistently higher than those reported for short term (A). This is something of a surprise since in general elasticities are thought to be constant (for a given time period) regardless of the scale of the increase in any explanatory variable. This finding could support an argument that cross-elasticities are increasing as rate of fuel price growth increases. This would be a very important theory if true. It might be suggestive of greater demand impacts into the future since fuel price increases are expected in the long term. However this theory is somewhat defeated by the lack of statistical significance of the Short Term (A) data. The case for additional research in this area is clearly warranted.

The analysis of time lag was suggestive of a 7 month high in expectations of lag and also of a combined 1, 4 month and 7 month lag. Future research should explore the behavioural dynamics of time lag impacts. It would be feasible for a user survey to target passengers who have diverted to transit as a result of fuel price increases such that the rationale and

dynamics of this change could be elaborated. In this way transit system providers might be better prepared for significant patronage boosts with a potential 4-7 month warning resulting from time lag effects.

The analysis also suggested there was no basis in this data to suggest the $1/litre threshold resulted in any particularly different impacts on transit demand. The theory that this threshold is a significant decision point for car owners is not supported by the analysis.

7 Conclusions

This paper has undertaken a statistical analysis of the relationship between recent fuel price changes and increases in public transport demand through an analysis of data collected for the Melbourne public transport system.   International evidence of fuel price cross elasticities was also reviewed. Much variability in reported values was found however values in Australian conditions were suggested to lie in the 0.07 to 0.80 range. Analysis estimated cross elasticity values for heavy rail at 0.475 and in aggregate (no tram) at 0.217. These are at the high end of reported values in Australian conditions. Short term values calculated from the last 24 months where fuel prices have increased by a larger margin where higher still; 0.537 (heavy rail) and 0.319 (aggregate no tram).

A number of areas for further research were identified:
- Peak and Off Peak cross elasticities should be examined particularly for rail. This research has supported a potential finding that peak rail elasticities could be as high as 1.0. This has significant and important implications for peak rail capacity planning; a major problem with Australian transit systems.
- The travel behavioural dynamics of fuel price changes should be explored with respect to those with access to a car and those without. The research has suggested park and ride and kiss and ride access to transit may be influenced by fuel price increases. The research should seek to understand how these changes affect travel behaviour patterns.
- The research has suggested the theory that cross-elasticities grow with the size of fuel price increases. This would be an alarming finding given the already stressed capacity of Australian public transport in the peak and the fact that fuel price increases are expected in the short, medium and long term.
- Some evidence of time lag influences between fuel price change and transit demand has been shown. It would be beneficial to understand how this occurs through behavioural research. It may be possible for transit providers to anticipate and plan for future capacity management if time lag effects can be predicted with greater certainty.

Acknowledgments

References

Algers S, Daly A, Kjellman P & Widlert S (1995) 'Stockholm Model System (SIMS): Application' Topic 25, *World Conference on Transport Research* 7th Conference

ABS, (2003) 'National Regional Profile – Melbourne Statistical Division' ABS cat. no. 1379.0.55.001

Australian Automobile Association (2006) Melbourne Average Auto Fuel prices. www.aaa.asn.au/issues/petrol.htm (Accessed Feb 2006)

Australasian Bureau of Statistics (2005a) 'Australian Demographic Statistics' ABS Cat No 3101.0

Australasian Bureau of Statistics (2005b) 'Consumer Price Index' ABS Cat No 6401.0

Dargay JM and Hanley M (2001) 'The Demand for Local Bus Service in England' *Journal of Transport Economics and Policy*, Vol 36 Part 1 p 73-91

Booz Allen Hamilton (1999) 'Melbourne Tram and Train Forecasts' for Serco Australia .

Booz Allen Hamilton NZ (2001) 'Wellington Fares Study' for Wellington Reregional Council 2001

Booz Allen Hamilton (2003) 'Passenger Transport Demand Elasticities ' for Transfund new Zealand January 2003

Boulahbal M and Madre J L (2000) 'Dynamic Analysis and Forecasting of Public Transport Demand Using a Combination of Demographic and Econometric Approaches' *European Transport Forum* Seminar K, PTRC

Bovy PHL, Van Der Waard J & Baanders A (1991) 'Substitution of Travel Demand between Car and Public Transport Possibilties' *PTRC* SAM Seminar H 1991

Bray D J & Associates (1995) 'Transport Strategy for Adelaide: Background Report' Transport Policy Unit, SA

de Jong G & Gunn H (2001) 'Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe' *Journal of Transport Economics and Policy* Vol 35 Pt 2

Department of Infrastructure (2003) Annual Report

Department of Infrastructure (2004) Annual Report

Department of Infrastructure (2005a) Annual Report

Department of Infrastructure (2005b) 'Understanding the Market for Public Transport Public Transport Division Feb 2005.

Goodwin PB (1992) 'Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes' *Journal of Transport Economics and Policy*, Vol 26 No. 2 p 155-186

Hanley M Dargay J Goodwin P (2002) 'Revoiew of Income and Price Elasticities in the demand for road traffic' Final report ESRC Transport Studies Unit Oxford 2002

Kocur G, Hyman W & Aunet B (1982) 'Wisconsin Work Mode-Choice Models based on Functional Measurement and Disaggregate Behavioural Data' *Transportation Research Record* 895, p 24-32

Litman T (2004) 'Transit Price Elasticities and Cross-Elasticities' Forthcomming in the Journal of Public Transportation

Luk J and Hepburn S (1993) 'New Review of Australian Travel Demand Elasticities' Australian Road Research Board Research Report 1993/12

Rail Industry Forecasting Framework () Passenger Demand Forecasting Handbook Version 4

Storchmann, KH (2001) 'The Impact of Fuel Taxes on Public Transport - An Empirical Assessment for Germany' *Transport Policy*, Vol 8, No 1 p 19-28

Taplin JHE, Hensher D A & Smith B (1999) Preserving the Symmetry of Estimated Commuter Travel Elasticities *Transportation Research Part B*, 33, pp 215-232

TRACE (1999) 'Elasticity Handbook: Elasticities for Prototypical Contexts' Prepared for the European Commission, Director General for Transport Contract No. RO-97-SC. 2035

Travers Morgan (1990) 'Urban Bus Study Stage 3: Analysis of Public Transport Patronage Trends'

The Age (2005) 'Public transport the ticket as petrol goes crazy' September 10 2005

Wang GH and Skinner D (1984) 'The Impact of Fare and Gasoline Price Changes on Monthly Transit Ridership: Empirical Evidence From Seven US Transit Authorities' *Transportation Research* 18B pp 29-41

Wallis I and Schmidt N (2003) 'Australian Travel demand Elasticities – An Update of the Evidence' *ATRF* 2003

Willis D (1994) 'Adelaide Public Transport Patronage Regression Study 1985-1993' Paper for Master of Transport Management, University of Sydney