UNITED STATES ELECTRIC VEHICLE ADOPTION AND ITS CONTRASTING WORKFORCE IMPACTS

A THESIS

Presented to

The Faculty of the Department of Economics and Business

The Colorado College

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Arts

By

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May 19, 2024

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Mathematical Economics

Abstract

This thesis examines the impact of electric vehicle (EV) adoption on the automotive manufacturing workforces of Indiana and California, states with significant differences in both EV policy and sales. Using statistical regression techniques, it explores how EV adoption and manufacturing market variables affect employment levels. Despite some statistical limitations, the findings indicate a divergent impact: a positive relationship between national EV sales and employment in California, with its aggressive EV policies, and a negative relationship in Indiana, where traditional automotive manufacturing prevails. This highlights the complexity of labor transitions during increasing EV production and the importance of regional policies in influencing job creation or erosion. The findings can inform state EV policy, labor market research, and auto manufacturing labor union discussions when considering the diverging impacts the study outlines between EVs and labor.

KEYWORDS: Electric Vehicles, Auto Manufacturing Workforce, Vehicle Market Analysis

ON MY HONOR, I HAVE NEITHER GIVEN NOR RECEIVED UNAUTHORIZED AID ON THIS THESIS

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Section 1: Introduction

The transition towards electric vehicles (EVs) is transforming the automotive industry, with significant implications for manufacturing jobs and compensation. While there is a growing consensus that EVs will create new jobs in the long term, the impact on existing manufacturing jobs in the short term is less clear (Jaeger et al., 2023). Traditional gasoline cars include internal combustion engines (ICE), of which, the manufacturing process involves complex and intensive processes, involving the assembly of thousands of parts from hundreds of suppliers. Currently, the industry employs just over one million people in the United States with a median annual wage of $58,000 (US Bureau of Labor Statistics, 2023). Manufacturing jobs in the automotive industry are typically unionized, with the United Auto Workers (UAW) representing over 400,000 workers (United Auto Workers, 2023). Disembarking from this complicated, labor-intensive assembly process presents potential disruptions for workers and the auto manufacturing industry.

Contemporary UAW goals target compensation, hours, right to strike, and benefits, but they fail to specifically address the inevitable supply chain disruptions the transition to EVs will cause workers (United Auto Workers, 2023). EVs are simpler to produce than traditional ICE vehicles, requiring fewer parts and less assembly time, leading to concerns that EV adoption will reduce headcount in the automotive manufacturing sector. Even Ford's CEO, Jim Farley, acknowledges that "Electric vehicles will require 40% less labor to build than current combustion vehicles" (White, 2022). Nevertheless, it's crucial to acknowledge that the EV industry is rapidly changing, and preconceived notions might not align with the actual developments. According to the UAW, there are new opportunities for high-quality jobs to design, manufacture, and maintain EVs if the US institutes industrial policy which trains its workforce for these new responsibilities (United Auto Workers, 2018). Given these conflicting forces – simplicity of production and demand for innovative jobs – great ambiguity exists regarding the net impact on headcount and compensation within the auto manufacturing workforce directly resulting from EV adoption.

Quantifying this issue is complicated; EV adoption significantly varies state-by-state, ICE vs EV manufacturing jobs can use different skill sets, and the reasons for headcount reduction vary from automation to cheaper production overseas. To combat these complications, this thesis will compare two states: Indiana and California. Specifically, this research seeks to answer the question, what impact does the adoption of EVs have on the auto manufacturing workforce? In 2022, Indiana accounted for .7% of EV vehicle registrations nationwide, compared to 37.0% of California (US Department of Energy, 2023). Meanwhile, both of their auto manufacturing workforces are robust; Indiana accounted for 108,000 jobs in the auto manufacturing industry in 2022, compared to 32,000 in California (US Bureau of Labor Statistics, 2023). Through the isolation of EV adoption into two regions, this comparison framework can help quantify whether the introduction of EVs influences auto manufacturing job markets.

This study begins with a literature review discussing factors influencing auto manufacturing job markets, EV adoption, and the balance between labor and capital by reviewing existing quantitative research and enacted policies. Because of the limited quantitative analysis surrounding workforce impacts, the methodology of this study will implement statistical regression techniques using employment and EV adoption contextualized with state-level EV subsidy and auto manufacturing policies. Next, this study discusses the model, its key assumptions, and the statistical significance of the results. A few key limitations exist surrounding applicability and confounding variables, so this study addresses those in relation to the model's findings. The model will be used to describe the workforce impacts within Indiana and California and broader implications within the United States. The paper will conclude by summarizing key findings, discussing the contributions to research, and highlighting the societal implications and room for further research.

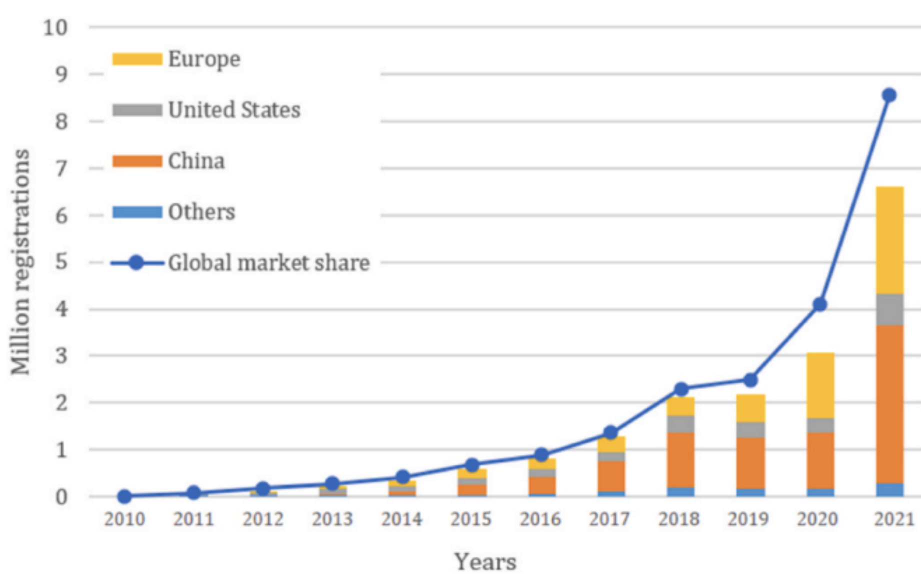
Section 2: Literature Review

I. Rise of Global EV Adoption

While this study's scope is the United States, there is significant literature about EV adoption globally and its causal factors. In terms of sheer vehicle registration numbers, China, Europe, the United States, and Japan stand as the undisputed frontrunners in the global EV market (Tan et al., 2023). Particularly notable in Figure 1 is China; the country has seen roughly half of recent global EV vehicle registrations, "a result of effective EV policies implemented by the Chinese government" involving both vehicle subsidies and charging infrastructure development (Tan et al., 2023). Existing research acknowledges that certain individual countries, such as China, may have greater EV adoption rates than other regions, but studies show the global average cost of vehicles has fallen significantly and range increased (World Energy Investment, 2020). Such trends in cost and range set the stage for global adoption, opening the products up to consumers with longer commutes or greater price sensitivity.

Figure 1

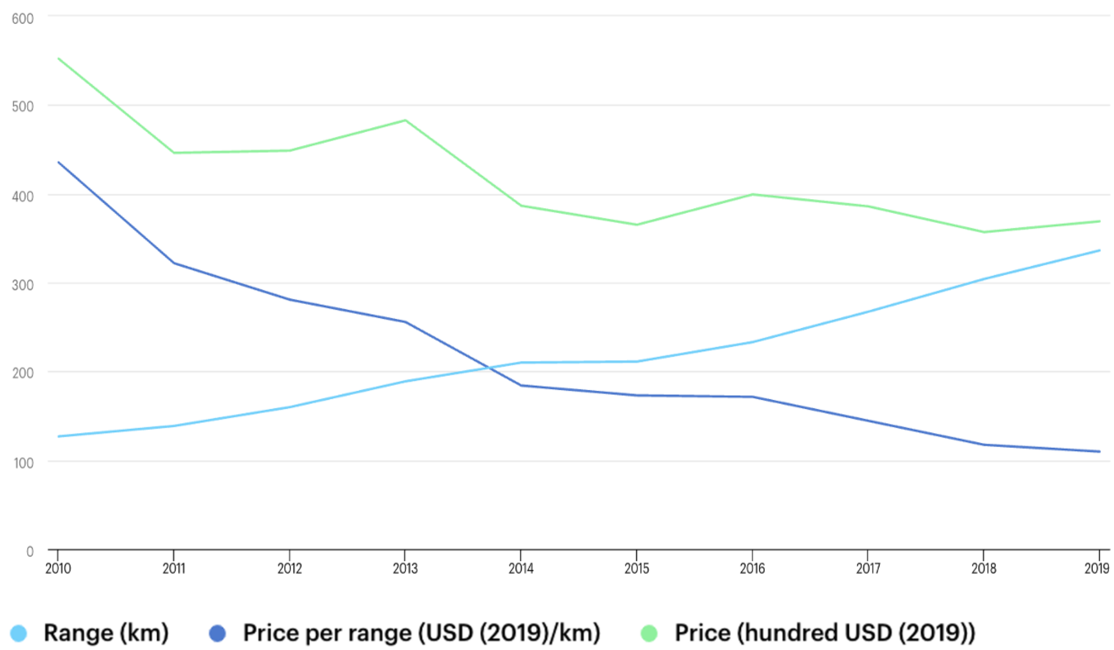
Global EV Registrations from 2010 till 2021 (IEA, 2020)



Amongst the major factors influencing global adoption are consumer barriers. Existing literature discussing the barriers and drivers to global EV adoption specifically cites safety, range limitations, model options, and awareness of incentive programs as key barriers to widespread global adoption (Haddadian, 2015). Despite these social barriers being legitimate, the state of EVs in Europe, China, and the United States, amongst other regions, already addresses many of these concerns. Tesla's Model Y earned the National Highway Traffic Safety Administration's highest safety rating in the United States and is known to be an American industry-leader in crash safety (National Highway Traffic Safety Administration, 2021). Furthermore, EV ranges are increasing as battery technology continues to develop, as seen with the decreasing the cost per vehicle range in Figure 2, and incentive programs to expand consumer access to charging do exist in many regions (The White House, 2021). Based on the existing literature, we expect EV adoption to increase globally as the main barriers continue to be addressed.

Figure 2

Average Price and Driving Range of BEVs (IEA, 2020)



Within the United States, adoption is a matter of when, not how. McKinsey and Company projects ICE vehicles to constitute less than half of all new vehicle sales by 2030 (Fischer et al., 2021). In this projection, electric vehicles include hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell electric vehicles (FCEVs), and battery electric vehicles (BEVs). BEVs make up most of these new projected sales, demonstrating the shift towards EVs will likely be dominated by vehicles entirely reliant on charging infrastructure. When assessing the factors for adoption, numerous variables influence the adoption of EVs, but above all is the price. In the United States EVs have a wider range of prices compared to ICE vehicles, but Figure 3 shows that, as of 2022, the EV market provides prices within range of ICE vehicles (Tan et al., 2023). This cost dynamic sets the stage for broader adoption across the United States, for a fall in EV prices negates the narrative of significant cost premiums.

Although the overall outlook for EV adoption in the United States is promising, political factors in individual states, like Indiana, could impede this movement.

Figure 3

EV and ICE Vehicle Price Range for the United States (Tan et al., 2023)

II. Political Considerations

Given the imperative role of policy to facilitate widespread adoption of EVs, the political landscape sets an underlying framework for discourse. Notably, Indiana's state governance contrasts the more liberal stance observed in California, indicative of a prevailing conservative influence in the state. The Republican Party has asserted control over Indiana's office of governor, senate, and house since 2011, maintaining control of at least two offices since 2005 (Ballotpedia, 2023). Throughout this period, Indiana Republicans have enacted a varied spectrum of environmental policies, encompassing initiatives ranging from the establishment of recycling programs to the rescission of prior subsidization measures (Indiana Department of Environmental Management, 2022). Despite varied policies, an examination of budgetary modifications within the Indiana Department of Environmental Management unveils a discernible pattern: Republican leadership corresponds with diminished emphasis on emission reduction. According to the Environmental Integrity Project, an inflation-adjusted analysis reveals there was a 20% reduction in the budgetary allocation from 2008 to 2018 (Environmental Integrity Project, 2019). While not strictly deterministic, this budgetary decline signifies that Indiana's conservative leadership does not prioritize funding for the implementation of environmental measures.

California's governmental paradigm stands in stark contrast to Indiana. The state has a robust electoral history with the Democratic Party, resulting in Democratic hegemony across all three state offices since 2011 and control of at least two offices since 1997 (Ballotpedia, 2023). Concurrently, California is a prominent force in the oil industry, consistently ranking within the top seven oil-producing states within the nation (U.S. Energy Information Administration, 2023). Oil industry lobbying has been shown to increase private profits by manipulating political actions, potentially presenting a hinderance for EV policy (Brown, 2018). However, California remains singular in its commitment to environmental issues as "the only state with emissions reduction targets that are simultaneously economy-wide in their scope, ambitious, and legally binding" (Karapin, 2018, p. 318). Noteworthy is the surge in California's inflation-adjusted budget for the California Environmental Protection Agency, seeing a 74.5% increase from 2008-2018 (Environmental Integrity Project, 2019). This juxtaposition highlights that, despite the presence of the oil industry, a liberal governance framework, as exemplified by California, can pass substantial legislative reforms and allocate considerable budgetary support for the promotion of EV adoption.

III. Policy Approach

Regardless of state politics, both Indiana and California have access to federal government EV incentive programs. For example, the federal government enacted the Clean Vehicle Credit in 2008, a bill which has seen updates with the Inflation Reduction Act of 2022, providing taxpayers who purchase an EV or FCEV up to a $7,500 tax credit if the vehicle was produced within the United States (U.S. Department of Energy, 2023). Federal tax credit programs influence both EV adoption and domestic production in all states, even ones who directly oppose spending on the green transition or a shift towards EV production, possibly dampening the contrast between the EV markets in Indiana and California. For EV producers, federal policies provide incentives to manufacture EVs in the United States. The Inflation Reduction Act of 2022 includes a tax credit for EV manufacturers that use critical minerals that are extracted, processed, or recycled in North America – an incentive designed to encourage the development of a domestic EV supply chain (Bush, 2022).

In addition to tax credits, the United States government offers grants and loans to companies that are developing and manufacturing EVs and supporting infrastructure (The White House, 2021). These programs can help to reduce the risk of investing in EV production and make it more attractive for companies to do so in the United States. Overall, federal EV policies play a significant role in supporting both EV adoption and domestic production, making EVs more affordable for consumers and encouraging companies to manufacture EVs in the United States.

On the state-level, policy varies significantly between the two states. By 2035, California aims for 100% of all new light-duty vehicle sales to be zero emission vehicles (ZEV) – a grouping of EV subcategories. Numerous policy implementations support this ambition, namely vehicle and charging station subsidization, private sector production regulations, and low-income access programs (U.S. Department of Energy, 2023). California offers a robust EV purchase subsidization program in addition to federal programs, including up to $3,500 and $4,500 in rebates for purchases of PHEVs and BEVs. Furthermore, the subsidies extend to charging stations, where rebates are typically $1,500 for personal use and between $3,000 and $10,000 for public use. California policy also imposes quotas on manufacturers, setting minimum production levels for ZEVs in the state (Baldwin et al., 2021). The gradual introduction of production mandates primes the private sector for EV production without significantly stifling business involvement in California.

In contrast to California's multi-faceted approach to EV promotion, Indiana adopts a less proactive stance. Unlike California, which offers a range of incentives for EV adoption, including rebates, subsidies, and charging infrastructure development support, Indiana does not provide direct financial incentives for EV purchases or charging infrastructure development (U.S. Department of Energy, 2023). This contrasting approach reflects Indiana's preference for incremental measures within existing infrastructure rather than a radical shift towards a comprehensive EV strategy, further evidenced by the state's emphasis on diesel emission reduction grants for retrofitting vehicles (Indiana Department of Environmental Management, 2022). This policy difference highlights the contrasting approaches taken by different states in the United States to address the transition towards a more sustainable transportation system. California's proactive and comprehensive EV promotion strategy stands in stark contrast to Indiana's more reactive and incremental approach, reflecting the unique political and economic landscapes of each state. Regardless of their differing stances on EV production, both California and Indiana will undoubtedly feel the effects of its adoption on the auto manufacturing workforce.

IV. Impact on the US Workforce

In the context of the United States, limited research delves into the repercussions of EV adoption on the automotive manufacturing workforce. Barrett and Bivens (2021) conducted a study utilizing sensitivity analysis to comprehend the impact of EV adoption within different auto manufacturing workforce scenarios, projecting future outcomes. Their research discerned that policy inaction would result in a job loss ranging from 15,000 to 75,000, while the onshoring of powertrain production and increase in domestic vehicle shares could potentially create around 150,000 jobs (Barrett and Bivens, 2021). Derived from these findings is a compelling call to action; the implementation of investment policies in domestic production by the government could yield a substantial surge in job opportunities during the transition to EVs. Moreover, Barrett and Bivens contextualized union membership in relation to wages. Historical data shows a fall in union membership correlates to a fall in wage premiums for the auto manufacturing sector (Barrett and Bivens, 2021). While causation has not been proven, examining the implications of EV adoption on the auto manufacturing workforce in the United States within the broader context of labor issues strengthens the study by considering potential confounding variables.

The potential impact of EV adoption on the United States auto manufacturing workforce is a complex and evolving issue that demands careful consideration. While studies such as Barrett and Bivens provide valuable insights into the potential job losses and gains associated with the transition to EVs, it is crucial to recognize the limitations of purely predictive models. These models can be useful for forecasting potential scenarios but often lack the statistical significance of historical data analysis. To address this weakness, an in-depth examination of the relationship between EV transition variables and employment figures is necessary. Considering this, this study will now outline the methodological framework employed to gather and analyze data relevant to the research question.

Section 3: Methodologies

I. Introduction

Existing literature has established the impact of electric vehicle EV adoption on various aspects of the automotive industry, including manufacturing, supply chains, and consumer behavior. However, this literature focusing on individual factors contributing to EV adoption largely neglects the impact to regional workforces. This paper aims to take a more comprehensive approach by examining the interplay of multiple factors that influence EV adoption rates in two starkly contrasting regions: Indiana and California. Additionally, while previous studies have explored the overall impact of EV adoption on the automotive industry, this paper delves deeper into the specific effects on auto manufacturing employment. By analyzing data from these two states with varying EV adoption levels, this study seeks to identify the key factors that drive workforce changes in the auto manufacturing sector because of the transition to EVs. This comparative analysis will provide valuable insights into the effects of national trends in EV adoption on regional automotive workforces.

The purpose of the study is to determine the impact the introduction of EVs has on the auto manufacturing workforce. To quantify this, we will compare the historical relationship between variables related to EV adoption – such as vehicle registrations, EV policy, and gasoline prices – and labor data for Indiana and California.

II. Model Overview

This model involves two, independently run Ordinary Least Squares (OLS) statistical tests to evaluate the impact of EV sales, amongst other variables, on Indiana and California's auto manufacturing workforces. To accomplish this, we've compiled 153 timeseries datapoints from January 2011 until September 2023 reflecting EV sales, lightweight vehicle sales, gasoline prices, real private investment in auto manufacturing and an industrial production index to regress against auto manufacturing headcount changes in the two states.

Initial empirical model:

$$\text{Auto Manufacturing Headcount} = \beta_0 + \beta_1(\text{EV Sales}) + \beta_2(\text{Lightweight Vehicle Sales}) + \beta_3(\text{Gasoline Prices}) + \beta_4(\text{Real Private Investment}) + \beta_5(\text{Industrial Production Index}) + \varepsilon$$

Given the distinct landscapes of both states – Indiana leaning towards ICE production and California embracing EVs – we hypothesize that EV sales will positively influence California's worker headcount while having minimal impact on Indiana. Conversely, real private investment, we predict, will negatively affect headcount in both states given the adoption of manufacturing automation. Gasoline prices, however, are expected to have a smaller negative impact on California due to its higher EV production and hence lesser dependence on gas. Finally, we hypothesize both overall lightweight vehicle sales and the industrial production index to positively influence the headcount in both states.

III. Relevant Variables

Except for real private investment, all variables in the study were collected as monthly datapoints and compiled into the time series dataset. For the quarterly data with real private investment, we conducted a data transformation. The data transformation went as follows: divide each quarterly data point into three, then take that new value and set it for each of the three months within that quarter, effectively averaging the quarterly data into monthly data. This may limit the relationship between real private investment and headcount since the transformed data will have less variability. For greater depth, the list of variables and their summary statistics are described below, and the sources are listed in works cited section.

Table 1

Relevant Variables, Descriptions, and Sources

Variable	Description
IND	Indiana total auto manufacturing worker headcount, thousands of workers
CAL	California total auto manufacturing worker headcount, thousands of workers
BEV	U.S Battery Electric Vehicle sales
PHEV	U.S. Plug-in Hybrid Electric Vehicle sales
All_EV	Combined U.S. BEV and PHEV sales
LW_Sale	U.S. light weight vehicle sales, millions of units
LW_Sale_lag	U.S. light weight vehicle sales, millions of units, lagged one month
Gas	Average unleaded gasoline price per gallon in U.S. city, U.S. dollars
Gas_lag2	Average unleaded gasoline price per gallon in U.S. city, U.S. dollars, lagged two months
Private_Investment	U.S. real private fixed investment in new motor vehicle production, billions of U.S. dollars
Private_Investment_lag	U.S. real private fixed investment in new motor vehicle production, billions of U.S. dollars, lagged one month
Indus_Prod	U.S. industrial production total index, baseline year 2017=100

Source: Bureau of Labor Statistics, Alliance for Automotive Innovation, Federal Reserve Bank of St. Louis

Table 2

Summary Statistics of Relevant Variables

Variable	Obs	Mean	Std. dev.	Min	Max
IND	153	59.04	4.90	36.90	66.00
CAL	153	15.20	10.02	3.90	36.00
BEV	153	20,231.78	25,559.90	84.00	106,139.00
PHEV	153	7,775.42	5,755.11	165.00	27,002.00
All_EV	153	28,007.20	30,862.47	367.00	132,833.00
LW_Sale	153	1,570,000.00	1,796,405.00	8,482,000.00	1,810,000.00
LW_Sale_lag	152	1,570,000.00	1,802,343.00	8,482,000.00	1,810,000.00
GAS	153	3.02	0.68	1.77	5.06
Gas_lag2	151	3.00	0.67	1.77	5.06
Private_Investment	153	24.12	8.03	10.03	34.87
Private_Investment_lag	152	24.20	8.00	10.03	34.90
Indus_Prod	153	99.83	3.24	84.60	104.12

IV. Limitations

Several key limitations deserve consideration. Firstly, the reason why we picked California and Indiana for their contrast in EV – 903,620 BEV registrations to just 17,710 – while insightful, raises questions about extrapolating vehicle registrations to accurately represent manufacturing (US Department of Energy, 2023). This limits the model's direct application to production analysis. Additionally, the relative infancy of EV technology restricts our data to the past decade, potentially constraining statistical significance. Lastly, there is an inevitable overlap between EV and lightweight vehicle sale data. This potential overlap could introduce multicollinearity between the EV and lightweight vehicle sales variables, potentially impacting the independent estimation of their individual effects. Other multicollinearity issues could include the industrial production index's relationship with real private investment since greater production levels may lend itself to more investment in production.

V. Statistical Robustness

Our statistical analysis encountered several limitations, including moderate multicollinearity, significant heteroskedasticity, notable autocorrelation, and pronounced deviations from normality in model residuals. While were able to address the heteroskedasticity by using robust standard errors, data transformations or the adoption of nonparametric methods provided minimal improvements to the model's statistical robustness. Given this, we opted to proceed with our linear models, interpreting findings with caution. This decision reflects an understanding of the data's complexity and taking a balanced approach to drawing insights under statistical constraints. Further details on these limitations are discussed in the appendix section.

Table 3

California Auto Manufacturing Workforce Model

Source	Sum of Squares	df	Mean Square			
Model	14437.3612	5	2887.47225	Number of obs	=	151
Residual	562.435838	145	3.87886785	F(5, 145)	=	744.41
Total	14999.7971	150	99.9986472	Prob > F	=	0
				R-squared	=	0.9625
				Adjusted R-squared	=	0.9612
				Root MSE	=	1.9695

CaliforniaHeadcount	**Coefficient**	**Standard Error**	**t**	**P>t**	**[95% conf. interval]**	
EVSales	0.0001476	0.0000119	12.41	0.000	0.0001241	0.0001711
LightweightVehicleSales_lag	4.94E-07	2.21E-07	2.23	0.027	5.66E-08	9.32E-07
lagged2_gas	-2.20542	0.4268981	-5.17	0.000	-3.049166	-1.361673
AutoManufacturingPrivate_lag	-0.7259919	0.0499237	-14.54	0.000	-0.824664	-0.6273198
IndustrialProductionIndex	0.4836571	0.091849	5.27	0.000	0.3021211	0.665193
_cons	-20.71981	6.56029	-3.16	0.002	-33.68596	-7.753662

Table 4

Indiana Auto Manufacturing Workforce Model

Source	Sum of Squares	df	Mean Square			
Model	3140.64459	5	628.128917	Number of obs	=	151
Residual	290.159784	145	2.00110196	F(5, 145)	=	313.89
Total	3430.80437	150	22.8720291	Prob > F	=	0
				R-squared	=	0.9154
				Adjusted R-squared	=	0.9125
				Root MSE	=	1.4146

IndianaHeadcount	**Coefficient**	**Standard Error**	**t**	**P>t**	**[95% conf. interval]**	
EVSales	-0.0000735	8.54E-06	-8.6	0.000	-0.0000904	-0.0000566
LightweightVehicleSales_lag	1.16E-06	1.59E-07	7.28	0.000	8.43E-07	1.47E-06
lagged2_gas	-2.871873	0.3066241	-9.37	0.000	-3.477903	-2.265843
AutoManufacturingPrivate_lag	-0.274202	0.0358582	-7.65	0.000	-0.3450744	-0.2033297
IndustrialProductionIndex	0.9949506	0.0659716	15.08	0.000	0.8645605	1.125341
_cons	-41.06587	4.711999	-8.72	0.000	-50.37894	-31.75279

VI. Final Model

The creation of these two models, as seen in Table 3 and 4, is deeply influenced by statistical testing and theoretical considerations. Notably, shifting to robust standard errors and lagging variables helps improve the model's outcomes without meaningfully impacting its relationships. This process highlights the dynamic nature of econometric analysis and its responsiveness to empirical challenges and theoretical insights. While statistical complications do exist with the findings, such as potential non-linearity and positive autocorrelation, these findings still offer insightful contributions to the automotive sector's evolving dynamics, even in the face of reduced statistical certainty.

Final empirical model:

Auto Manufacturing Headcount (California, Indiana) = β_0 + β_1(EV Sales) + β_2(Lightweight Vehicle Sales, 1-month lag) + β_3(Gasoline Prices, 2-month lag) + β_4(Real Private Investment, 1-month lag) + β_5(Industrial Production Index) + ε

Section 4: Results and Analysis

I. California Model

Our first OLS regression (see Table 3) delves into the factors influencing California's auto manufacturing headcount. The model boasts an R-squared value of 0.96, indicating excellent fit and suggesting our chosen independent variables effectively explain the variance in headcount. Moreover, except for lightweight vehicle sales, all P-values fall below the 1% threshold, confirming the statistical significance of individual relationships.

Examining specific variables, we find clear support for many of our hypothesized relationships. As predicted, EV sales display a positive relationship with California's auto manufacturing workforce. This suggests that national increases in EV sales will likely translate into greater demand for headcount within California’s auto labor market. Interestingly, though, while lightweight vehicle sales (including both EVs and ICE vehicles) also exhibit a positive association, its coefficient is smaller than that of EVs. This nuance underlines the increasingly influential role EVs are playing in California's auto workforce growth. Further bolstering our hypotheses, gasoline prices demonstrate an expected inverse relationship with headcount. Rising lagged gas prices, by making vehicle ownership less attractive, appear to lead to reductions in the auto manufacturing workforce. Additionally, lagged private investment in the industry, as hypothesized, shows a negative relationship with headcount, likely reflecting the increasing implementation of automation technology. Finally, our chosen control variable, the industrial production index, reinforces our understanding of the sector. As expected, its positive coefficient reflects the need for more workers during periods of higher production and vice versa.

II. Indiana Model

Shifting our focus to Indiana, the second OLS regression (see Table 4) examines the unique dynamics shaping its auto manufacturing workforce. This model boasts a sufficient R-squared value of 0.92, suggesting our chosen variables effectively explain a substantial portion of the variance in headcount. Notably, all P-values remain below the 1% threshold, reaffirming the statistical significance of these relationships.

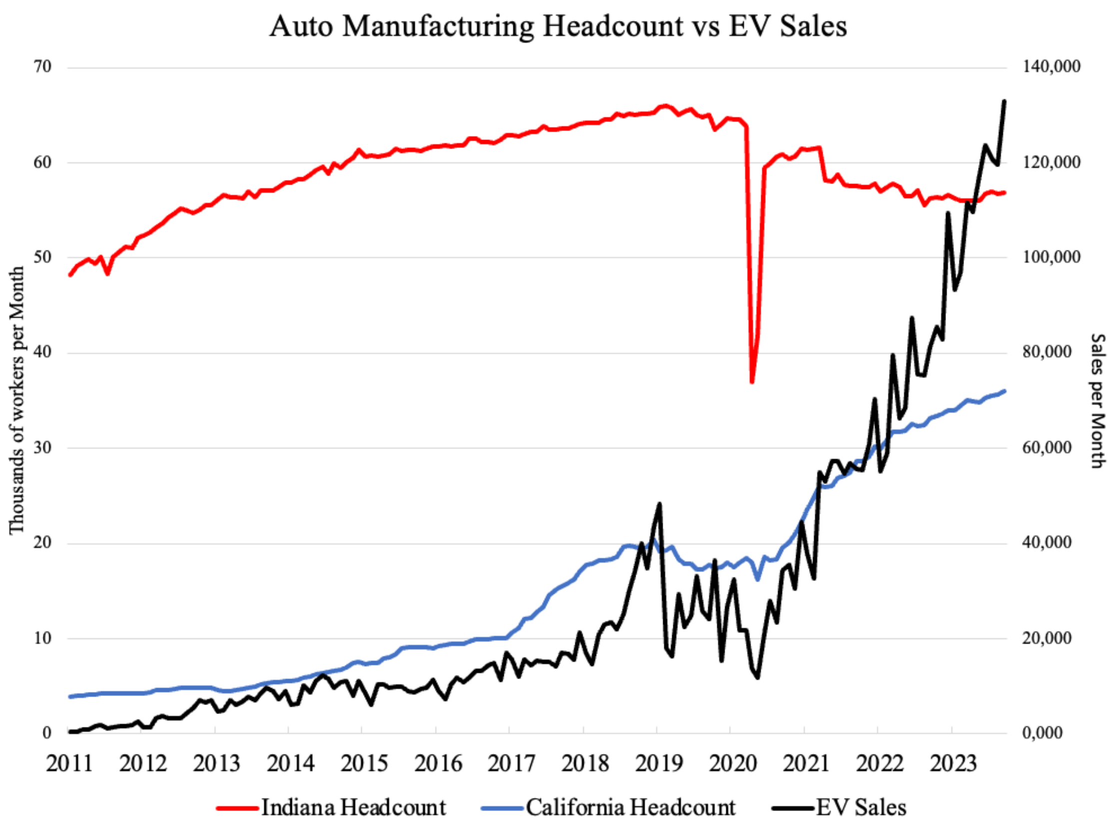
While many hypothesized relationships echoed those observed with the California model, Indiana unveiled an interesting divergence regarding EV sales. Contrary to our initial expectations of a minimal effect, the regression revealed a significant negative association between national EV sales and Indiana's auto manufacturing headcount. This unexpected negative association raises questions about Indiana's adaptation to the growing EV market compared to California. While the specific reasons remain to be explored, the data hints at potential contributing factors like production capacity, capabilities, and other factors which will be explored in the discussion section. The other hypothesized relationships largely held true. National vehicle sales, encompassing both EVs and ICE vehicles, exhibited a positive relationship with headcount. Similarly, lagged gasoline prices maintained their inverse association with headcount, underlining the influence of fuel costs on the industry's workforce. Moreover, lagged private investment's negative relationship and the industrial production index's positive relationship with headcount remained consistent with the California model.

Overall, the Indiana model paints a nuanced picture of the state's auto manufacturing landscape. While some hypothesized relationships aligned with national trends, the unexpected role of EV sales warrants further investigation. This finding highlights the importance of understanding local contexts and their potential deviations from broader patterns.

Figure 6 displays the divergent trends between a stagnant auto manufacturing headcount in Indiana and Californian workforce growing in tandem with EV sales. This disparity may suggest regional economic differences. Furthermore, such trends in EV production capability growth in conjunction with sales growth may present statistical challenges, like autocorrelation and confounding variables. These observations underscore the need for nuanced analysis to understand the regional labor responses to the EV market's evolution.

Figure 6

Indiana and California Auto Manufacturing Workforce vs EV Sales



Source: Bureau of Labor Statistics, Alliance for Automotive Innovation

Section 5: Discussion

I. Labor Sensitivity

As anticipated, electric vehicle adoption significantly influenced auto manufacturing workforces, but in divergent ways. California displayed a robust positive correlation between EV sales and auto manufacturing employment, while Indiana experienced a negative association. This regional disparity underscores the critical need to move beyond national trends and examine the dynamics within specific geographical and political contexts. Figure 6 visually depicts this divergence, highlighting how embracing EV manufacturing has the potential for auto manufacturing workforce growth, whereas failure to shift towards EV production can lead to workforce stagnation.

These findings directly support Barrett and Bivens' labor sensitivity theory by providing empirical evidence for its regional applicability. California's proactive stance — exemplified by its $200 million support to in-state EV manufacturing, ambitious EV charging infrastructure development, and EV sales requirements — has positioned it as the national leader in electric vehicle jobs (Office of Governor Gavin Newsom, 2023). In contrast, Indiana's lack of supportive policies translates to a marginal share of its workforce engaged in EV production; a 2021 nationwide manufacturing plant study found 24,358 jobs directly attributable to ICE vehicles and 960 jobs directly attributable to EVs, showing Indiana’s significant workforce composition of ICE production (Hughes-Cromwick, 2021). This aligns with Barrett and Bivens' hypothesis that policy inaction could lead to significant job losses (ranging from 15,000 to 75,000), while onshoring powertrain production, as demonstrated by California, could potentially create around 150,000 new jobs.

Like Barrett and Bivens' argument, the contrasting outcomes in California and Indiana offer an illustration of how proactive policy interventions can foster new opportunities in the wake of EV adoption, while a lack of such policies can lead to workforce stagnation. This finding suggests that regionally tailored policy attending to EV production and consumer demand will be critical for ensuring a smooth transition for the U.S. auto manufacturing workforce as the EV revolution inevitably unfolds.

The differing impacts of EV adoption on California and Indiana's auto manufacturing workforces might be partly explained by current regional variations in EV production capacities. Indiana's lower EV production and stronger ICE vehicle presence, compared to California's robust EV industry, likely contribute significantly to their divergent workforce impacts. Such divergence underlines the crucial role of regional infrastructure and technological readiness to realize the employment benefits offered by the EV transition. This aligns with Fischer et al.'s emphasis on the necessity of EV-related infrastructure, such as charging and vehicle services, suggesting regions with developed EV ecosystems are more adept at leveraging employment advantages of this automotive shift (2021).

Other labor sensitivity issues exist beyond merely headcount. Collective bargaining, when supported with accurate labor research, holds the potential to navigate these transitions effectively. Jaeger et al. highlight a notable development in the industry: less EV plants are unionized in comparison with traditional auto manufacturing plants, marking a possible paradigm shift (2023). They further elaborate on emerging challenges, including salary erosion and the rise of part-time workforces amidst the EV transition. While this study focuses primarily on headcount, there exists a gap in research concerning the broader implications of unionization and labor standards within the evolving EV landscape. Future investigation is warranted to explore the effects of union movements and labor standard shifts as the industry transitions towards EVs.

II. Coefficient Magnitude Significance

The analysis highlights a significant difference in how EV sales and overall vehicle sales influence auto manufacturing employment. When compared to the lightweight vehicle sales coefficient, the EV sales coefficient is over 60 times greater in magnitude for both California and Indiana. This significant difference in coefficient sizes emphasizes that manufacturers respond more markedly to changes in EV sales than to broader vehicle market trends. The growing EV sector, with its potential for expansion, seems to have a more substantial effect on manufacturing employment compared to the traditional automotive industry.

However, the robust correlation with EV sales may reflect an existing industry optimism about the future trajectory of EV adoption rather than a heightened importance in EV sales, leading to an observed statistical significance influenced by market sentiment. One indication of market optimism fueling manufacturing shifts may be shrinking production costs. According to the report, “the EV value proposition [globally] for consumers improved by 12% compared with 2018 and 36% compared with 2015”, displaying technological development’s influence in guiding the industry towards cost parity with ICE vehicles, thereby serving as a significant impetus for a market transition (World Energy Investment, 2020). Similarly, the weaker link between overall vehicle sales and employment changes may be less about the actual market fluctuations and more about the industry's established confidence consumer demand. While the findings are statistically significant, they likely represent a range of factors from uncaptured market dynamics to a causal relationship between sales volatility and manufacturing employment. Such ambiguity highlights the complexity of the underlying relationships in the industry and need for the isolation of EV market trends.

III. Limitations

This study, while providing valuable insights into the impact of EV adoption on the auto manufacturing workforce in California and Indiana, encounters several limitations that must be acknowledged.

By relating national EV sales data to these two states' workforces, the research fails to fully capture the diverse range of factors influencing EV adoption and workforce dynamics in other regions – such as regional production abilities, domestic trade, and manufacturing incentives, amongst other factors. The study's findings are thus applicable to contextually similar regions: robust EV policy stance and production capabilities or lacking EV policy and production. Regions with more scattered economic, political, and social landscapes may have less to glean from this study. Future research should consider a broader range of states or regions to provide a more comprehensive understanding of the EV transition's impact on the auto manufacturing workforce across the United States.

The EV market is rapidly evolving, with technological advancements and shifting consumer preferences. These dynamic changes pose a challenge in predicting future workforce trends based on past and current data. The creation of a new auto industry will inevitably lead to job growth, but uncertainty exists surrounding the headcount for the total workforce, given Ford's prediction EVs will require 40% less labor (White, 2022). Future research should evaluate workforce growth in conjunction with EV production levels to evaluate overarching effects. This research may help reveal the trajectory of the U.S. auto manufacturing workforce rather than establishing individual relationships within the industry.

In this study, while state-level policies have been a focus, quantifying their impact poses a challenge due to the qualitative nature of policy analysis. Future research could benefit from identifying proxies or quantitative measures that can effectively gauge the quantitative impact of these policies. This approach may allow for a broader selection of states in future studies, moving beyond the binary policy environment of California and Indiana we decided to use. Such a method could provide a more nuanced understanding of how varying degrees and types of EV policies influence the auto manufacturing workforce. Additionally, the complex interplay between state, federal, and international policies, and their collective impact on the workforce, warrants a more comprehensive approach to capture the full spectrum of policy influences.

For future areas of study, there is a need to expand the scope in terms of both the time frame and the range of variables considered. Extending the time frame would allow for the observation of longer-term trends and the evolution of the EV market and its workforce implications. Incorporating a wider range of variables could provide a more thorough understanding of the multifaceted nature of the EV market and its workforce dynamics. Furthermore, addressing the statistical challenges identified in this study, such as the introduction of non-linear relationships and the mitigation of positive autocorrelation, is crucial. Taking this holistic approach by addressing limitations related to time, statistical confidence, policy considerations, and the dynamic EV market could yield deeper insights into the transitioning auto manufacturing sector and inform strategies to navigate the EV adoption era.

Section 6: Conclusion

This study assesses how EV adoption and national economic trends affect regional auto manufacturing labor markets. Given the variance in manufacturing capabilities, consumer demand, and political landscapes across the US, we constructed two models that regress national economic variables against auto manufacturing headcount data from California and Indiana, allowing us to attend to regional differences. After running these models, we found a few key takeaways. First, EV sales are positively related to California employment but negatively related to Indiana employment. We also found EV sales coefficients to have significantly larger magnitudes (over 60 times larger) than lightweight vehicle sales coefficients for both models.

Independent variables, including EV and total car sales, gasoline prices, private investment, and manufacturing indices, were key predictors of state-specific auto manufacturing employment and significant at the 1% level, barring lightweight vehicle sales for the California model. Notable statistical limitations — autocorrelation, heteroskedasticity, and non-normality, however — may inflate these findings. After employing methods such as using robust standard errors, base changes, and lagging, some uncertainties persist, reducing our confidence in the model's precision.

This study contributes to the literature by providing empirical evidence for the regional impacts of EV adoption on the auto manufacturing workforce, improving labor market discussions within the context of EV adoption. Specifically, it supports existing labor forecast research by quantifying the level of sensitivity within the auto manufacturing workforce to EV adoption and other national trends. Such findings have implications for Barrett and Bivens' sensitivity model (2021), suggesting that domestic sales, in addition to their hypothesized relationship between domestic investment and labor market health, is a determining factor in auto manufacturing job growth. Integrating these insights with Tan et al. (2023), which explores the determinants of EV adoption, our analysis shows the cyclical relationship between increased EV adoption rates and job creation in the auto manufacturing sector, particularly in regions poised for EV production. This synergy underscores the importance of understanding the multifaceted drivers of EV adoption as they directly contribute to employment trends in the automotive industry.

Furthermore, these findings have implications for government policymakers and unions. For regions like Indiana, the data suggests strategic planning and policy support are needed to mitigate potential job losses in the auto manufacturing sector. Conversely, California resembles the benefits of embracing EV technology and infrastructure shifts, outlining a potential path for economic development and job creation. This study also offers insights for the UAW's strategic direction, reinforcing their support for sales incentive programs and hesitancy for unbound private investment. Hence, this study’s findings suggest tailored policy and union strategies which consider regional dynamics are important when navigating the transition towards EVs.

The impact of EV sales on the auto manufacturing labor market, as demonstrated by the large EV sales coefficient for both models, supports the idea that sales incentive programs play a catalyzing role in the development of manufacturing workforces. This labor sensitivity implies that policies promoting EV sales could have a positive impact on sectoral employment for regions with EV manufacturing capabilities. Additionally, the significant negative relationship between private investment and manufacturing employment points to an area ripe for further investigation. Understanding how private manufacturing investment interacts with specific areas of employment amid an EV transition are key for developing strategies that not only mitigate job losses but also channel the economic opportunities presented by automation.

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Section 8: Appendix

I. Further Statistical Limitation Discussion

After running scatterplots for each of independent variable against the two dependent variables, California and Indiana auto manufacturing headcount, no significant non-linearity seems to exist. This observation led us to proceed with the linear model and conduct further tests to ensure the statistical integrity of our findings

Multicollinearity Analysis

The regression models for California and Indiana, examining the relationship between EV sales, lightweight vehicle sales, gasoline prices, auto manufacturing private investment, and industrial production index, show different levels of multicollinearity. For California, the Mean Variance Inflation Factor (VIF) stands at 4.79, indicating a moderate level of multicollinearity, which is acceptable but should still be treated with caution. The individual VIF values for Auto Manufacturing Private Investment, Lightweight Vehicle Sales, and EV Sales are slightly above 5, suggesting more significant multicollinearity. The Indiana model mirrors these multicollinearity levels, with a Mean VIF at 4.79. The findings indicate that while multicollinearity is present, it may not critically undermine the validity of the models.

Heteroskedasticity Test

We identified significant heteroskedasticity in both models using White's test for heteroskedasticity. For the California model, the test indicated a chi-squared value of 88.92 (df = 20) at the 1% confidence level. Similarly, the Indiana model exhibited a chi-squared value of 108.94 (df = 20) at the 1% confidence level. These results pointed to a substantial presence of heteroskedasticity, implying the error variances were not constant across observations. To account for this issue, a robust regression approach was used. By using robust standard errors in the regression models, we adjusted for the irregularity in variance by enhancing the reliability of the coefficient estimates – a solution that does not require a data or model transformation.

Autocorrelation Test

In both the California and Indiana models, the Breusch-Godfrey Test indicated the presence of autocorrelation. Preliminary tests using two lags resulted in a chi-square statistic of 78.7 for California and a chi-square statistic of 8.1 for Indiana, showing varying levels of autocorrelation. To address this, we introduced variable lags which make intuitive sense within the model. Both lightweight vehicle sales and real private investment in auto manufacturing were lagged one month to address the static nature of the traditional vehicle market and sales in comparison to the EV market. Gasoline prices were lagged two periods to account for strong innate volatility within the market. To ensure consistency, all independent variable modifications were made in both models.

For the California model, a chi-square statistic of 62.6 was observed, and for the Indiana model, a chi-square statistic of 17.5 was observed. These values continue to suggest high autocorrelation in the residuals, which could affect the efficiency and reliability of the coefficient estimates. While this presence of autocorrelation does not negate the significance of the findings, it does warrant a cautious interpretation. The autocorrelation in these models implies that future values of the dependent variable are influenced by their past values, a common occurrence in time-series data, which should be considered when drawing conclusions from the models. Despite this limitation, the insights gained from the analysis remain valuable, albeit with an understanding of the potential impact of autocorrelation on the results.

Normality Analysis

In the analysis of the Indiana auto manufacturing headcount model, the skewness and kurtosis tests for normality revealed significant deviations from the normal distribution. Specifically, the tests showed significant p-values for skewness (0.0074 for Indiana and .0031 for California) and kurtosis (0.0001 for Indiana and 0.0018 for California). These results indicate a pronounced departure from normality in the residuals of the model, suggesting that the error terms are not evenly distributed around zero with constant variance. Given the fact that initial corrective measures such as data transformation or the adoption of nonparametric methods yield minimal improvements to the model's statistical robustness, we decide to proceed with caution. This approach allows us to draw valuable insights from the model while acknowledging the potential impact of the deviations from normality on the significance of our results.