

Civic Culture and Electric Vehicle Adoption: A Global Analysis Using LASSO and SHAP

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Abstract—Global efforts to tackle the consequences of climate change have pushed Electric Vehicles (EV) into the spotlight. However, adoption rates of EV vary substantially across countries. While prior research predominantly focused on government incentives, infrastructure, and business models, far less is known about the socio-cultural factors that enable EV adoption. Our study addresses this gap by examining the role of civic culture, specifically institutional and interpersonal trust, in impacting national EV adoption rates. Using sales data from the International Energy Agency and World Values Survey indicators from 21 countries, we apply Least Absolute Shrinkage and Selection Operator (LASSO) regression and SHapley Additive exPlanations (SHAP) analysis as a unique methodology. Results show that environmental commitment, confidence in political institutions, and interpersonal trust are among the strongest predictors of EV adoption. This research contributes cross-disciplinary insights by extending Civic Culture Theory into the domain of sustainable technology diffusion and highlights the importance of socio-cultural factors for policymakers and automakers seeking to accelerate the transition to EVs.

Keywords—electric vehicle, sustainability, Least Absolute Shrinkage and Selection Operator (LASSO), SHapley Additive exPlanations (SHAP) analysis

I. INTRODUCTION

As the world confronts escalating consequences of global warming and other challenges related to the degradation of our natural environment, sustainability has become an urgent, long term global priority. Tackling these issues requires sweeping changes in the way we live, work, and play, among which the transition to battery Electric Vehicles (EV) represents an integral step to achieving sustainability goals. Carbon emission is the primary driver of global warming and climate change [1]. In turn, about 15% of total global carbon emission comes from road transportation alone [2]. As such, reducing the number of fossil fuel-powered vehicles (hereafter referred to as internal combustion engine or Internal Combustion Engine (ICE) vehicles in short) and replacing them with zero emission EVs can go a long way in protecting our environment.

However, the transition from ICE vehicles to EVs requires significant global effort that involves businesses, policymakers, and consumers. ICE vehicles have been the mainstay for road transportation since early 1890s [3] and for more than a hundred years, entire industries and their supply chains have been built around this technology. Therefore, from an automotive business perspective, switching to EVs calls for huge investments in research and development, substantial changes to production lines and new business models. To cover the high costs of EV batteries, selling prices

have to be raised, making EVs generally costlier compared to equivalent ICE models. As a result, policy makers in many countries offer financial incentives to offset the higher prices and encourage market adoption. These incentives often work in tandem with a suite of other non-financial support and legislations. Charging infrastructure is another critical area that often necessitates political intervention to overcome complex challenges, including upgrading of electrical grids. From a consumer perspective, there are trust issues to navigate with the adoption of new technologies as well as changes in lifestyles and travel patterns.

To date, EV adoption rates (measured as share of EVs in total new car sales) differ substantially across countries, with Norway as the global leader at 80% while some countries in Latin America and Southeast Asia come in well below 10% [4]. Global transition from ICE vehicles to EV remains a complex and prolonged journey. In order to understand and find ways that can accelerate the process, policymakers and scholars continue to study different factors that impact EV adoption rate. So far, scholarly research has focused mainly on government policies [5], economics [6], infrastructure development [7], and consumer behavior [8].

EV adoption requires significant adjustments on the part of consumers. After all, a century of driving ICE vehicles has bred much familiarity. Therefore, switching to new EV technologies calls for trust that political institutions will continue to provide the necessary impetus for increasing accessible charging infrastructure and for other supporting services to grow. There is also a need for trust in a collective social motivation to transit from ICE vehicles to EVs. Besides political support, mass adoption by consumers is similarly critical for sustaining the growth of aforementioned supporting infrastructure. Achieving critical mass will also support an active pre-owned market to maintain the resale value of EVs.

Despite the importance of trust in political institutions and the community on EV adoption, little research has been done in this area. As such, the aim of our paper is to address this gap in literature. The findings can help further advance our knowledge on EV adoption beyond political interventions and supporting infrastructure.

One important framework that can help elucidate this relationship is Civic Culture Theory. Originally developed by Gabriel Almond and Sidney Verba, civic culture refers to a society's institutional trust and collective responsibility that enable democracies to remain stable [9]—two constructs that are central to our study. In the context of EV adoption, a civic culture may, therefore, helps to explain why some societies

demonstrate stronger public support and greater willingness to adopt sustainable technologies than others.

II. LITERATURE REVIEW

Research on EV adoption started gaining interest and momentum from around 2010 as the topic of climate change began to catch widespread global attention. These studies cover several dimensions of EV adoption including charging infrastructure, policies, and business models. Carlton and Sultana [7] posit that for EVs to overtake ICE vehicles as the dominant type of road transportation, there has to be fair distribution of charging infrastructure. They find some communities facing a distinct lack of such charging facilities which, in turn, impacts the rate of EV adoption. Moreover, this can also lead to EV becoming yet another symbol of social divide. Despite being a pressing issue, there is still a clear lack of research in this area of charging equity.

Government EV policies represent another major stream of research that has seen a growing amount of literature. Figenbaum [5] studies the success of Norwegian policies and incentives in encouraging EV adoption over a period of 25 years. As the country's transportation sector is heavily taxed, the authorities have considerable scope to introduce EV incentives such as VAT exemption, registration tax exemption, and other financial as well as non-financial benefits such as free parking and access to bus lanes. These policies, combined with rapid developments in the global EV industry, help establish Norway as the world's leading country in EV adoption rate.

Hardman [10] expands the scope and conducts a literature review of 41 papers that investigated the effects of recurring and non-financial incentives on EV adoption. He found that 76% of the papers looking at effectiveness of allowing bus lane usage in encouraging EV adoption reported a positive relationship. In addition, 90% of the 20 studies on parking incentives for EVs found them to be effective measures. Road toll waivers and annual tax reductions are other successful policies.

Beside infrastructure and policies, another group of researchers investigates business models and the economics that help accelerate EV production, improve marketing impact, and consequently increase adoption rates. Yang and Hung [6] explore challenges faced by the EV industry in Taiwan and look to the Japanese market for best practices in building up a sustainable EV business model. Automakers must start by looking at their customer value propositions and target communication messages at the relevant market segments. Likewise, the government has to step in with subsidies, encouragement for EV adoption among the population, and perhaps even be a fleet buyer of EVs for the public sector.

EV adoption is a major transition with many stakeholders involved. Consumers are one such key stakeholder. In addition to incentives and supporting infrastructure, consumers have to trust that political institutions are committed to the sustainability cause with consistent policies and support the growth of critical infrastructure over the long term. Nevertheless, government cannot drive these transitions alone. Society must also share a collective motivation towards sustainable transportation. As such, trust in social cohesion is also essential. Despite the importance of

such institutional and interpersonal trust factors in EV adoption, there is relatively little research done in this area. Kitt *et al.* [11] explore the role of trust in Canadian accepting climate related policies. The study finds that trust in government does have a consistent and positive relationship with the acceptance of policies. On the other hand, psychological and social-demographic factors show less consistent relationships. Song *et al.* [8] conduct a cross-cultural study that compares the psychological and behavioral characteristics of EV owners in the US and China while Ryghaug and Toftaker [12] have similar research with Norwegian consumers. Both studies reported consumers' personal attitude towards driving EVs, including experiencing a sense of fulfilling one's social responsibilities and a feel good factor. Nothing has been mentioned about interpersonal trust in both studies.

To address this gap in literature on institutional and interpersonal trust in EV adoption, we turn to Civic Culture Theory as an appropriate theoretical framework for our study.

Originating from political science, Gabriel Almond and Sidney Verba introduced the concept of civic culture in 1963 to describe a specific mix of values that support a stable democracy. In these countries, citizens possess trust in their political institutions and remain politically passive. However, at the same time, they feel that they do have the ability to influence political outcomes when necessary. These societies are further characterized by strong interpersonal trust and social cohesion [9].

Civic Culture Theory has since been used to study cultures and communities. Bordandini *et al.* [13] adopt the theory to study evidence of differences in civic culture across both north and south of Italy. The authors propose that among the entire Italian population, there is a third group of people—those who are civic minded yet disillusioned with political institutions. Durante *et al.* [14] study the relationship between civic culture and social distancing during the Covid-19 pandemic. They find that people first reduced their mobility as a voluntary response to the virus but were able to continue doing so, in accordance with social distancing policies, only with a civic culture. This culture, therefore, helped to internalize people to live with mobility restrictions.

To the best of our knowledge, Civic Culture Theory has never been used to study EV adoption. As we are investigating how both institutional and interpersonal trust influence EV adoption, this theory from the political science domain is well-positioned to support our analysis. Such cross-disciplinary application could also give us valuable insights into socio-cultural drivers of EV adoption.

Therefore, guided by this theoretical foundation, we propose the following hypotheses:

H1: Trust in political institutions within a country has a positive correlation to the level of EV adoption in that country.

H2: Trust within communities in a country has a positive correlation to the level of EV adoption in that country.

III. METHODS

For our study, national electric vehicle adoption was measured using EV sales in 2024, obtained from the Global EV Data Explorer by the International Energy Agency (IEA). This dataset is widely recognized as the authoritative source

for cross-country EV statistics. To address right-skewness and accommodate countries with negligible sales, the variable was transformed as:

$$\sqrt{\log_EV_Sales_i} = \log(EV\ Sales_i + 1) \quad (1)$$

Country level socio-cultural, political, economic, and security-related indicators were drawn from World Values Survey Wave 7 (WVS), collected between 2017 to 2022. These items capture individual level value systems aggregated at the national level. These include environmental concern and ecological priorities, institutional trust and political confidence, social identity, group belonging, national orientation, economic expectations and uncertainty, perceptions of safety, security, and social order as well as globalization attitudes.

Data cleaning and pre-processing were implemented through a four-stage pipeline. The analysis focused exclusively on markets with demonstrated EV adoption. Consequently, countries reporting zero or missing EV sales volumes in 2024 were excluded row-wise from the dataset. Filtering procedure reduced the dataset to 21 countries with valid outcome data. Sporadic missingness was identified across predictor variables, consistent with the challenges of compiling harmonized cross national indicators. Missing values were imputed using univariate mean substitution, calculated separately for each variable. All retained predictors were standardized to z-scores. The resulting analytical dataset comprised 21 countries and a refined set of numeric predictors, dimensionally suitable for modelling.

Given the unfavorable ratio of predictors to observations ($p > n$), variable selection was necessary to reduce overfitting and isolate the most influential correlates of EV adoption. We employed Least Absolute Shrinkage and Selection Operator (LASSO) regression [15], which estimates coefficients while simultaneously shrinking weaker predictors toward zero via an L1 penalty:

$$\min_{\beta} \left\{ \sum_{i=1}^n \left(y_i - \beta_0 - \sum_{j=1}^p \beta_j x_{ij} \right)^2 + \lambda \sum_{j=1}^p |\beta_j| \right\} \quad (2)$$

The regularization parameter λ controls model sparsity: larger values force more coefficients to zero, retaining only those predictors with the strongest marginal association with the dependent variable [16]. LASSO is well-suited for small-n, large-p datasets because it yields parsimonious models while maintaining interpretability [17].

$$\lambda \in \{0.01, 0.005, 0.001, 0.0005\} \quad (3)$$

A manually specified grid of increasingly stringent regularization parameters was evaluated using the scikit-learn implementation of LASSO. The sparsest non-empty solution occurred at $\lambda = 0.01$, which retained 19 predictors with non-zero coefficients. From these, the ten largest (absolute) coefficients were extracted for subsequent

interpretation. These represent the strongest value-based and attitudinal determinants of national EV adoption.

To complement the LASSO feature selection approach, we applied SHapley Additive exPlanations (SHAP) to quantify each predictor's marginal contribution to model outputs [18]. SHAP decomposes a prediction into additive feature attributions based on cooperative game theory. For predictor j , the SHAP value ϕ_j is:

$$\phi_j = \sum_{S \subseteq F \setminus \{j\}} \frac{|S|!(|F| - |S| - 1)!}{|F|!} \left[f(S \cup \{j\}) - f(S) \right] \quad (4)$$

where F is the full feature set and S denotes any subset excluding j [19].

KernelSHAP was used to obtain model-agnostic feature attributions for the LASSO model. KernelSHAP was selected because:

- (1) Model-agnostic: It supports linear estimators such as LASSO.
- (2) Theoretically grounded: It satisfies the axioms of Shapley value attribution (local accuracy, missingness, consistency).
- (3) Suitable for small-n datasets: Kernel-based approximations remain stable when the number of observations is limited.

SHAP values were computed for each country–predictor pair, generating a contribution matrix that enabled detailed visualizations (summary plots, heatmaps, and hierarchical clusters). These reveal heterogeneity across countries and highlight patterns not visible in global coefficients. All analyses were conducted in Python (version 3.11).

IV. RESULT AND DISCUSSION

LASSO regression with regularization parameter $\lambda = 0.01$ identified 19 predictors with non-zero coefficients from the initial pool of WVS-derived variables. To enhance interpretability and focus on the most influential determinants, we report the 10 predictors exhibiting the largest absolute coefficients. These variables collectively represent the socio-cultural value orientations most strongly associated with cross-national variation in EV adoption.

Table 1 presents the top 10 LASSO-selected predictors, ranked by coefficient magnitude, alongside their original WVS question wording and conceptual interpretation in the context of EV adoption.

The LASSO results reveal three dominant themes underpinning cross-national EV adoption patterns:

- 1) Environmental commitment and values: Two of the strongest predictors - willingness to sacrifice income for environmental protection ($\beta = 1.50$) and prioritization of environment over economic growth ($\beta = 0.37$)—indicate that EV adoption is fundamentally driven by societal commitment to ecological sustainability. Countries where environmental protection values are deeply internalized exhibit a substantially higher EV adoption ratio. While this dominant theme may not be surprising, it also suggests that a cohesive social orientation toward

common motivations is necessary for high EV adoption rates.

- 2) Institutional trust and governance credibility: Confidence in parliament emerged as the second-strongest predictor ($\beta = 1.43$), underscoring the critical role of perceived policy stability in technology transitions requiring long term infrastructure investments. EV adoption entails substantial sunk costs—both for consumers (vehicle purchase) and governments (charging networks, grid upgrades)—that are only recouped over extended time horizons. High institutional trust reduces uncertainty regarding policy continuity, thereby lowering perceived adoption risk [20]. This finding, therefore, provides empirical support for H1.

- 3) Social trust and cosmopolitan orientation: Multiple trust related variables—generalized trust ($\beta = 0.26$), neighborhood trust ($\beta = 0.13$), and positive views of regional integration ($\beta = 0.41$)—collectively emphasize the social embeddedness of technology diffusion. EV adoption is not purely an individual decision but a collective transition requiring coordination across actors (manufacturers, utilities, policymakers, early adopters). High-trust societies may more readily overcome coordination failures and free rider problems inherent in infrastructure-dependent innovations [21]. Additionally, openness to regional integration correlates with receptivity to globally diffusing technologies and harmonized standards. Taken together, these results provide strong support for H2.

Table 1. Top 10 Predictors of national EV adoption identified by LASSO ($\lambda = 0.01$)

Rank	Predictors		
	Conceptual Domain	LASSO Coefficient	WVS Survey Item
1	Environmental action	1.5013	“I am willing to give part of my income for the environment.”
2	Institutional trust	1.4289	“How much confidence do you have in Parliament?”
3	Regional integration	0.4101	“Do you have a favorable or unfavorable opinion of ASEAN?”
4	Environmental priority	0.3726	“Protecting the environment should be given priority, even if it causes slower economic growth.”
5	Economic optimism	0.3289	“How satisfied are you with the way the economy is developing?”
6	Generalized trust	0.2582	“Most people can be trusted or you can’t be too careful?”
7	Security values	0.2375	“Importance of security, safety, and social order values.”
8	Household financial satisfaction	0.1475	“How satisfied are you with the financial situation of your household?”
9	Neighborhood trust	0.1284	“How much confidence do you have in your neighbors?”
10	National pride	0.0801	“How proud are you to be [nationality]?”

Note: Coefficients represent standardized effects: a one-standard-deviation increase in the predictor corresponds to the reported change in log-transformed EV sales, holding other variables constant. All predictors were retained at $\lambda = 0.01$ from an initial pool of WVS-derived variables ($n = 21$ countries).

Notably absent from the top predictors are purely economic variables such as GDP per capita or energy prices, which featured prominently in earlier EV adoption studies [22]. This suggests that conditional on achieving a baseline level of economic development (implicit in the sample selection of countries with observed EV sales), civic culture-related factors of institutional and interpersonal trust exert significant influence on adoption trajectories. Material constraints appear secondary to value orientations in shaping aggregate demand.

Our findings also indicate that the 21 countries in our final dataset can be broadly placed into three clusters with civic cultural distinctions:

Cluster 1: Canada, Germany, Australia, Netherlands, New Zealand.

Countries in this cluster exhibit consistently strong positive SHAP contributions from environmental and institutional value dimensions. In general, they are also representative of relatively stable democracies displaying strong civic cultures.

Cluster 2: Japan, Chile, Slovakia, China, India, Thailand, Malaysia, Indonesia.

This cluster demonstrates heterogeneous SHAP patterns indicative of transitional value orientations. The patterns suggest that EV adoption is primarily policy-led or infrastructure-driven [23], rather than deeply entrenched cultural commitments. The diversity of this cluster with a mixed presence of civic cultures—spanning high income Japan and rapidly developing Indonesia—indicates that countries at different development stages may occupy similar

positions when environmental and trust values are still consolidating.

Cluster 3: Russia, Colombia, Brazil, Mexico, Romania, Cyprus, Greece, Uzbekistan.

Countries in this cluster are characterized by value-conservative profiles with weak or negative environmental SHAP contributions, indicating lower ecological priority and reduced institutional trust, with diminished or negative SHAP contributions from governance variables. In these contexts, EV adoption appears constrained by cultural and institutional factors. Lower salience of environmental concerns, weaker governance legitimacy, and stronger preferences for traditional energy security reduce responsiveness to conventional EV incentives. There is also less evidence of a civic culture.

Across the three clusters, national value profiles exhibit systematic associations with EV adoption patterns that extend beyond economic conditions or infrastructure availability. While causality cannot be inferred definitively from cross-sectional data, the clear separation of clusters suggests that cultural orientations shape consumer receptivity to EV technologies. These results highlight that the global diffusion of EVs is not merely a function of technological readiness or market incentives but is also embedded in broader societal value systems, especially those related to institutional and interpersonal trust.

V. CONTRIBUTIONS AND IMPLICATIONS

This study makes two important theoretical contributions.

First, the findings expand our knowledge on factors that impact EV adoption within a country, beyond those covered

extensively by prior studies on government policies, infrastructure, and economics. Once a country has reached a baseline level of economic development, a civic culture of institutional and interpersonal trust could be as important as political interventions in supporting EV adoption.

Second, our research contributes to the development of Civic Culture Theory. For the first time, this framework has been applied to a study on sustainable technology diffusion. As cross-disciplinary research, we offer fresh insights to both EV adoption literature and Civic Culture Theory.

By using LASSO and SHAP in our study, this paper makes a methodological contribution as well. These techniques allow us to uncover complex socio-cultural factors that traditional approaches may not.

Beside theoretical and methodological contributions, our findings have implications for both policymakers and automakers as well. First, in order to accelerate EV adoption rates, it is important for governments to recognize that public trust in political institutions and society plays important roles in the adoption process. EV policies should be consistent, transparent, and communicated clearly. The population has to be educated on the importance of sustainability and the harm ICE vehicles have on the environment. These efforts help to embed a culture of sustainability and, over time, foster interpersonal trust.

It is also important that automakers take country clusters based on level of civic culture into consideration when mapping out their EV market entry strategies. This clustering technique can help set expectations on adoption rates and consequently business planning processes.

VI. LIMITATIONS AND FUTURE RESEARCH

Several limitations on this research should be acknowledged.

First, the final data set consists of 21 countries. This can limit the generalizability of our findings. Future research could incorporate data from more countries as and when they become available.

Next, this study relies on cross-sectional data collected in 2024 for EV adoption while WVS data were collected from 2017 to 2022. The slight difference in time frame between the two datasets means that caution has to be applied when interpreting causal inferences. When they are available, future research could use new datasets that are more aligned in time frames.

Lastly, national aggregate indicators inevitably flatten local cultural nuance, particularly in large or regionally diverse nations. Analytical choices, including variable imputation and feature-selection thresholds, also introduce uncertainty. Further research should adopt longitudinal, policy-linked, and multi-scale approaches to better illuminate how civic culture interacts with public policy and market development during technology transitions.

VII. CONCLUSIONS

This study explores the relationship between civic culture in a country, specifically institutional and interpersonal trust, and EV adoption rate in that country. Using LASSO regression and SHAP analysis on EV adoption and WVS data from 21 countries, our findings show that trust-related

cultural orientations are among the top predictors of EV adoption rates, providing empirical support for our hypotheses. These findings extend our knowledge on factors that impact EV adoption, beyond the traditional areas of government policies and charging infrastructure.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Chong Guan and Victor Kwan collected the data while Chong Guan designed the analytical methodology using LASSO regression and SHAP analysis. Victor Kwan wrote the paper and both authors approved the final version.

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