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Modelling small-area electric vehicle uptake across Australia

David Mitchell[1], Robert Monterosso[1]

[1]Bureau of Infrastructure and Transport Research Economics,
Department of Infrastructure, Transport, Regional Development and Communications

Email for correspondence: david.mitchell@infrastructure.gov.au[1]

Abstract

Electric vehicles (EVs), while presently comprising only a small fraction of all registered vehicles in Australia, are expected to increase significantly over the next several decades as manufacturers increase the range and number of EV models available. The timing and spatial distribution of future EV uptake will have implications for electricity generation capacity and the infrastructure necessary to support distribution of electricity required to meet future EV energy needs. Ensuring adequate EV charging infrastructure is available in the right places will be integral to support future EV uptake.

There have been a range of studies that have investigated likely future EV uptake in Australia at national and state level, but few studies that have considered likely uptake at a more granular scale and none for the whole of Australia. This paper analyses current spatial EV uptake at small-area geographic scale across Australia, and estimates the relative importance of a range of socioeconomic variables and other relevant factors, such as EV charging infrastructure availability and installed rooftop solar generating capacity. The paper also uses the empirical results to estimate the likely future rate of EV uptake spatially across Australia. The results suggest that uptake is likely to be concentrated in higher-income and more populated areas of major capital cities. Uptake in non-urban and regional areas are likely to lag uptake in cities.

1. Introduction

Electric vehicles (EVs) presently comprise a small fraction of all registered vehicles in Australia, but the number of EVs entering the fleet is expected to increase significantly over the next several decades as vehicle manufacturers produce more EVs.

The rate of future Australia EV uptake remains uncertain and will depend on a range of factors. Key factors likely to affect future uptake include the price and operating costs of new EVs, overcoming consumer anxiety about EV driving range, and access to charging infrastructure. The spatial distribution of future EV uptake will have implications for electricity generation capacity and the supply infrastructure necessary to meet future EV energy needs. Ensuring adequate EV charging infrastructure is available where needed will be integral to support future EV uptake.

This paper analyses spatial EV uptake at small-area geographic scale across Australia, and estimates factors that most influence consumer demand for EVs, infrastructure options available for charging EVs, and socioeconomic factors likely to influence EV uptake rates across different regions.

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1. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Department of Infrastructure, Transport, Regional Development and Communications. The authors thank two anonymous referees for their constructive feedback. All errors remain the responsibility of the authors.

2. Current state of EVs in Australia

Australia's EV market is currently very small and uptake lags that of many other developed and some larger developing countries. In 2020, approximately 0.6 per cent of all new light vehicle sales in Australia were EVs, and less than 0.1 per cent of the light vehicle fleet were EVs. In comparison, EV sales comprised around 11.4 per cent of total new car sales across Europe in 2020, 5.4 per cent in China, and almost 75 per cent in Norway.

Surveys of consumer attitudes to EVs suggest several key factors are significant to the higher EV uptake observed in Europe, China and elsewhere, these include:

- the high up-front cost of EVs, relative to conventional internal combustion engine vehicles (ICEVs) – several states provide direct financial support for new EV purchase
- availability of a broader range of EV makes and models, catering to a wider range of consumers
- adequacy and availability of EV charging infrastructure
- EV driving range anxiety, which appears to be of great concern in Australia where average travel distances may be longer than in many other countries.

The literature also suggests that the cost differential between EVs and conventional vehicles will diminish over time. In particular, EV battery costs are projected to decline, which combined with increasing EV vehicle availability and greater competition, will help reduce up-front vehicle costs, thereby helping to accelerate the transition to EVs.

2.1 Electric vehicle sales

In 2020, there were approximately 6,900 new EVs sold in Australia (EVC 2020a), an increase of 15 per cent over calendar 2019 EV sales (5,940 vehicles) and a 200 per cent increase over calendar 2018 EV sales (approximately 2,300 vehicles) (Costello 2020; FCAI 2020; Dowling 2021). Over the 10 years 2011–2020, cumulative EV sales totalled around 22,600 vehicles (see Figure 1).[2]

The regional distribution of EV sales varies across states and territories. EV sales volumes are highest in the three largest jurisdictions (EVC 2019).

Over the same period, sales of non plug-in hybrid vehicle have increased from around 8,800 vehicles in 2010 to around 60,000 vehicles in 2020—cumulative sales of non plug-in hybrids over that period totalled 195,000 vehicles (BITRE estimates based on FCAI 2020).

2.2 Electric vehicle fleet

The Australian Bureau of Statistics (ABS) Motor Vehicle Census (MVC) reports the total number of EVs and HEVs on register was approximately 12,840 vehicles as at the end of January 2020 (ABS 2020).[3] The MVC also implies that approximately 50 per cent of all EVs on register in January 2020 were manufactured in calendar 2019.

BITRE (2021) reviewed the MVC data by make and model and noted the electric vehicle category includes around 3,250 non plug-in HEVs, such as the Toyota Prius, Camry and/or Corolla. BITRE (2021) also noted a further 2,400 EVs manufactured between 2010 and 2020 where the make and/or model is not recorded in the MVC—i.e. Unknown or Not applicable. BITRE (2021) notes that excluding non plug-in hybrids and electric vehicles where make and

2. These figures refer to plug-in electric vehicles (PEVs), which includes both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEV).
3. MVC estimates for 2021 imply total registered light EVs numbered 20,095 as at 31 January 2021.

model is not known reduces the number of registered known EVs to around 7,007 vehicles in 2020.

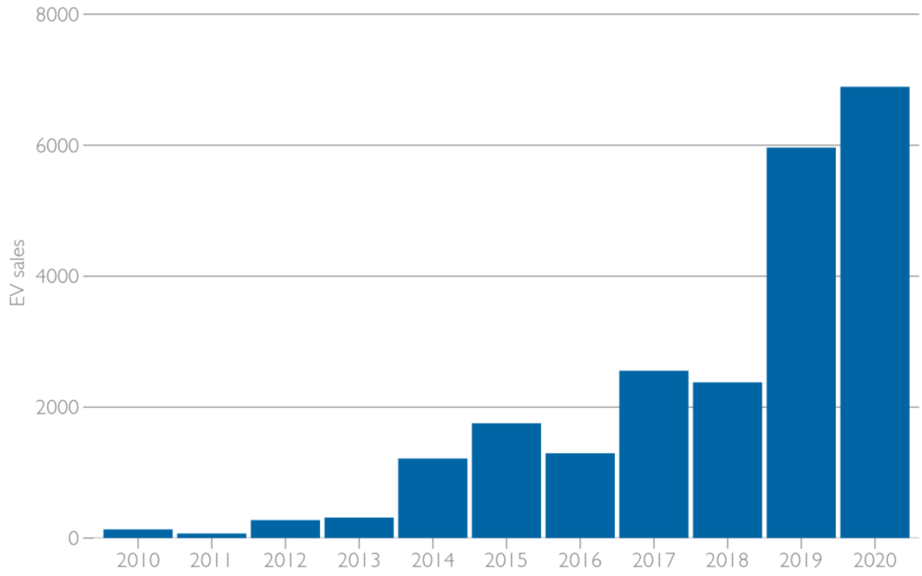


Figure 1: Annual EV sales in Australia, 2011–2020

Understanding the current and future uptake of EVs would be greatly improved by the collection of more accurate and comprehensive information about EV types by state and territory motor registries. The accurate collection and separate enumeration of BEVs, PHEVs and HEVs, and provision for potential future uptake of FCEVs, by state and territory motor vehicle registries (MVRs) will help better understand trends in Australia's future transport sector emissions, and transport's contribution to reducing Australian greenhouse emissions.

2.3 Spatial distribution of early EV uptake

Figure 2 shows estimates of electric passenger vehicles and LCVs on register between 2013 and 2020, by state and territory. Several features are immediately observable:

- electric vehicle uptake is strongest among the three largest jurisdictions—New South Wales, Victoria and Queensland
- electric passenger vehicle uptake dominates—there are few electric LCVs available
- the number of registered electric passenger vehicles grew significantly in 2020
- the Australian Capital Territory revised downwards the number of registered EVs in the territory by more than 2000 vehicles between the 2018 and 2019 MVCs.[4]

Figure 3 shows the spatial distribution of EV registrations by postcode across Australia in 2020, and highlights the concentration of EVs in Australia's larger urban areas. According to 2020 MVC data (ABS 2020), over 80 per cent of EVs and HEVs on register as at 31 January 2020, were in a postal area within one of Australia's major capital cities.

4. A comparison of the 2018 and 2019 MVC data, by make and model for the ACT suggests that most of these revisions involved re-classification of non plug-in hybrid electric vehicles, such as the Toyota Camry, Corolla and Prius, among others.

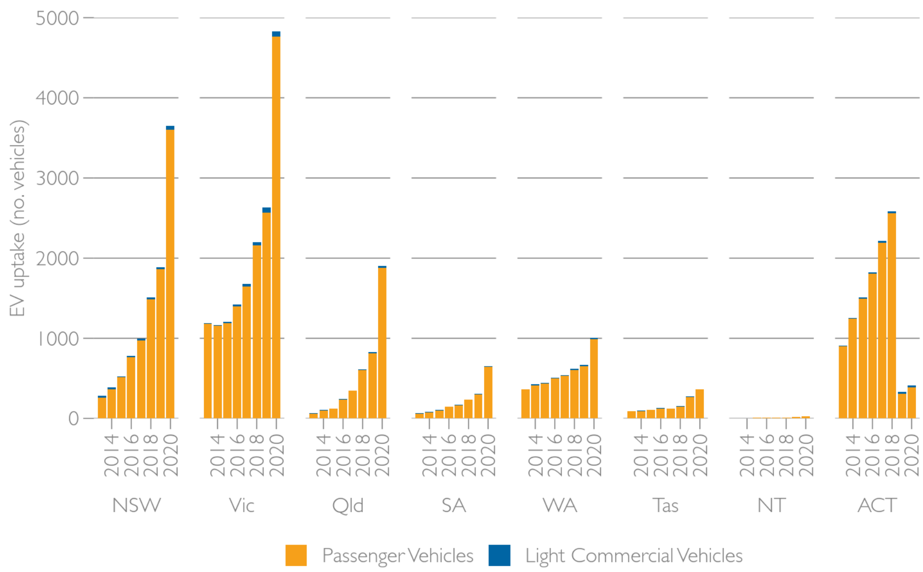


Figure 2: Raw registered light EVs by jurisdiction, 2013–2020

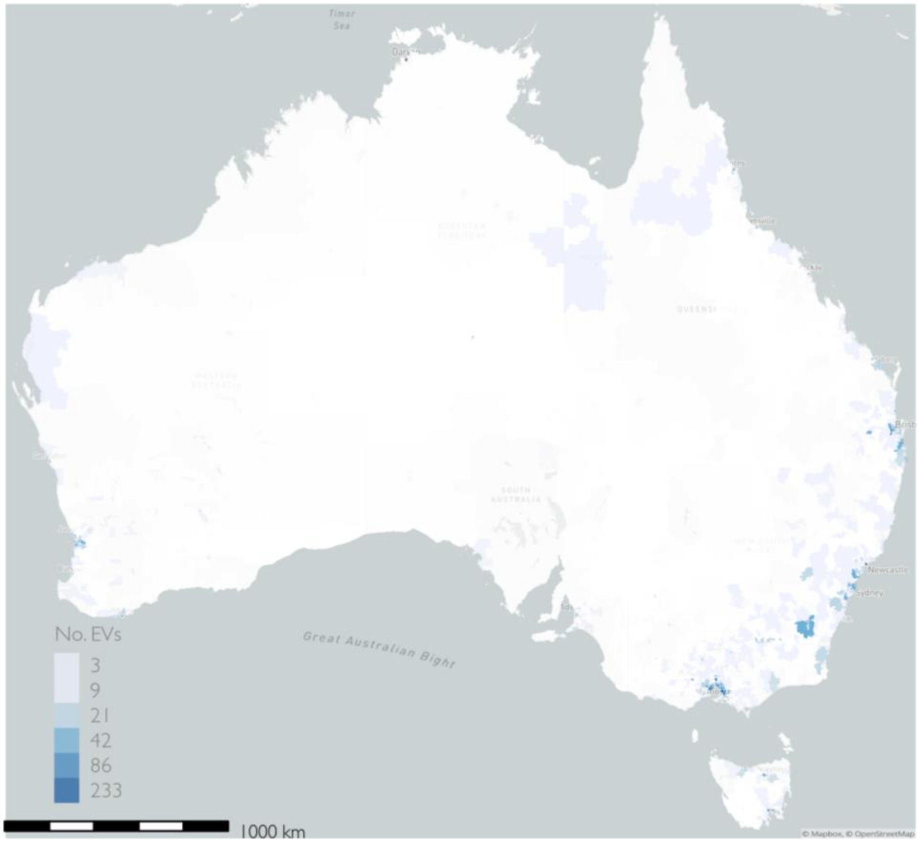


Figure 3: Spatial distribution of EVs in Australia, 2020

Table 2 shows the top 20 postcodes for registered EVs and HEVs in 2020, and associated suburbs. Postal areas with high reported EV uptake in 2020 include:

- Postcode 2304 – 233 EVs, which includes the suburbs of Mayfield, Mayfield West, Mayfield East, Mayfield North and Warabrook, and the industrial areas around the Port of Newcastle (including Kooragang Island)
- Postcode 3000 – 147 EVs, which comprises Melbourne CBD
- Postcode 2190 – 140 EVs, which covers Greenacre and Chullora, in Sydney. Chullora largely comprises light industrial and commercial operations.

- Postcode 5042 – 127 EVs, which includes the Adelaide suburbs of Clovelly Park, Bedford Park, St Marys and Pasadena, and also the former Mitsubishi Motors assembly plant—now the Tonsley Innovation district
- Postcode 4301 – 123 EVs, which includes the Brisbane suburb of Redbank Plains and Collingwood Park.

Other postal areas with high EV uptake include the following suburbs: Sydney CBD (NSW), Mile End (SA), Laverton North (Vic.), Richmond (Vic.), Dandenong and Dandenong South (Vic.), Mulgrave (Vic.), Cloverdale and Kewdale (WA).[5] Most of these suburbs, with the possible exception of Richmond, include significant commercial and/or industrial areas, suggestive of some proportion of EV ownership in these areas being business related rather than wholly household related. The suburb of Mulgrave, for example, includes commercial operations of several major international motor vehicle manufacturers, including BMW, Mercedes-Benz and Mazda.

Table 1: Top 20 postcodes by EV count, 2020

Postcode	Main suburb	City	State	EVs	EV share	EVs per capita
					(%)	(EVs/'000 persons)
2304	Mayfield	Newcastle - Maitland	NSW	233	1.43	14.7
3000	Melbourne	Melbourne	Vic.	147	0.40	2.8
2190	Greenacre	Sydney	NSW	140	0.56	5.0
5042	Clovelly Park	Adelaide	SA	127	1.23	11.1
4301	Redbank Plains	Brisbane	Qld	123	0.45	3.7
2000	Sydney	Sydney	NSW	103	0.42	3.1
5031	Mile End	Adelaide	SA	103	0.79	9.9
3026	Laverton North	Melbourne	Vic.	102	0.77	1,016.0
3121	Richmond (Vic.)	Melbourne	Vic.	98	0.28	2.7
3175	Dandenong	Melbourne	Vic.	97	0.15	1.7
6105	Cloverdale	Perth	WA	96	0.28	5.9
3170	Mulgrave (Vic.)	Melbourne	Vic.	95	0.39	4.5
3043	Gladstone Park	Melbourne	Vic.	93	0.23	4.9
2030	Vaucluse	Sydney	NSW	88	0.83	5.8
7009	Moonah	Hobart	Tas.	83	0.52	6.5
2088	Mosman	Sydney	NSW	80	0.40	2.6
3142	Toorak	Melbourne	Vic.	75	0.66	5.3
3004	Melbourne	Melbourne	Vic.	73	0.45	6.8
3101	Kew (Vic.)	Melbourne	Vic.	68	0.36	2.5
2065	Wollstonecraft	Sydney	NSW	65	0.30	1.9

Sources: ABS (2020) and author estimates.

Table 1 also highlights that even in the largest uptake areas, EVs comprise typically less than 1 per cent of all registered light vehicles within those postal areas and are generally less than 10 vehicles per thousand persons. By contrast, national average light vehicle ownership is around 650 vehicles per thousand persons.

5. Richmond includes a Tesla Service Centre, which may account for its high EV uptake. Laverton North is a predominantly commercial area, that includes the Toyota manufacturing plant, car auction sites and logistics firms, and relatively low population base, which would all contribute to its outsize per capita EV ownership.

3. Modelling spatial electric vehicle uptake

3.1 Selected empirical studies of EV uptake

There have been a small number of studies that have examined the spatial uptake of plug-in electric vehicles (PEVs) and hybrid electric vehicles (HEVs). Three recent studies have been undertaken in Canada (Dimatulac and Moah 2017), the United Kingdom (Morton et al. 2018) and the United States (Chen, Wang, and Kockelman 2015). Factors considered in these analyses included:

- population/no. households
- education level – e.g. post-secondary education share
- occupation/employment status
- household size
- household income
- dwelling type – e.g. semi-detached vs higher density dwelling stock
- average commuting distance
- EV uptake – i.e. no. EVs per 1000 cars
- charging infrastructure – i.e. available local public EV charging infrastructure.

Dimatulac and Moah (2017), investigated uptake of HEVs in Windsor, a mid-size metropolitan centre in Ontario, Canada, using multinomial logit (MNL) model to estimate the probability of HEV uptake at *zone* level.[6] Dimatulac and Moah (2017) noted that demographic factors account for a large proportion of variability in ownership (R^2 = 0.69). All variables were found to be statistically significant and the spatial autocorrelation term had a positive and statistically significant effect on HEV adoption.

Morton et al. (2018) investigated uptake of EVs in the United Kingdom (UK) across approximately 380 lower-tier local authorities across the UK. In a review of the literature Morton et al. (2018) noted that 'lead markets for EVs are likely to be sited in large, densely populated urban areas' (Morton et al. 2018, p. 120). The analysis used georeferenced data on EVs registered by private households that have qualified for the UK Government's plug-in car grant, which covers both PHEVs and BEVs. They modelled the number of EV registrations against socioeconomic, household and transport system characteristics. Using an ordinary least squares regression between the number of EV registrations per thousand cars, their model specification explains a large proportion of variability in ownership (R^2 = 0.72). Again, all variables were statistically significant. They note, however, that the spatial patterns reflect the adoption behaviour in the early market for EVs, and suggest that further work is required to better understand the temporal dynamics as the market transitions from 'early adoption' to mainstream (Morton et al. 2018, p. 128).

Chen et al. (2015) modelled the uptake of EVs for the south-eastern region of Pennsylvania (near Philadelphia). The data set comprised 2.2 million personal-vehicle registrations in April 2012, covering 18,674 EVs, including HEVs such as the Toyota Prius and Honda Civic HEV. The response variable was the number of Prius-HEVs, non-Prius HEVs and conventional (ICE) vehicles for each Census block group. Chen et al. (2015) reported that all variables, bar road density (centreline road length), were statistically significant in EV uptake. EV uptake was higher among higher income zones, zones with higher employment and population den-

6. The size of the regional zones in Dimatulac and Moah (2017) appear much smaller than Australian postcodes.

sity, but lower in zones further from the CBD. They also noted some spatial correlation (clustering) effects, suggesting potential increasing purchase rates as EV penetration increases.

4. Australian spatial EV uptake model

4.1 Methodology

For this paper, we used a logit model specification to estimate spatial variation in Australian postal area-level EV uptake to 2020, against the following range of socioeconomic factors:

- median household income
- dwelling type – proportion of detached houses
- average household size – number of persons
- job density – number of jobs per person
- education level – proportion of persons with a university degree or higher
- median commute distance
- population density
- household solar generation capacity
- EV charging capacity (installed power capacity of EV charging sites).

Several area-specific variables were included to account for differences in EV uptake between capital cities, other significant urban areas and other areas.

The logit model specification is specified in Equation (1):

$$S_r^{EV} = \frac{1}{1 + e^{-\sum_i \beta_i z_{ir}}}$$

where

S_r^{EV} – denotes the proportion of electric vehicles in region r
z_{ir} – is the set of i socioeconomic factors in region r
β_i – logit model parameter estimates.

The logit (or logistic) model is commonly used to model uptake of new technologies, as it is bounded between 0 and 1 and better approximates the S-shaped rate of technology uptake typically observed. Other empirical specifications were not tested for this paper. The model was specified and estimated at postal area level across all of Australia. Factors not explicitly identified in the model included electric vehicle prices, EV model availability and EV driving range.

4.2 Data

Data was primarily sourced from the ABS Motor Vehicle Census and ABS Census of Population and Housing, with additional data compiled from other sources.

Postal area-level estimates of EV uptake in 2020 were sourced from detailed ABS Motor Vehicle Census data available through ABS TableBuilder (ABS 2019). Postal area-level socioeconomic characteristics variables were sourced from the 2016 Census of Population and Housing data available through ABS Census TableBuilder (ABS 2016). Key Census data items include:

- number of households by median household income
- number of households by dwelling type
- number of households by average household size
- number of persons by employed persons per unit population (employment density) by postal area of residence

- number of persons by education level
- number work journeys by median commute distance
- average population density

Other variables and sources include:

- household solar generation capacity estimates were sourced from the Clean Energy Regulator's (CER) postcode-level data for small-scale installations (CER 2020).
- EV charging site locations and installed power capacity were compiled from charge site data available through OpenChargeMap and PlugShare's online site (Recargo 2020; OpenChargeMap contributors), and aggregated to Australian postal areas.

Figure 4 shows the location of all operational EV charging sites across Australia in early 2021, categorised by maximum available charging speed—fast, slow or trickle charging—at each operating site.

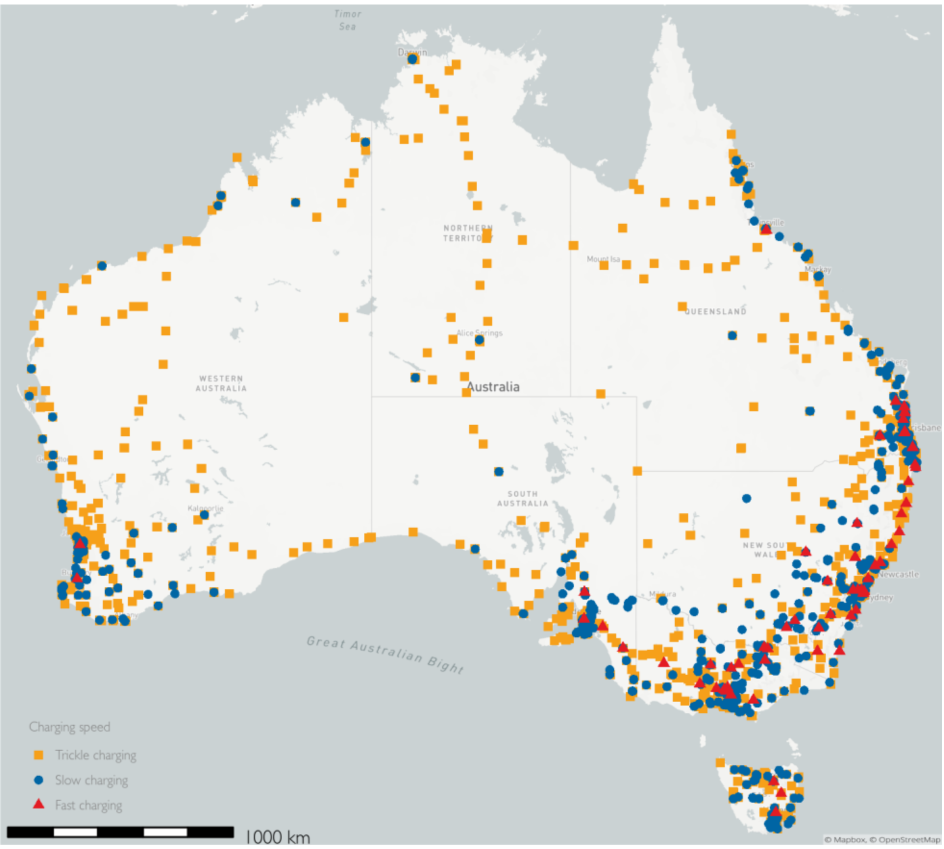


Figure 4: EV charging sites, Australia, 2020, by charging speed

4.3 Postal areas and statistical geography

While postal areas are the basic spatial area for the analysis, they are not ideal for statistical geographic analysis because they can vary significantly in size and are not necessarily tied to population and settlement patterns. They are, however, the smallest geographic area for which motor vehicle registration data is available. While it would be possible to allocate vehicle registration to some other small-area geography, using population concordances, this was not done for this paper.

Australian postal areas also include postcodes reserved for non-standard use—e.g. PO Boxes, competition mail, government departments, large companies, etc.—and postcodes covering principally uninhabited or non-residential, commercial or industrial areas with low or nil vehicle ownership. Non-standard postal areas, with few or no registered vehicles, were excluded from the analysis.

4.4 Empirical results

All empirical estimates were derived using R – the free language and environment for statistical computing (R Core Team 2021). Two empirical specifications were estimated:

i) national-level estimates including all approximately 2700 separate postal areas across Australia;
ii) separate state-territory regressions, including all postal areas in each specific jurisdiction.

All results are reported in Table 2. The national-level model includes state-level alternative specific constants, which allow for systematic differences in fractional uptake across jurisdictions, but no jurisdiction-specific variation in the contribution of individual variables to EV uptake. The state-specific models allow for differences in the impacts of the independent variables on EV uptake across jurisdictions.

4.4.1 All Australia model results

Empirical results for the whole-of-Australia model specification show that most of the specified variables are statistically significant influences on EV uptake – positive-signed estimates indicate a direct relationship between EV market share and the relevant factor, and negative-signed terms indicate an inverse relationship (column 2, Table 4). The results suggest median household income, household size, education level, commuting distance and population density all have a statistically significant impact on EV uptake. Installed rooftop solar capacity and local EV charging capacity are also statistically significant and have a small positive impact on EV uptake. The model also reveals significant differences in uptake rates across jurisdictions, and between capital city and non-capital city regions – with uptake proportionately higher in capital cities and significant urban areas than in other areas. Figure 5 shows the fit of the all-postal area logit model of EV uptake against actual EV uptake rates in 2020.

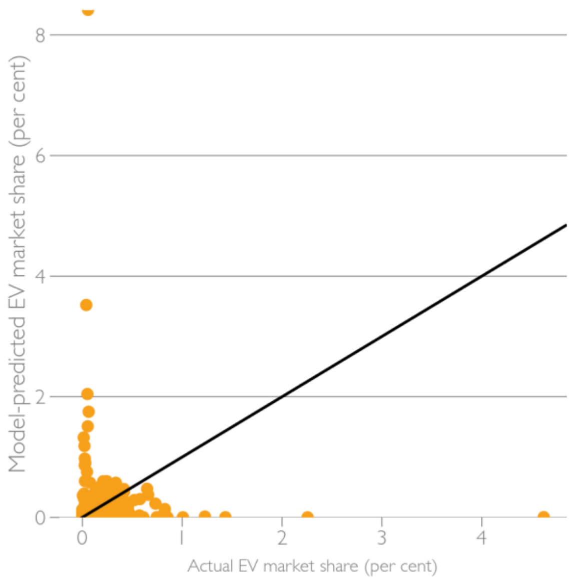


Figure 5: Postal area-level EV uptake logit model – Actual vs. fitted results

The implied R^2 value for this model is 0.54 which suggests the model accounts for 54 per cent of the observed variation in the spatial distribution of early EV uptake, which is quite reasonable for such a model.

Table 2: EV uptake logit model results

Variable	Aust	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
Intercept	-14.667***	-15.24***	-15.86***	-18.58***	-16.39***	-14.09***	-12.01	-27.11**	0.130
	(1.228)	(3.583)	(4.330)	(2.735)	(2.222)	(2.786)	(15.310)	(8.676)	(22.459)
Median h'hold income	2.24e03***	3.63e-03**	2.49e-03	3.75e-03**	1.34e-03	-1.01e-03	4.38e-03	4.06e-03	-2.20e-03
	(5.77e-04)	(1.10e-03)	(1.51e-03)	(1.33e-03)	(2.06e-03)	(1.37e-03)	(6.56e-03)	(5.06e-03)	(9.46e-03)
Median h'hold income sq.	-4.74e-07**	-6.05e-07*	-6.59e-07	-7.17e-07+	-3.74e-07	1.72e-07	-1.40e-07	-1.33e-06	6.72e-07
	(1.62e-07)	(2.83e-07)	(4.55e-07)	(3.77e-07)	(7.32e-07)	(3.85e-07)	(2.59e-07)	(1.36e-06)	(2.19e-06)
Detached houses	-3.52e-04	1.96e-03	-1.14e-02	1.07e-02	-1.15e-02	4.79e-03	-1.24e-02	8.56e-03	-7.90e-03
	(3.53e-03)	(8.31e-03)	(8.15e03)	(8.16e-03)	(9.86e-03)	(8.01e-03)	(2.51e-02)	(3.35e-02)	(1.13e-02)
Avg. household size	-1.33e-02	-5.92e-01	8.65e-01+	-3.85e-01	-5.78e-01	-4.32e-03	-3.78e-01	9.44e-01	-3.16e-01
	(1.86e-01)	(4.82e-01)	(4.73e-01)	(4.34e-01)	(5.18e-01)	(3.41e-01)	(1.87)	(1.88)	(1.177)
Job density	5.88	2.651	1.399	16.591	9.398	5.131	-21.718	45.261	-36.368
	(5.92)	(19.129)	(22.053)	(15.233)	(11.668)	(12.203)	(87.352)	(41.364)	(68.236)
Job density squared	-13.60+	-13.999	-10.574	-34.345+	-7.363	-8.342	36.881	-63.244	42.248
	(7.87)	(24.851)	(28.486)	(20.534)	(16.892)	(15.014)	(120.632)	(55.588)	(75.329)
Education level	0.178***	0.223***	0.172***	0.183***	0.167***	0.128***	0.053	0.121	0.172
	(1.43e-02)	(0.037)	(0.031)	(0.034)	(0.037)	(0.031)	(0.097)	(0.284)	(0.099)
Median commute distance	-4.02e-03	-8.9e-03	6.58e-03	-6.07e-03	2.67e-02	-4.67e-03	5.31e-02	-2.83e-02	1.71e-02
	(5.83e-03)	(1.11e-02)	(1.53e-02)	(1.11e-02)	(2.01e-02)	(1.30e-02)	(4.58e-02)	(7.36e-02)	(1.12e-01)
Population density	4.25e-04***	2.14e-04	4.43e-04*	1.16e-03***	9.83e-04	2.26e-03***	3.27e-03	9.75e-03*	-1.30e-05
	(8.18e-05)	(1.39e-04)	(1.75e-04)	(2.85e-04)	(7.43e-04)	(5.56e-04)	(3.24e-03)	(4.02e-03)	(8.58e-04)
Population density sq.	-2.2e-08***	-9.48e-09	-2.41e-08+	-1.32e-07**	-2.18e-07	-5.27e-07***	-7.27e-07	-4.43e-06*	9.18e-08
	(5.60e-09)	(7.90e-09)	(1.29e-08)	(4.62e-08)	(2.61e-07)	(1.53e-07)	(2.01e-06)	(1.70e-07)	(3.36e-07)
Rooftop solar	1.41e-04***	1.88e-04***	1.81e-04***	9.35e-05***	1.39e-04***	7.75e-04***	5.91e-04***	-8.44e-06	6.54e-07
	(7.81e-06)	(1.85e-05)	(2.28e-05)	(1.10e-05)	(3.52e-05)	(1.93e-01)	(1.64e-04)	(1.56e-04)	(4.17e-05)
EV charging capacity	8.94e-04***	5.31e-04	4.89e-04	1.26e-03*	4.37e-05	4.93e-03**	7.70e-05	3.75e-02	3.91e-03
	(2.35e-04)	(3.66e-04)	(4.63e-04)	(5.99e-04)	(8.28e-04)	(1.54e-03)	(1.08e-03)	(2.51e-02)	(4.66e-03)
State: NSW	-1.347**								
	(0.475)								
State: Vic.	-0.934*	–	–	–	–	–	–	–	–
	(0.473)								
State: Qld	-1.763***	–	–	–	–	–	–	–	–
	(0.478)								
State: SA	-2.156***	–	–	–	–	–	–	–	–
	(0.481)								
State: WA	-1.768***	–	–	–	–	–	–	–	–
	(0.476)								
State: Tas.	-0.622	–	–	–	–	–	–	–	–
	(0.513)								
State: NT	-2.683***	–	–	–	–	–	–	–	–
	(0.602)								
State: OT	-2.506+	–	–	–	–	–	–	–	–
	(1.363)								
Capital city GCCSA	1.060***	0.686	1.335**	0.423	-0.486	3.345***	-2.349+	-0.472	0.168
	(0.219)	(0.488)	(0.459)	(0.495)	(0.707)	(0.539)	(1.331)	(1.940)	(0.743)
Capital city SUA	0.398+	0.285	0.103	0.667	1.779*	-1.685**	3.143*	-0.562	-0.379
	(0.232)	(0.534)	(0.469)	(0.550)	(0.746)	(0.620)	(1.521)	(1.576)	(0.581)
Num. obs.	2635	612	694	437	338	376	116	35	24
R2	0.548	0.587	0.526	0.631	0.510	0.604	0.374	0.552	0.901
R2 Adj.	0.544	0.577	0.516	0.618	0.489	0.589	0.288	0.239	0.748
AIC	11686.7	2692.2	3184.5	1825.8	1474.9	1584.7	583.6	165.6	28.5
BIC	11827.8	2762.8	3257.2	1891.1	1536.1	1647.6	627.6	190.5	47.4
Log Lik.	-5819.374	-1330.086	-1576.264	-896.920	-721.462	-776.375	-275.790	-66.824	1.742
F	143.977	60.654	53.851	51.455	24.054	39.373	4.319	1.763	5.867

Statistical significance: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: Author estimates.

Table 3 shows the implied elasticities[7] for EV uptake with respect to the key socioeconomic variables. The results imply that EV uptake is highly responsive to household income, with an implied elasticity of approximately +3.5 with respect to median household income. The impact diminishes, however, as incomes increase – as the implied elasticity of EV uptake with respect to squared household incomes is approximately -1.2.

Table 3: Postal area EV uptake logit model-implied elasticities

Variable	Aust	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
Median h'hold income	2.771	4.669	3.037	4.719	1.515	-1.356	4.563	7.293	-4.553
Median h'hold income sq.	-0.726	-0.998	-0.982	-1.137	-0.482	0.312	-1.511	-4.309	2.888
Detached houses	-0.027	0.144	-0.893	0.811	-0.857	0.351	-0.978	0.524	-0.482
Avg. household size	-0.032	-1.479	2.075	-0.963	-1.388	-0.011	-0.869	2.548	-0.789
Job density	2.359	1.058	0.563	6.579	3.777	2.145	-8.020	16.506	-16.644
Job density squared	-2.187	-2.229	-1.715	-5.401	-1.189	-1.457	5.029	-8.412	8.858
Education level	1.290	1.746	1.338	1.158	1.105	0.856	0.360	0.700	2.917
Median commute distance	-0.050	-0.099	0.088	-0.080	0.327	-0.050	0.770	-0.222	0.169
Population density	7.24e-03	2.02e-02	805e-02	1.77e-02	1.18e-02	3.55e-03	3.08e-02	5.14e-01	-1.69e-02
Population density sq.	-6.43e-06	-8.48e-05	-7.97e-06	-3.10e-05	-3.15e-05	-1.29e-06	-6.49e-05	-1.26e-02	1.57e-01
Rooftop solar	0.238	0.407	0.237	0.277	0.257	0.048	0.445	-0.006	0.278
EV charging capacity	3.07e-02	3.05e-02	1.44e-02	4.27e-02	8.58e-04	7.90e-02	4.19e-03	2.66e-01	1.50e-01

Sources: Author estimates.

EV uptake is also positively correlated education level (elasticity = 1.3), which confirms an *a priori* hypothesis that more highly educated individuals and/or households tend to be higher early adopters of new technology, a result also observed in other empirical studies (e.g. Dimatulac and Moah 2017; Morton et al. 2018).

For household size, it was hypothesised that increases in household size would reduce the demand for EVs, meaning that the relationship is negative. This is observed in the results (elasticity = -0.032).

Job density and population density also appear to have a positive impact on EV uptake, i.e. EV uptake is higher in higher density residential and employment postal areas. The number of jobs in a postal area has a strong positive effect on EV uptake (elasticity = 2.36). Population density exhibits a far smaller effect (elasticity = 0.007). Both job and population density squared terms are negative, suggesting EV uptake increases with both factors but at a diminishing rate.

The empirical results imply commuting distance has a small negative effect on EV uptake demand (elasticity = -0.050), i.e. EV uptake declines with increasing median commute distance. This result is slightly counter-intuitive as EVs would potentially offer greater operating cost savings, over ICEVs, for households with longer commute distances.

Installed local public EV charging infrastructure is estimated to have a (marginally) statistically significant but small positive impact on spatial EV uptake (elasticity = 0.032) – implying a 10 per cent increase in EV charging capacity would increase proportional uptake by 0.3 per cent. In contrast, installed rooftop solar generating capacity has a proportionately larger impact on spatial EV uptake (elasticity = 0.24).

7. The elasticities reported in Table 5 are logit model share elasticities, defined as: $\frac{\partial S_i}{\partial x_j}\frac{x_j}{S_i} = \beta_j x_j (1 - S_i)$, which measures the percentage change in market share in response to a percentage change in the independent variable x_j.

These results have implications for the potential effectiveness of alternative policy measures designed to encourage EV uptake.

4.4.2 State and territory-specific model results

The EV uptake model was also estimated separately for each state and territory. Table 2 (columns 3-10) shows the empirical results for each state/territory model. Again, positive-signed estimates indicate a direct relationship between EV market share and the relevant factor, and negative-signed terms indicate an inverse relationship. The implied R^2 values for each model are also shown in the table – for most jurisdictions the implied R^2 value is around 0.5-0.6, and as high as 0.75 in the case of the ACT. The exceptions are Tasmania and the Northern Territory where the implied R^2 values are generally lower.

Figure 6 shows the fit of each of the separate state and territory postal area-level logit model predicted EV uptake against actual uptake in 2020 (outliers not shown). The black line represents the line of *perfect equality*, i.e. where model predicted EV uptake equals actual uptake. The model results show a large degree of variation in EV uptake at postal area level across jurisdictions, which is not surprising at this early stage in the uptake of EV technology.

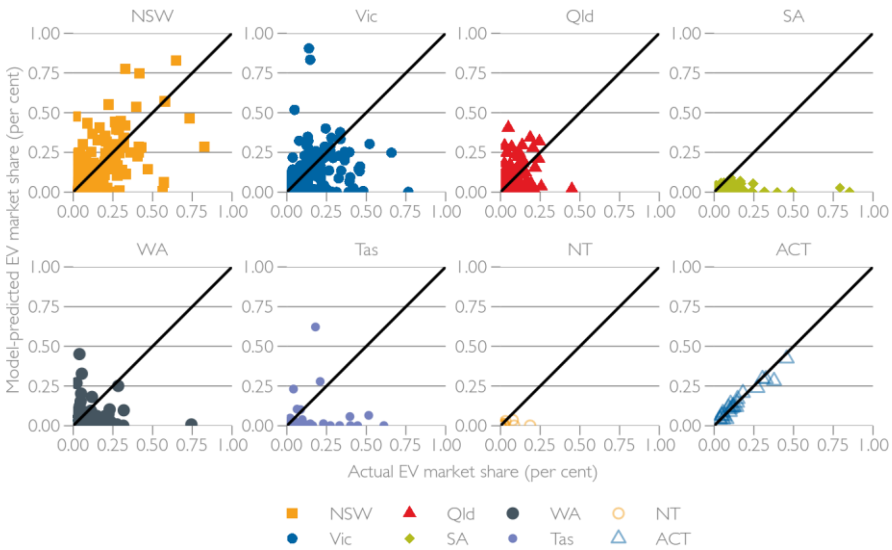


Figure 6: State/territory postal area-level EV uptake logit model – Actual vs. fitted results

Table 3 (columns 3-10) shows the implied elasticities for EV uptake with respect to the key socioeconomic variables across each jurisdiction. While the relative influence of the different socioeconomic factors appears broadly consistent with the national level estimates – i.e. household income, job density and education level factors are estimated to have a stronger influence on EV uptake than other factors – the size of estimated elasticities for each socioeconomic factor can vary significantly across jurisdictions.

The estimated sign of some socioeconomic factors is does not accord with our *a priori* expectations. For example, the state-specific model estimates imply EV ownership is generally most responsive to changes in median household income, with the impact generally diminishing with increasing income, but the relative size of the impact varies across jurisdictions – the impact of median income on EV uptake is higher in New South Wales (elasticity = 4.7), Queensland (4.7), Tasmania (4.6) and the Northern Territory (7.2), but lower in Victoria (3.0) and South Australia (1.5). In contrast, the elasticity of median household income is negative for Western Australia and the ACT. Similarly, the impact of job density on EV uptake is strongly positive, but declines with increasing density, across most jurisdictions, with the exception of Tasmania and the ACT, where the job density elasticity is negative.

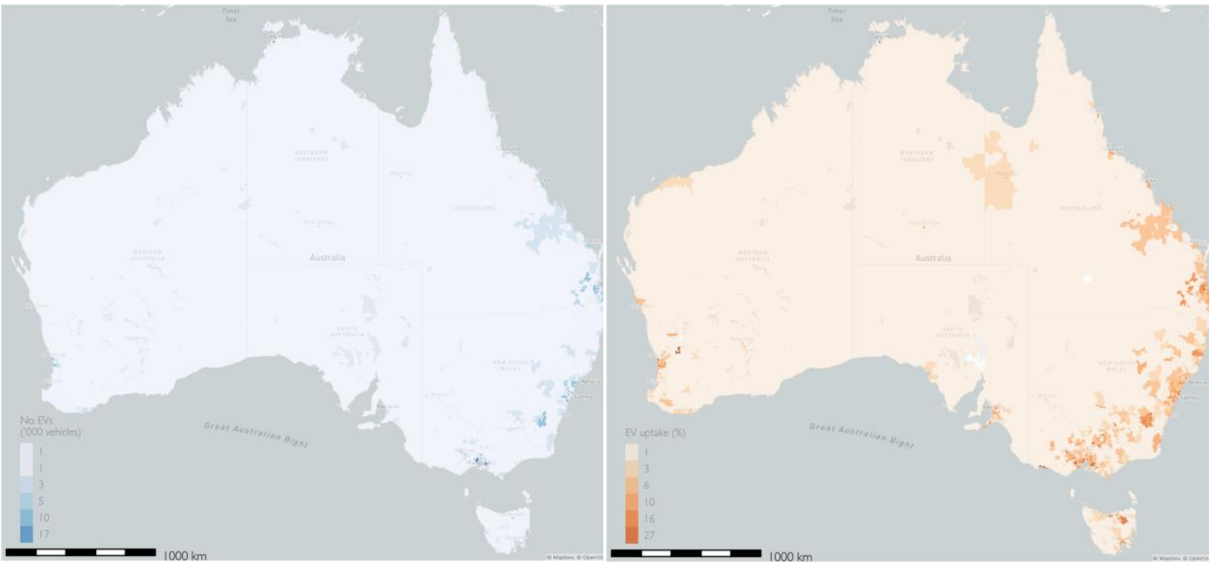
The observed variation in the size and sign of the EV uptake empirical elasticities across jurisdictions could be due to several reasons, including variations in the accuracy of the EV registration data across jurisdictions, the high degree of natural variability due to the presently low level of EV uptake in Australia, and possibly the influence of the use of postal areas as the base spatial analysis unit.

Given the variability in the national and state-level parameter estimates, across different socioeconomic variables, and the very early state of EV uptake, it is recommended that these models be re-estimating periodically as EV uptake increases over the next decade, to update our understanding of the relative contribution of different factors to spatial EV uptake.

5. Projected future spatial EV uptake

The empirical results presented in the previous section may be combined with socioeconomic characteristics of the population to project likely future postal area-level EV uptake across Australia. While space constraints preclude provision of full details of the methodology here, it involves weighting population and household socioeconomic characteristics according to their relative potential influence on EV uptake and applying the weighting to the population in each postal area, according to the socioeconomic profile of that area, and summing the result to derive an overall EV uptake *score* for each postal area. The postal area EV uptake scores then influence the proportional distribution of total projected future Australian EV uptake across all postal areas in each future projection year. The method necessarily includes assumptions about potential future total Australian EV uptake (e.g. BITRE 2019).

Figure 7 shows the projected EV uptake by postal area in 2030 – Panel 1 shows the projected number of EVs and Panel 2 shows EV uptake as a share of total registered light vehicles.



Panel 1 – No. vehicles
Panel 2 – EV share

Figure 7 Projected Australian EV uptake, 2030, by postal area

The method projects that early EV uptake is likely to be concentrated in higher-income and more heavily populated postal areas in major capital cities and other urban areas. Conversely, EV uptake in regional areas is likely to lag city uptake. EV uptake is projected to increase to between 0 and 25 per cent of total light vehicles in postal areas in 2030, with the EV ownership remaining below 5 per cent across more than 75 per cent of postal areas. By 2050, about 50 per cent of postal areas are projected to experience EV uptake of less than 5 per cent, but over 30 per cent of postal areas will experience light vehicle EV uptake of greater than 50 per cent. Under the base scenario, a large number of postal areas are projected to have little EV uptake by 2050 – most of these postal areas are in rural and regional areas.

6. Final remarks and further work

6.1 Key findings

This paper has presented empirical estimates of socioeconomic and other factors on spatial EV uptake in Australia to 2020. The results imply that household income, job density and education level are among the most significant influences on early uptake. Other factors, such as commute distance, population density and household size are estimated to be less significant to EV uptake. The model results also suggest that installed local EV charging capacity and household solar generating capacity both have statistically significant, but have numerically small, impacts on EV uptake. The results also imply that EV uptake is significantly higher in capital city areas and other significant urban areas than in rural and regional areas.

The empirical results can also help evaluate the effectiveness of alternative EV policy options aimed at increasing earlier EV uptake. Typical policy options suggested include:

i) financial assistance to lower the up-front cost of new EVs,
ii) schemes to reduce the registration costs of EVs relative to ICEVs; and
iii) provision of additional EV charging infrastructure.

The results presented in Section 4.4 suggest that measures that directly impact the relative purchase cost and/or the ongoing cost of EV ownership are likely to have a greater impact on EV uptake than measures that increase EV charging infrastructure availability – the empirical results imply expanded EV charging infrastructure will have only a very minor impact on EV uptake.

Section 5 showed how the spatial uptake model results can be used to project likely future EV uptake, based on assumed national-level EV uptake projections and small-area level socioeconomic characteristics. The results imply that EV uptake will be proportionately stronger in capital cities and other urban areas than in regional areas, primarily due to higher (on average) incomes, population levels, job densities and education levels.

6.2 Further work

The research also highlighted areas for further work and improvement in the accuracy and comprehensiveness of registered vehicle data.

Section 4 showed significant variation in the estimated influence of different socioeconomic variables on EV uptake across jurisdictions. Given the variability in the national and state-level parameter estimates, across different socioeconomic variables, and the very early state of EV uptake, it is recommended that these models be re-estimated periodically over the next decade, as EV uptake increases, to update the estimates of the significance of different factors to spatial EV uptake.

There are also significant discrepancies between cumulative EV sales, based on FCAI (2020) estimates and the number of registered EVs, as recorded by motor vehicle registries and shown in the MVC (Australian Bureau of Statistics 2020). Understanding the current and future uptake of EVs would be greatly improved by the collection of more accurate and comprehensive information about EV types by state and territory motor registries. The accurate collection and separate enumeration of BEVs, PHEVs and HEVs, and provision for potential future uptake of FCEVs, by state and territory motor vehicle registries (MVRs) will help better understand trends in Australia's future transport sector emissions, and how transport is contributing to reducing Australia's overall greenhouse emissions.

Lastly, we note that the 2021 MVC, released in June 2021, is the final issue of the ABS MVC. In view of the importance of MVC data to a wide range of transport policy, regulatory, planning and research, the Department of Infrastructure, Transport, Regional Development and Communications (DITRDC), through BITRE, is working with Austroads to explore options for standing up a replacement for the MVC using National Exchange of Vehicle and Driver Licensing System (NEVDIS) data. Working with NEVDIS to produce MVC outputs may offer greater opportunity to influence the accuracy and coverage of motor vehicle registry capture of BEVs, HEVs, PHEVs, FCEVs and, in the future, connected and automated vehicles.

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