Stimulating LEV Sales in Australia: Exploratory Analysis of Experiences in 15 World Cities

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QUT/AutoCRC Current Research Planning around LEVs

1. Preparing national surveys (across 4 countries) to assess market supply and demand issues
2. Working with auto manufacturer to focus on PHEVs
3. Working with energy company to focus on charging behaviour
4. Working with industry to examine inductive charging technology roll out strategies
5. Working with stakeholders to assess real world driving experiences/planned future purchase needs

Overall Aim of this Research

In support of planned Australian research (through Auto CRC), quantitatively explore data from multiple world cities in order to identify significant factors and their roles in influencing LEV market penetration (MP) rates

(Brief) Literature

- Fossil fuelled vehicles are the dominant form of personal transportation due to cost, availability and support infrastructure [1]
- Fossil fuel vehicles significantly contribute to global carbon emissions [2]
- MP rates are interdependent on technologies, infrastructure and consumer preferences [3]
- Consumers form preferences for vehicles based on observed performance of all technologies [1]

[1] Vooren, A. V. D., & Alkemade, F. (2012). Managing the Diffusion of Low Emission Vehicles. Engineering Management, IEEE Transactions on, 59(4), 728-740. doi: 10.1109/tem.2012.2185802

[2] Veazey, M. V. (2002). Low emission vehicle study. Materials Performance, 41(12), 13-13.

[3] Nishino, N., Iino, T., Tsuji, N., Kageyama, K., & Ueda, K. (2011). Interdependent decision-making among stakeholders in electric vehicle development. CIRP Annals - Manufacturing Technology, 60(1), 441-444. doi: http://dx.doi.org/10.1016/j.cirp.2011.03.048

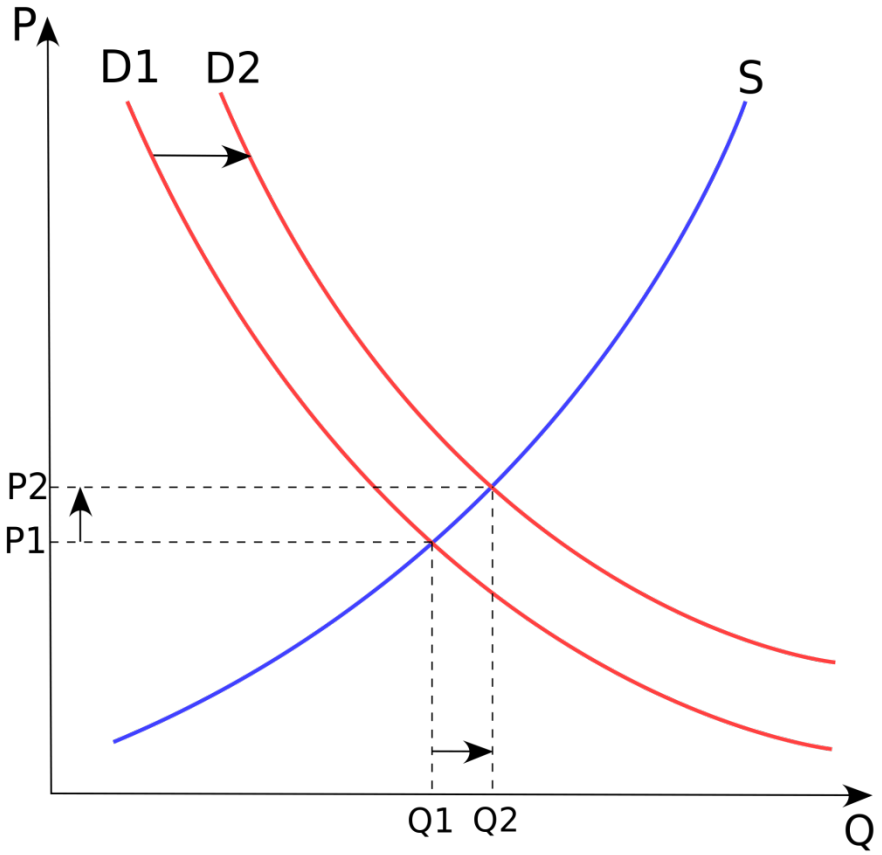
- A US study [1] on government policy impacts on MP of clean vehicles suggests that a combination of policies and costs with a **7-year payback period could double MP rates**. With the current US energy mix, EVs will not achieve CO2 targets; whereas ultra fuel efficient ICEs may (72mpg or greater).
- In a Swiss study [2] focused on MP of natural gas powered vehicles, the authors emphasize "*the influence of the height and timing of subsidies, tax reductions and other stimulation policies are not well understood*."
- A Canadian study [3] on MP of clean vehicles concluded that "*reduced monetary costs, [tax incentives], and low emissions rates would encourage households to adopt a cleaner vehicle. .., incentives such as free parking and permission to drive in HOV lanes….were not significant*."

[1] Barter et al. Parametric analysis of technology and policy tradeoffs for conventional and electric light-duty vehicles. Energy Policy 46 (2012).
[2] Janssen et al. Model aided policy development for the MP of natural gas vehicles in Switzerland. Trans Res Part A 40 (2006)
[3] Potoglou and Kanarglou. Household demand and willingness to pay for clean vehicles. Trans Res Part D 12 (2007)

- In a comprehensive review of current studies of LEV MP [1], the authors state: "*modelling of [LEV] MP rates should include improved interfaces with consumer surveys, modelling of automakers' actions,* ***federal and state policy and its effect on automotive markets****, competition among technologies,* ***market volume****, vehicle classifications, and model parameters sensitivity analysis.*"
- There are numerous MP studies in the literature:
  - Discrete choice studies of household-level vehicle purchase decisions
  - Time series studies of MP over time
  - Agent-based modelling studies
- **Very few** that recognize the possible simultaneity of supply and demand in the marketplace, and apply an **IV approach**

[1]Al-Alawi and Bradley. Review of hybrid, plug in hybrid, and electric vehicle market studies. Renewable and Sustainable Energy Reviews: 2013

Some Relevant Underlying Theory: Idealised Market Demand for Clean Vehicles



Demand is a function of price (perceived product value), and can be altered by government policies, prices, etc.

For example, a “free parking” policy might shift the demand curve to the right, from D1 to D2.

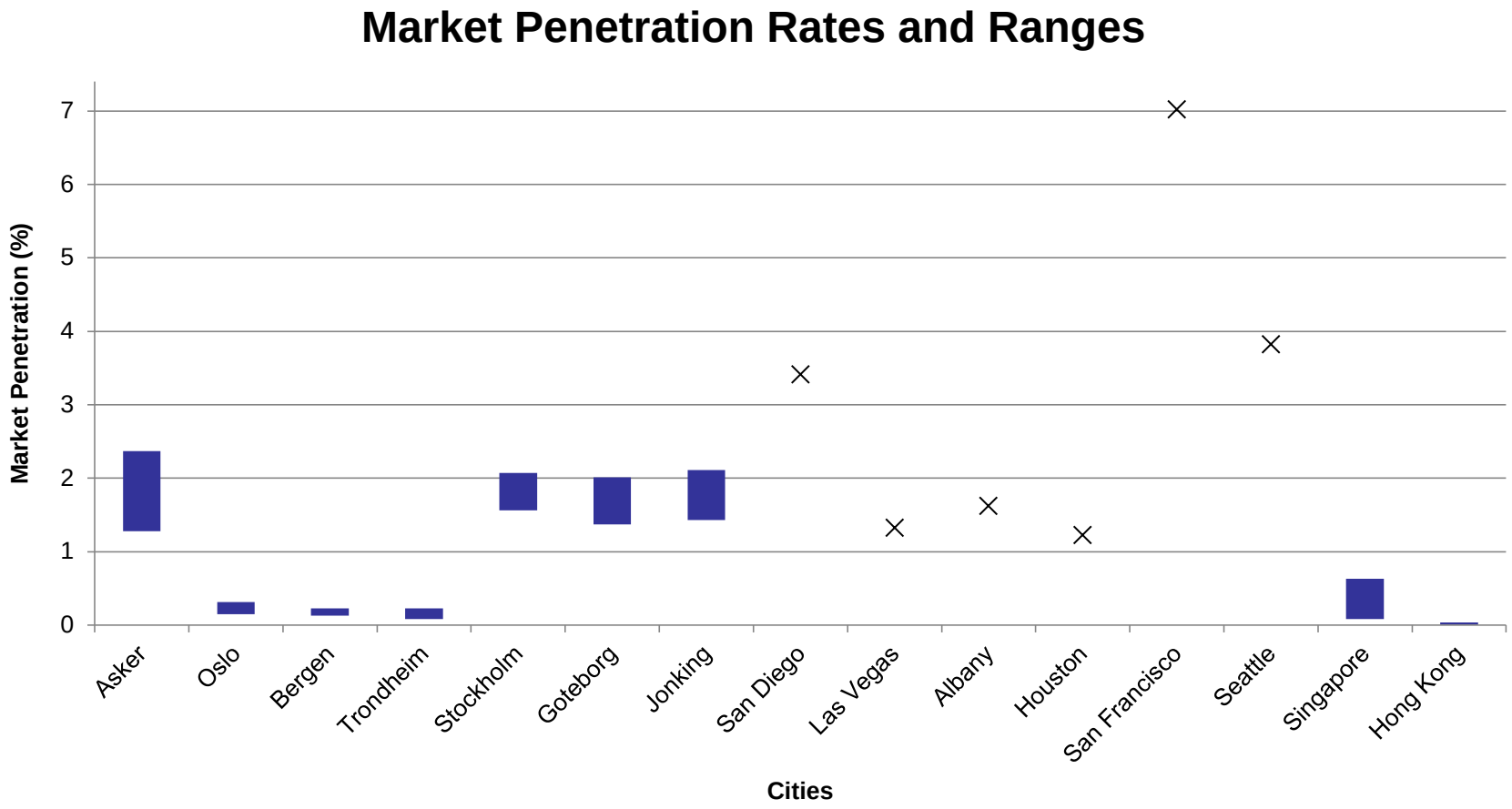
A shift to the right should increase the market penetration (Q1 to Q2), and the marketplace would respond by increasing the price from P1 to P2.

However, this view assumes there will not be a supply shift.

Specific aims and questions

1. Test for evidence of simultaneity in the MP data: (are demand and supply curves independent?)
2. Examine how a variety of market costs influence MP
3. Examine the role that government policies seem to play in MP

Background Data



SOURCES: Analys, Trafik. (2008-2012). Traffic Analysis. In Trafik Analys (Ed.).
Beresteanu, Arie, & Li, Shanjun. (2011). GASOLINE PRICES, GOVERNMENT SUPPORT, AND THE DEMAND FOR HYBRID VEHICLES IN THE UNITED STATES*. International Economic Review, 52(1), 161-182.
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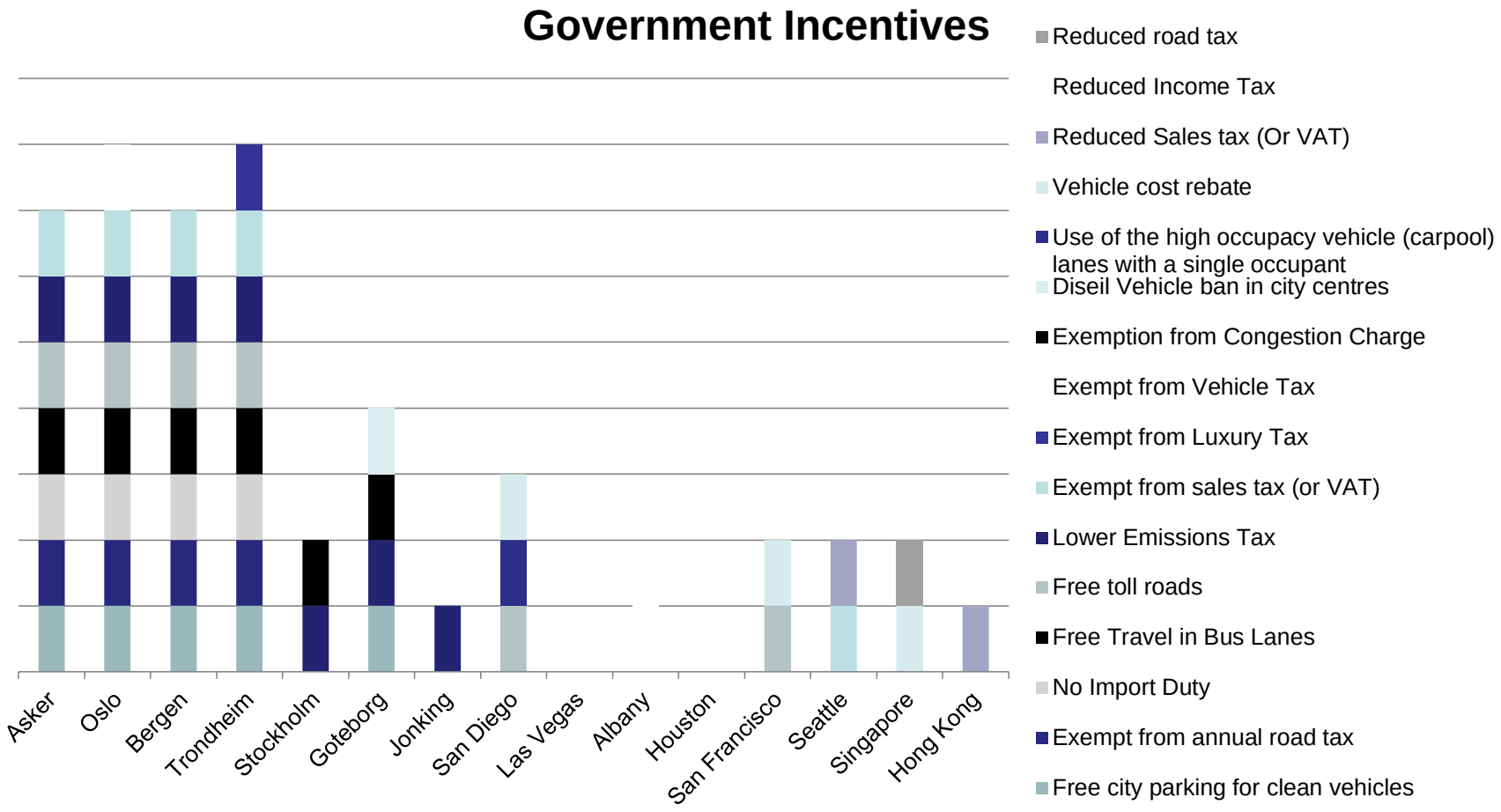
Continuous Data Available for Modelling

Pneumonic	Description	Measurement Units	Mean Value
MP	Market Penetration Rate	%	1.093
NR	Number of newly registered vehicles in the region	#cars	1281.4
TOTREG	Total number of newly registered vehicles in the region	#cars	192920
PCINC	Per Capita income for a given region	$USD	50934
POPDEN	Population Density for a given region	Population/km^2	11002
CRLCST	Manufacturer Retail Price for base model Toyota Corolla	$USD	33602
PRCST	Manufacturer Retail Price for base model Toyota Prius	$USD	46013
INFL	Inflation rate for a given region	%	2.368
FUEL	Average cost of fuel within a given region	$USD/Gal	5.9986
ClnCstPct	Clean Vehicle Cost (Prius) as a percentage of household income (proxy)	%	90.625
ClnVehSur	Premium placed on the cost of a clean vehicle as a percentage of the ICE vehicle (proxy)	%	38.1

Government Policy Data Available (indicators)



SOURCES: Beresteanu, Arie, & Li, Shanjun. (2011). GASOLINE PRICES, GOVERNMENT SUPPORT, AND THE DEMAND FOR HYBRID VEHICLES IN THE UNITED STATES*. International Economic Review, 52(1), 161-182.
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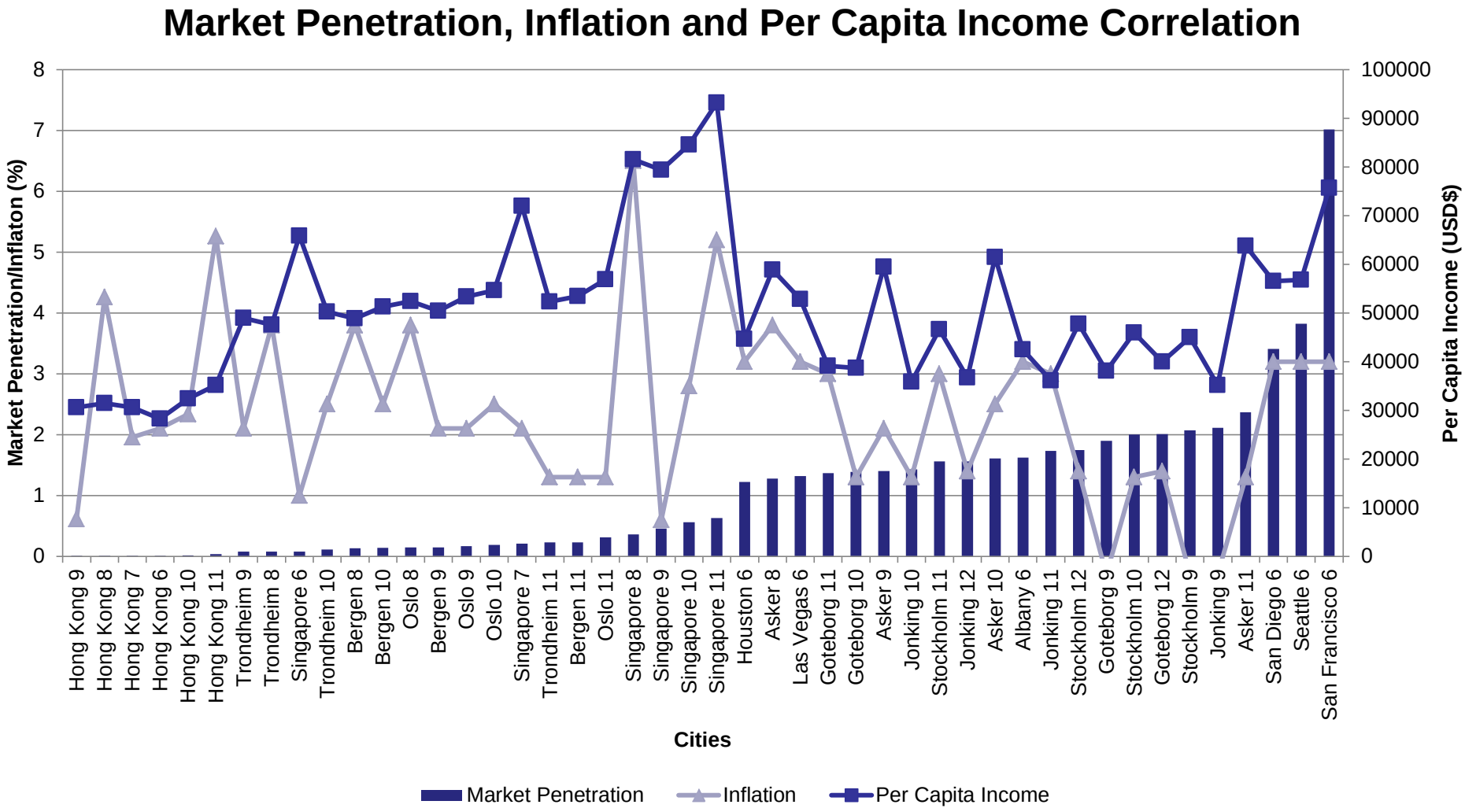
Singapore, National Environment Agency -. (2012). Green Vehicle Rebate, from app2.nea.gov.sg/topics_gvr.aspx

Background Data



Modelling Approach

- The assumption of independent supply and demand curves is first tested
- Supply variables are captured through a premium on a clean vehicle (proxied by relative price of the Toyota Prius to Corolla, base models)
- Demand side variables are captured by various cost variables
- We test policy indicators as having direct effects on demand (increase) or supply (through a price premium)

GMM Instrumental Variables Estimation of Simultaneous MP and Clean Vehicle Surcharge

```
Number of clusters (country) = 15                     Number of obs =       46
                                                      F(  6,    14) =    34.27
                                                      Prob > F      =   0.0000
Total (centered) SS     =   76.8553342                Centered R2   =   0.5761
Total (uncentered) SS   =   131.804206                Uncentered R2 =   0.7528
Residual SS             =  32.57626687                Root MSE      =    .8415

------------------------------------------------------------------------------
             |               Robust
 MrktPenRate |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   ClnVehSur |   .0777984   .0103209     7.54   0.000     .0575698    .0980269
   inflation |  -.2956262   .0668421    -4.42   0.000    -.4266343   -.1646182
    pcinc10k |   .4629396   .0850584     5.44   0.000     .2962283     .629651
     FTIR10k |   3.383409   .4415246     7.66   0.000     2.518037    4.248782
ClnVehCstPct |  -.0495685   .0072179    -6.87   0.000    -.0637154   -.0354217
  ReducedVAT |   .9737041   .1702029     5.72   0.000     .6401126    1.307296
    Constant |  -3.386457   1.064092    -3.18   0.001     -5.47204   -1.300875
------------------------------------------------------------------------------
Anderson canon. corr. LR statistic (identification/IV relevance test):  60.472
                                                      Chi-sq(4) P-val =    0.0000
------------------------------------------------------------------------------
Hansen J statistic (overidentification test of all instruments):         6.619
                                                      Chi-sq(3) P-val =    0.0851
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Interpretation of MP Model

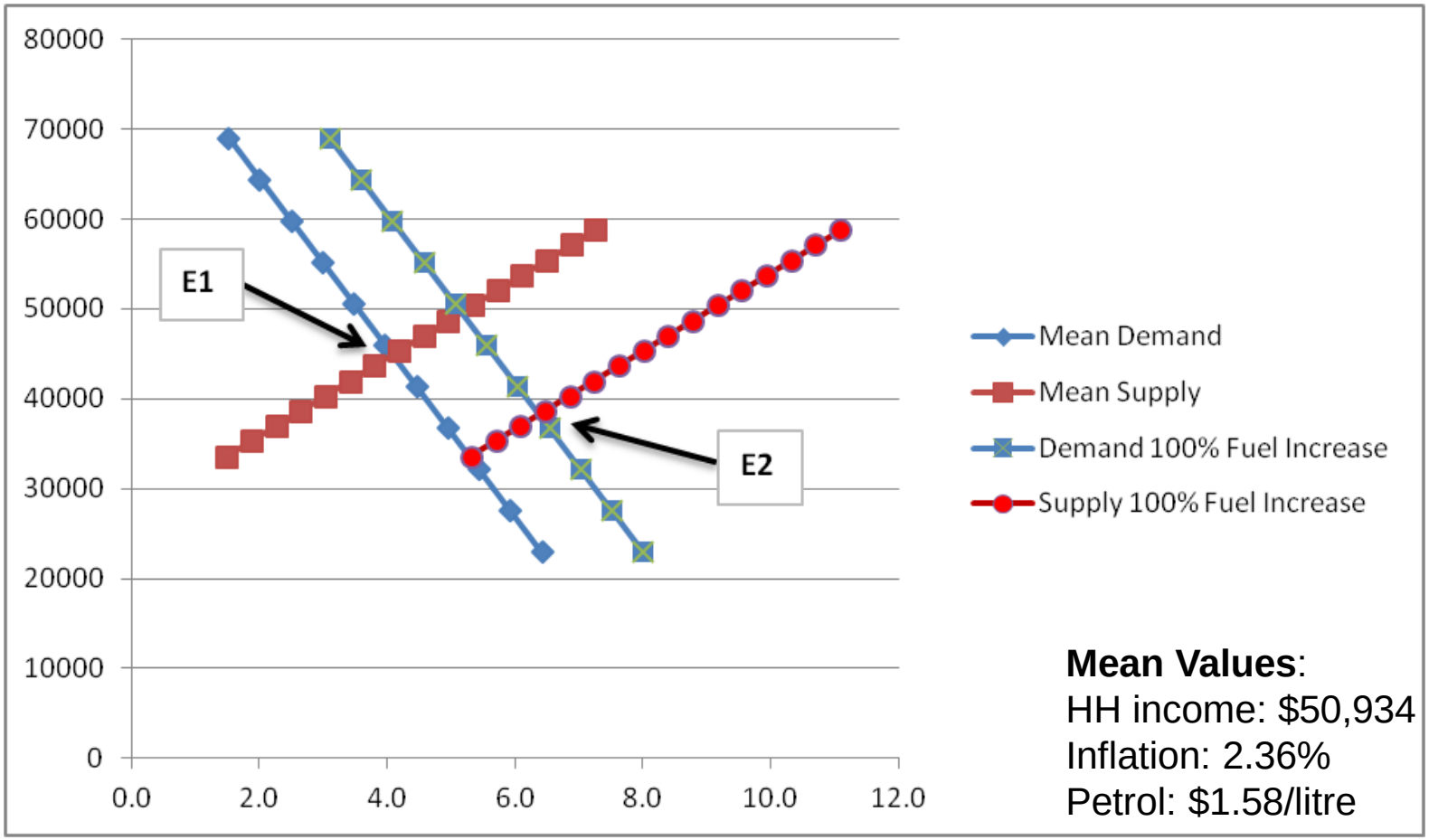
Market Penetration Cost Factors	Estimated Elasticity
Clean vehicle surcharge[1]	0.07% increase in MP per 1% premium increase
Per capita med income/10k	0.46% increase in MP per 10k increase in med income
Reduced sales tax (VAT)	0.97% increase in MP for a reduced sales tax incentive
Fuel cost per 10k income[2]	3.38% increase in MP per unit increase in fuel/10k
Clean vehicle cost (as a percentage of med hhinc)	0.05% decrease in MP per 1% increase in hh income
Inflation rate	0.29% decrease in MP per 1% increase in inflation

(1) The clean vehicle surcharge is endogenous. It captures the value of government policies on the price offered for the vehicle.

(2) fuel cost is in US dollars per gallon. Average fuel cost per 10k is 1.23

Clean Vehicle Surcharge (proxy) Policy Factors	Estimated Elasticity
Market penetration rate, %	7.6% increase in surcharge per 1% increase in MP
Reduced road tax	29.0% increase in surcharge
Reduced emissions tax	14.8% increase in surcharge
Exempt from sales tax	11.0% increase in surcharge

Model Implied Aggregate Supply and Demand Curves for Clean Vehicles (1 example)



Mean Values:
HH income: $50,934
Inflation: 2.36%
Petrol: $1.58/litre

Conclusions

- Increases in clean vehicle surcharge, fuel price (relative to income), household income, and reduced sales tax positively influence the clean vehicle MP
- Inflation and the cost of clean vehicles (relative to income) negatively influence the market penetration of clean vehicles
- Most clean vehicle government policies serve to 1) increase the clean vehicle premium price, then 2) increase market demand due to bundling of values and the simultaneity of supply and demand

Further Work

- A larger sample of cities is desired
- Better measurement of clean vehicle premiums, and *differentiation* among competing technologies is needed in updated modelling
- How to capture auto-maker constraints in modelling the supply curve would lead to improved ability to reflect industry factors (e.g. homologation costs)
- Sensitivity econometric improvements are desired
- It may be possible to monetise the government policy variables