California Economic Policy: Learning from California's Zero-Emission Vehicle Program

Technical Appendix

Description

In this technical appendix, I. Patent Analysis details search terms and data used to access patent activity in relationship to changes in regulations related to the ZEV program. II. Environmental Outcomes presents calculations of the environmental effects of changes in the ZEV mandate.

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Technical Appendix

Patent Analysis

Patents are required by law to publicly reveal the details of a completed invention that meets thresholds of novelty, usefulness, and non-obviousness. They are best thought of as an outcome of invention that has an eye to commercialization; studies have shown that they can be linked to events that occur outside the firm such as investment in R&D (see Griliches, 1990, for a review). There are three main challenges involved in using patents in research: (1) Technical difficulties arise in both locating patents of interest and allocating these patents to relevant industrial and product groups; (2) analysis difficulties arise from variations in the strategic decisions of entities to apply for patent protection; and (3) comparison difficulties arise because of "qualitative homogeneity" issues related to the question of whether all patents are of equal value simply because they have unique patent numbers (for more on the limitations of patents as a measure of innovative activity, see Taylor, Rubin, and Hounshell, 2005).

The patent analysis in this study was conducted using patent data from the U.S. Patent and Trademark Office. The Delphion search engine was used to perform the searches. The search terms used to create the datasets used for the analysis in the paper are shown in Table A.1.

Table A.1. Patent Search Terms

Vehicle Type	Search Terms	Results	Final Results
Battery-electric vehicle	((("electric vehicle") <in> (TITLE,ABSTRACT,CLAIMS)) AND ((180???*) <in> NC) AND NOT (("hybrid electric vehicle") <in> (TITLE,ABSTRACT,CLAIMS)))	333	320
Hybrid-electric vehicle	(((hybrid <near> vehicle*) <in> (TITLE,ABSTRACT,CLAIMS)) OR ((hybrid <near> car) <in> (TITLE,ABSTRACT,CLAIMS)) OR ((hybrid <near> automo*) <in> (TITLE,ABSTRACT,CLAIMS)) OR ((903???*) <in> NC))	2,121	2,005
Polymer electrolyte membrane (PEM) fuel cell vehicle	((fuel cell) <in> (TITLE,ABSTRACT,CLAIMS)) AND ((PEM) <in> (TITLE,ABSTRACT,CLAIMS)) OR ((polymer electrolyte membrane) <in> (TITLE,ABSTRACT,CLAIMS))	558	549

NOTES: All results figures are for the number of patents returned from the search. Each set was then manually read through to discard irrelevant patents. The number remaining following review is shown in the "Final Results" column.

The searches were designed to be conservative. For example, the battery-electric vehicle search was restricted to patents in Class 180, Motor Vehicles. This focused the search on vehicle themselves, primarily, rather than on vehicle components such as electric motors. This method likely underestimates the patenting activity. But, patent documents do not often include discussion of the application of a patented technology, which leaves the reader to infer an application. In the case of this search, some technologies were applicable across the vehicle types, so the problem would have been particularly challenging. This more conservative search methodology reduces this challenge. In each case, the search results were reviewed manually to eliminate any irrelevant patents.

For the analysis, we use the year that the patent was filed as the time variable. The search includes only patents that have been granted, so this does not result in the

inclusion of patents that were rejected. But, it is important to understand the amount of time that lapses between when a patent is filed and the date that it is granted. To insure that the time series provides a full representation of the patents that have been granted, we need to exclude the most recent years when patents have been filed but have not yet been granted. To do this, we calculated the average lag time, in years, between a patent's being filed and being granted. For each of our searches, this lag time was between two and two and a half years. Therefore, we considered patents from the earliest year available through 2003. Table A.2 shows the results of each of the searches.

Table A.2. Patent Search Results

	Technology		
Year Patent Filed	Battery-Electric Vehicle	Hybrid-Electric Vehicle	Polymer Electrolyte Fuel Cell
1966	2		
1967	1		
1968	3	1	
1969	2	4	
1970	3	4	
1971	1	5	
1972	5	9	
1973	4	11	
1974	4	4	
1975	2	11	
1976	4	5	2
1977	3	16	2
1978	5	13	1
1979	4	12	2
1980	5	14	4
1981	3	16	2
1982	2	12	0
1983	2	12	1
1984	3	13	1
1985	1	23	1
1986	3	26	1
1987	0	31	1
1988	2	40	8
1989	1	37	0

1990	4	46	2
1991	13	54	2
1992	14	44	1
1993	27	40	10
1994	31	48	6
1995	24	94	16
1996	27	106	18
1997	23	114	39
1998	17	143	53
1999	14	165	53
2000	16	271	70
2001	21	206	96
2002	19	201	113
2003	8	154	44
2004	4	75	9
2005		10	
Lag (years)	2.2	2.1	2.6

Environmental Outcomes

Calculation of the environmental effects of the changes in the ZEV mandate was performed for a hypothetical fleet of one million vehicles, approximately the number that will be required annually between 2005 and 2008 (shown in Figure 8). Table A.3 shows the values used to calculate the environmental performance of each vehicle type.

Table A.3. Average Lifetime NMOG Emissions (grams/mile)

Vehicle Type	**Tailpipe**	**Evaporative**	**Upstream**
SULEV[a]	0.0073	0.032	0.0310
AT-PZEV	0.0067	0.02	0.021
PZEV	0.0067	0.02	0.031
BEV	0	0	0.002
FCV	0	0	0.002

SOURCE: California Air Resources Board (2000).
NOTE: Upstream emissions for fuel cell vehicles are assumed to be equivalent to upstream BEV emissions.
[a]It was assumed that all non-ZEV-qualifying vehicles had the emissions characteristics of a SULEV because no other data were available.

The calculation is based only on upstream and evaporative emissions because it is assumed that the average tailpipe emissions under each scenario will be equivalent given manufacturer compliance with the non-methane organic gas average.

The calculation required an estimate of the number of vehicles of any type needed to comply with a given ZEV pathway. The number of vehicles was calculated assuming the credits shown in Table A.4. For a ZEV-eligible fleet of one million vehicles, the total number of credits needed to comply with the ZEV mandate is 100,000 (10% of one million). This is true for each of the four pathways.

Table A.4. Vehicle Credits

Vehicle Type	Credits
PZEV	0.2
AT-PZEV	0.7
BEV (original)	1
BEV (2003 base path)	10
FCV	40

The original ZEV mandate assumes that no additional credit is given for a BEV. For future compliance pathways, the number of credits needed for each vehicle type varies and is shown in Table A.5.

Table A.5. Number of Credits Needed of Each Vehicle Type

	Vehicle Type			
	BEV	**FCV**	**AT-PZEV**	**PZEV**
ZEV –(original)	100,000			
ACP (2003)		2,500	37,500	60,000
Base path (2003)	20,000		20,000	60,000

The credits are used to calculate the number of vehicles according to the following formula:

$$\#Vehicles = \frac{Credits\ Needed}{Credit}$$

Table A.6 shows the number of vehicles of each type assumed to be needed under each compliance pathway.

Table A.6. Vehicles Required Under Each Compliance Pathway in 2007

	BEV	FCV	AT-PZEV	PZEV	SULEV*
Baseline (no ZEV)	0	0	0	0	1,000,000
ZEV –(ooriginal)	100,000				900,000
ACP (2003)	0	250/4	53,543	300,000	646,394
Base path (2003)	2,000		28,571	300,000	669,429

*NOTE: SULEVs are not required, but are used as a proxy to represent the non-ZEV qualifying vehicles given data availability.

The emissions are calculated according to the following formula:

$$Emissions = \sum_{vehicle\ types} (E_{upstream} + E_{evaporative}) \cdot N_{vehicle\ type},$$

where

E = emissions from Table A.3

N = number of vehicles required from Table A.6.

References

California Air Resources Board, "Staff Report: 2000 Zero Emission Vehicle Program Biennial Review, " Sacramento, California, 2000.

Griliches, Z., "Patent Statistics as Economic Indicators—A Survey, " *Journal of Economic Literature,* Vol. 28, No. 4, 1990, pp. 1661–1707.

Taylor, M. R., E. S. Rubin, and D. A. Hounshell, "Regulation as the Mother of Innovation: The Case of SO2 Control," *Law and Policy,* Vol. 27, No. 2, 2005, pp. 348–378.