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California’s Zero Emissions Vehicle Mandate

Introduction

About one-third of the world’s greenhouse gas emissions come from the transportation sector (United States Environmental Protection Agency). More surprisingly, it is estimated that a typical passenger vehicle will emit about 4.6 metric tons of CO2 annually (Bleviss 2020). This is the energy equivalent of powering a household for roughly a year or charging 300,000 smartphones (EPA). This raises alarms as pollution rates from this everyday activity increase. For example, “beginning in 2016, the transportation sector overcame the power sector as the primary source of GHG emissions in the United States” (Bleviss 2020, pg. 1). The production of electric vehicles poses a potential solution to lower these harmful emissions and promote a healthier generation. The California Air Resources Board aims to further implement and evolve a policy known as the Zero-Emission Vehicle (ZEV) Mandate to combat this growing problem.

The California Air Resources Board adopted the Zero-Emission Vehicle requirement in 1990 as a part of the Low Emissions Vehicle regulation (California Air Resources Board 2024). This policy mandated auto manufacturers to produce a certain number of electric vehicles every year, in hopes to combat the emissions generated from gasoline-fueled vehicles. In the following sections, we describe California’s ZEV mandate, present a theory that examines the efficiency of this policy, and examine evidence from empirical literature to explain why the mandate is not allocatively efficient and why it is not equitable.

Policy Description

The ZEV program is a floor policy that sets mandatory sales requirements for auto manufacturers. The California Air Resources Board (CARB) enforces the requirements on all auto manufacturers in the state of California. Manufacturers must demonstrate compliance by earning ZEV credits, which are based on the number of qualifying vehicles sold. Manufacturers also have the option to buy from or sell permits to others.

The program was initially introduced in 1990 to improve California's air quality by transitioning the auto industry away from gasoline-fueled vehicles and towards cleaner alternatives such as plug-in hybrids and electric vehicles. Over time, the goal expanded to include reducing greenhouse gas emissions from the transportation sector. CARB determined that an entirely zero-emission vehicle fleet would meet the state's long-term air quality and climate goals. The ZEV program aims to pull electric-drive vehicles into the market that would not otherwise be commercially available (McConnell, Leard, and Kardos 2019).

The requirements have gone through several phases since 1990. The original 1990 regulation required 2% ZEV sales by 1998, 5% by 2001, and 10% by 2003. These turned out to be unrealistic goals given the high battery cost and limited range of EVs at that time (McConnell, Leard, and Kardos 2019). Initial electric vehicle prototypes used lead-acid batteries which had minimal range. Costs were estimated at over $1,000 per kWh (McConnell and Turrentine 2010). Automakers threatened to sue in 1996 over the 1998 target. The requirements were repeatedly delayed with the 1998 and 2001 targets removed completely. The 10% 2003 target remained but more vehicle types were added which made it hard for the policy to cover everything (McConnell, Leard, and Kardos 2019).

The second phase occurred from 2005-2017. With battery technology still slowly developing, ZEV rules were made more flexible. This included no minimum pure ZEV requirement, just a total credit percentage, which partial ZEVs could meet. There were also more generous credit multipliers involved, especially for longer-range electric vehicles. There was a minimum pure ZEV requirement added back in 2013-2017, but started at less than 1% and only reached 3% by 2017. Sales of pure ZEVs were still low until around 2012 (McConnell, Leard, and Kardos 2019).

The third and final phase stretches from 2018 to the present day. Only pure ZEVs and transitional ZEVs (plug-in hybrids) can earn credit after 2017. Requirements for ZEV credits increase from 4.5% in 2018 to 22% in 2025. The pure ZEV minimum increased from 2% in 2018 to 16% in 2025. Industry experts cite costs declining from around $1,000/kWh in 2010 down to $156/kWh by 2019 (Goldie-Scot, Logan. 2019). Further cost reductions to around $32-$54/kWh are expected by the mid-2020s if production volumes continue to increase (Walter et al. 2023).

The ZEV program uses tradable credits to provide flexibility to manufacturers. Each ZEV sold earns several credits based on the vehicle's electric range. Manufacturers can earn extra credits by overcomplying and selling excess credits to other automakers. The Zero-Emission Vehicle Regulation requires large-volume and intermediate-volume vehicle manufacturers to bring to and/or operate in California a certain proportion of their sales as plug-in hybrid electric vehicles or zero-emission vehicles. California is requiring that all new cars sold in 2035 or later be zero-emission vehicles (California Air Resources Board 2024). This system aims to reduce the overall cost of compliance for the auto industry. However, credit trading rules and vehicle credit values have changed frequently, creating uncertainty for long-term planning.

Theory

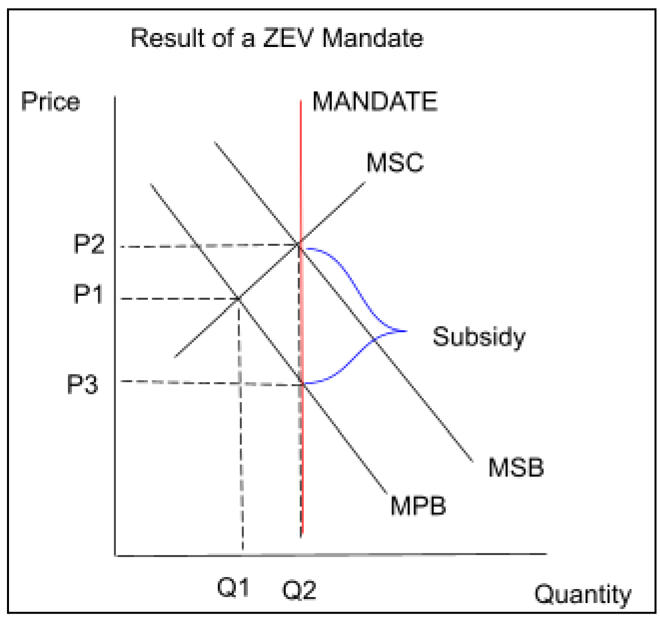
California’s Zero Emissions Vehicle (ZEV) mandate aims to tackle two very important problems: greenhouse gas emissions and the state’s air quality. The plan is carried out through efforts requiring auto manufacturers to sell an increasing percentage of ZEVs and plug-in hybrids. An efficient environmental policy maximizes the total social benefits relative to the total costs of achieving that reduction. A policy is allocatively efficient if the marginal social benefits equal the marginal costs while also inducing all modes of abatement.

As the urgency to address climate change looms, policymakers have sought out economically efficient tools to shift toward a low-carbon economy. One such mechanism is the efficient emissions tax, which aims to address the negative externalities of greenhouse gas emissions. The principle of the efficient emissions tax seeks to price carbon based on the estimated social cost of each ton of emissions. This tax initiates clear financial incentives for businesses and consumers to help reduce their carbon footprint by investing in clean technologies and sustainable practices. Revenue generated can then be reinvested into critical climate initiatives. While an efficient emissions tax is a powerful policy lever, it is open to political challenges. An alternative approach could be a combination of a gasoline tax and subsidies for zero-emission vehicles (ZEVs). By increasing the price at the pump and offsetting the higher upfront costs of ZEVs, this dual-pronged strategy can achieve similar emissions reduction goals in a potentially more palatable manner. It should be noted that for a policy of this nature to be efficient, it needs to accomplish inducing all modes of abatement.

An efficient emission reduction policy would contribute to the betterment of society by solving factors such as the actual reduction of greenhouse gas emissions, promoting innovation and investment in cleaner forms of energy, and helping promote more level competition between firms. The reduction in greenhouse gas emissions comes from the cleaner vehicles that are being produced and therefore pollution via driving decreases. Firms also have incentives to meet the demand for these vehicles and are financially motivated to invest in cleaner and more sustainable technologies and practices, hopefully igniting a cleaner society as a whole. Concerning fairer competition, an emissions tax ensures that polluters experience and internalize the full cost of their actions, rather than shifting the burden onto society or future generations.

However, it is understood that a policy that is optimally efficient holds many barriers that prevent such a policy from existing. Therefore a mandate, as discussed further, allows for an alternative method of environmental policy.

The ZEV mandate is a very important policy that offers much nuance into discussing the efficiency of the policy. It is noted that the mandate relies heavily on partnering policies. This infers that something such as a subsidy offers a better avenue to understand this topic and create efficiency that compliments the mandate. A mandate in essence tells manufacturers what they are required to make. This creates a difference between what producers make versus what consumers demand. This gap in supply and demand creates room for a subsidy to be implemented. The government's role is to incentivize the production of these vehicles and effectively lower the cost that consumers bear while also satisfying the higher costs that firms incur. One important thing to note however, is that the



mandate will not necessarily meet at the socially optimal costs and benefits. In theory, without any pairing of another policy, the price of electric vehicles would increase. This is due to the fact that the mandate doesn't follow market conditions.

An EV mandate becomes cost-effective when the social benefits outweigh the costs of implementation and compliance. A subsidy helps the cost-effectiveness of a policy of this nature because the firm is being paid the difference between how much a consumer is willing to pay and how much a firm is charging.

As previously mentioned, in order for the mandate to become more efficient, a subsidy is necessary to combine with the policy. A subsidy in this case would provide a financial incentive to customers related to the car market or even encourage producers to accelerate their electric vehicle manufacturing. Understanding the core fundamental idea behind a supply-demand model may help facilitate what the subsidy is doing in more digestible terms. A subsidy shifts the demand curve to the right. This shift increases the quantity demanded, and if demand increases, the financial benefit for producers becomes more apparent. Also of importance, if a subsidy is set equal to the marginal external benefit of emissions reduction, it can most likely achieve a level of allocative efficiency. This is done through incentivizing the socially optimal level of technological adoption.

Rather than the cap-and-trade ZEV Mandate, a subsidy is typically better designed to be more cost-effective as it allows both consumers and producers the opportunity to respond to price signals and produce ZEVs and PHEVs up to the point where the marginal cost equals the subsidized cost. However, subsidies require government funding, which may have budgetary implications and bring up concerns about the long-term feasibility.

One of the negative effects that arises from allowing mechanisms such as credit trading to occur is that by enabling automakers to comply at the lowest possible cost, constant change creates a level of uncertainty. The ZEV Mandate allows for credit trading to help achieve cost-effectiveness but may result in potential effects like the "rebound effect" and the "portfolio effect". These effects could potentially offset the emission reductions that were induced by the mandate, ultimately reducing the cost-effectiveness.

As the ZEV policy pushes relatively fuel-efficient vehicles into the market, this could result in the "rebound effect" (McConnell, Leard, and Kardos 2019). In this context, the "rebound effect" is when the implementation of the ZEV mandate leads to less energy saved than what was expected. The increase in consumption of energy sources offsets the energy savings that may otherwise be achieved. Another possible effect of the ZEV policy is that it reduces vehicle miles traveled due to ZEV range limitations (Davis 2019). In 2015-2016, new electric vehicles tended to be driven much less than an equivalent new gasoline vehicle. In the short run, the reason could be that households owning an electric vehicle transfer their miles driven to another vehicle owned by the household. This is known as the "portfolio effect" (Archsmith et al. 2019). These effects imply that the mandate could result in unexpected consequences that were not initially considered.

We also consider the equity of the mandate. Something of importance, related to this specific topic, is the high upfront costs of the program that may make them less accessible to low-income households. One fix for this is through a subsidy aimed at the improvement of equity by targeting specific income groups or communities to make them more affordable for everyone.

When evaluating the equity of the policy, the literature often considers the distribution of costs and benefits amongst different groups of people. We can measure this through the average income of low-income households and examine the percentage of income that an EV purchase would intake. This serves as a good financial measure of how affordable these EVs are. This includes racial or ethnic communities, different income groups, and different geographic regions. To measure the equity of the policy, policymakers have to consider the affordability of ZEVs and PHEVs for low-income households, geographic distributions of air quality improvements, the availability of the charging infrastructure, and potential impacts on the workforce across different areas.

In conclusion, while the mandate requires increased electric vehicle sales (ZEV and PHEV), a subsidy incentivizes adoption through market-based mechanisms. There are set criteria for which the policies should be evaluated and those include their ability to achieve emissions reductions, cost-effectiveness, equity considerations, and long-term political feasibility. In all likelihood, it can also be true that a combination of regulations and incentives may be necessary to address the complex challenges of transitioning to a zero-emissions transportation sector.

A policy is allocatively efficient if it covers all measures of abatement, meaning both producers and consumers are taking action to reduce greenhouse gas emissions, thus improving the state's air quality. Also, a policy is equitable if every group within a given community has equal distribution of the costs and benefits and if an EV purchase is not financially straining on low-income households.

Analysis

The economic literature that was reviewed highlights the difficulty in isolating the effects of the ZEV mandate on key outcomes of the policy, like innovation and increased sales of EVs. While suggestive evidence has provided that innovation activities have ramped up following the implementation of the ZEV mandate, the literature has not supported statistical evidence to prove the mandate is solely responsible. The ZEV policy has been important, and has spurred innovation while increasing the adoption of electric vehicles in the transportation sector. California's ZEV mandate has required auto manufacturers to sell a certain percentage of zero-emissions vehicles, which has forced them to invest in research and development and innovate new EV models. There has also been an increase in EV-related patents, which indicates that the mandate has been successful in driving technological change. The number of EV-related patents in 1990 went from almost zero to more than 70 per year by the late 1990s (Vergis and Mehta 2012). With this being said, this does not definitively prove that the mandate was solely responsible for the increase in EV related patents. Moreover, the development of new technologies for EVs encouraged new interactions between firms and innovations from some firms having spillover effects on others (Pilkington, Dyerson, and Tissier 2002).

Another important strength of the ZEV mandate is the adaptability and flexibility within the policy. The mandate has been roughly modified multiple times over its 30-year history to respond to changes in technology costs and capabilities (McConnell, Leard, and Kardos 2019). This flexibility has been crucial as the program has shifted from early EV adoption to mass market penetration. One improvement that has been brought up regarding the flexibility of the policy is the implementation of a "safety valve". A "safety valve" price mechanism is a way to adjust the ZEV credit market in which the number of credits available automatically adjust in response to if the price rises above a certain threshold (McConnell, Leard, and Kardos 2019). This relates back to our theory section that underlines the importance of maintaining lower prices and better helping consumers incur the costs associated with buying an electric vehicle. This also helps play into the role of a subsidy which should mitigate some risk that the firms take by choosing to manufacture these vehicles.

However, there are still some concerns regarding the cost-effectiveness of the ZEV mandate as the policy has been criticized as an expensive way to reduce emissions compared to a carbon tax. Prior studies have estimated that there were lower marginal compliance costs for other vehicle emission regulations like the Corporate Average Fuel Economy (CAFE) standards (McConnell, Leard, and Kardos 2019). These ideas raise concerns on whether or not the ZEV mandate is achieving emissions reductions in the most cost-effective manner possible. The mandate can achieve substantial emissions reductions by 2050, but the near-term costs may be higher than needed (Leard and Greene 2023).

The California ZEV mandate has also been crucial in driving multiple forms of emission reduction. Yet, the ZEV mandate is a relatively narrow policy that focuses primarily on promoting ZEV adoption from a more local perspective as its enactment is found only in the state of California, and only within a certain sector of the state's transportation.

Other policies that California views as complimentary to the ZEV mandate are consumer subsidies for the purchase of EVs and subsidies for investment in charging infrastructure (McConnell, Leard, and Kardos 2019). These subsidies increase the demand for EVs as the price that a consumer pays is lowered. Therefore, by itself, the ZEV mandate is not allocatively efficient, given its reliance on another governmental policy. If governmental policy aligns with the mandate, then there is a potential that this idea can come to fruition and positively ease the growing concern for emission rates.

Due to the ongoing nature of the mandate, there is no literature around the idea of whether or not the mandate is at the equilibrium level. While the papers do not explicitly state whether the mandate is at the equilibrium level, the discussion around adding flexibility mechanisms like the "safety valve" and the gaps identified between costs and credit prices reveal that the ZEV mandate may need to be continuously adjusted over time rather than being fixed at a static equilibrium level.

While the mandate is designed to increase the adoption of more expensive electric vehicles, this policy may put them out of reach for lower-income consumers. In a piece written by Susan Meyer, a writer spanning numerous industries and specializing in research and topics related to auto and home insurance, she found that the average sale price that a citizen in California pays for an average car is $34,000 (Meyer 2024). The Kelley Blue Book cites the average price of an electric vehicle as of March, 2024, to be $54,000 (Kelly Blue Book 2024). This $20,000 gap disproportionately affects lower-income households, who's tax brackets fall in the range of $11,000 to $58,000, making it more difficult for them to afford an electric vehicle compared to higher-income households. Given the expensive price for an EV, it makes most sense for a low-income household to purchase a fuel-reliant vehicle. This creates an issue regarding equity because the policy is disproportionately benefiting higher-income households. In order for a policy to be fully equitable, every group within a given community should experience all the costs and benefits at the same rate.

EV buyers are predominantly male, high-income, highly educated, homeowners, and predominantly white households, which suggests that underrepresented communities and low-income households are not benefiting from EVs at the same rate (Neyhouse and Petri 2021). It should also be noted that the distribution of charging networks is also not equitable. Charging infrastructure is disproportionately concentrated in wealthier neighborhoods, while low-income and minority communities often lack access to home charging and public charging stations, further limiting the feasibility of EV ownership for these groups (Neyhouse and Petri 2021).

Ultimately, in the case of California's ZEV mandate, there needs to be a policy implemented that allows lower-income households to as easily adopt an EV as it is for higher-income households.

Conclusion

California's ZEV mandate has been a driving factor in the significant progress seen in regards to the adoption of zero-emission vehicles. Since California's implementation of the mandate, 13 other states and Washington D.C. have adopted similar regulations to help combat emissions from greenhouse gasses (Maryland Department of the Environment 2024). The flexibility built into the policy, with credit trading and evolving requirements, has been crucial in keeping the mandate relevant as the EV market has rapidly advanced.

However, there are some important concerns and limitations that were discussed throughout the analysis that need highlighting. While the mandate has been effective at EV adoption, it may not be the most cost-effective approach compared to other policies like emissions taxes or subsidies. Potential equity issues, like EVs being largely inaccessible to lower-income households, are important concerns that policymakers are required to grapple with.

Lastly, the mandate has been a hallmark policy that has spurred the electric vehicle transition. Yet, as the state aims to accelerate progress towards their zero-emissions goals, a comprehensive policy assembly that encompasses regulations, incentives, and complementary measures may be needed. The careful balance of the objectives in terms of emissions reduction, cost-effectiveness, and equity are essential to the long term survival of the policy as California continues to refine and evolve its approach. By understanding the successes and shortcomings of the ZEV mandate, policymakers are given tools to better ensure a holistic and impactful strategy for decarbonizing the transportation sector.

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