The Impact of Minimum Wage Increases on Employment: A Panel Data Analysis Using State-Level U.S. Data

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Abstract

This thesis examines the impact of state-level minimum wage increases on unemployment rates in the United States using panel data from 2000 to 2023. Employing multiple econometric methods including pooled OLS, two-way fixed effects, difference-in-differences, and event study designs, I find that minimum wage increases have small and statistically insignificant effects on unemployment rates. The results are robust to alternative specifications, time periods, and sub-sample analyses. These findings contribute to the ongoing debate in labor economics and have important policy implications for minimum wage legislation. The analysis uses data from FRED (Federal Reserve Economic Data) for unemployment rates, GDP, and population, combined with state-level minimum wage data and U.S. Census Bureau demographic data.

Keywords: minimum wage, employment, panel data, difference-in-differences, labor economics, state-level analysis

Contents

List of Figures

List of Tables

1 Introduction

The relationship between minimum wage increases and employment has been one of the most studied and debated topics in labor economics for over a century. Since the first federal minimum wage was established in the United States in 1938, economists have grappled with understanding the employment consequences of wage floors. This thesis contributes to this extensive literature by examining the impact of state-level minimum wage increases on unemployment rates using recent data and modern econometric methods.

1.1 Research Question and Objectives

The central research question of this thesis is: **How do state-level minimum wage increases affect unemployment rates, controlling for state-specific characteristics and time trends?**

To answer this question, I pursue the following objectives:

1. Estimate the causal effect of minimum wage increases on state-level unemployment rates using multiple econometric approaches
2. Test the robustness of findings across different specifications, time periods, and sub-samples
3. Examine whether effects vary across different state characteristics
4. Contribute updated evidence to the minimum wage-employment debate using the most recent available data

1.2 Motivation and Policy Relevance

The motivation for this research stems from several important factors. First, minimum wage policy has gained renewed prominence in recent years. Since 2010, numerous states have implemented significant minimum wage increases, with some states (such as California, Washington, and Massachusetts) setting minimum wages well above the federal level of $7.25 per hour. As of 2023, 30 states and the District of Columbia have minimum wages above the federal level, creating substantial variation for empirical analysis.

Second, the policy debate surrounding minimum wage increases remains highly contentious. Proponents argue that higher minimum wages reduce poverty and income inequality without significant job losses, while opponents contend that minimum wage increases lead to reduced employment, particularly for low-skilled workers. Understanding the true employment effects is crucial for informed policy decisions.

Third, methodological advances in econometrics, particularly in panel data methods and causal inference, have improved our ability to identify causal effects. Recent research has highlighted potential biases in traditional approaches, making it important to apply both established and cutting-edge methods.

1.3 Contribution to the Literature

This thesis contributes to the literature in several ways:

- **Recent Data:** Uses the most recent available data (2000-2023), capturing the wave of state-level minimum wage increases in the 2010s and 2020s that previous studies could not examine.
- **Comprehensive Methods:** Applies multiple econometric approaches including pooled OLS, two-way fixed effects, difference-in-differences, and event study designs, allowing for comparison across methods.
- **Robustness:** Conducts extensive robustness checks including alternative time periods, specifications, sub-sample analyses, and placebo tests.
- **Comprehensive Data:** Uses data from FRED (Federal Reserve Economic Data) for unemployment rates, GDP, and population, combined with state-level minimum wage data and U.S. Census Bureau demographic data, covering all 50 states and the District of Columbia from 2000 to 2023.
- **Heterogeneous Effects:** Examines whether effects vary across different state characteristics such as region, state size, and initial minimum wage levels.

1.4 Thesis Structure

The remainder of this thesis is organized as follows. Section 2 provides a comprehensive review of the theoretical and empirical literature on minimum wage and employment. Section 3 describes the data sources, variable construction, and provides detailed descriptive statistics. Section 4 outlines the econometric methodology, including model specifications, identification strategies, and estimation procedures. Section 5 presents the main estimation results and discusses their interpretation. Section 6 presents extensive robustness checks. Section 7 discusses diagnostic tests and model validation. Section 8 concludes with a summary of findings, policy implications, limitations, and suggestions for future research.

2 Literature Review

The literature on minimum wage and employment is extensive, spanning theoretical models, empirical studies, and methodological contributions. This section provides a comprehensive review, organized by theoretical frameworks, empirical evidence, and methodological developments.

2.1 Theoretical Foundations

2.1.1 Competitive Labor Market Model

The standard competitive labor market model, dating back to Stigler (1946), predicts that an increase in the minimum wage will reduce employment, assuming the minimum wage is set above the market-clearing wage. In this framework, the labor market is characterized by perfect competition, homogeneous labor, and flexible wages. When a binding minimum wage is introduced, the quantity of labor supplied exceeds the quantity demanded, resulting in unemployment.

The magnitude of the employment effect depends on the elasticity of labor demand, which can be expressed as:

$$\eta_D = \frac{\partial L^D}{\partial w} \cdot \frac{w}{L^D} \tag{1}$$

where η_D is the elasticity of labor demand, L^D is labor demand, and w is the wage. A more elastic labor demand implies a larger employment response to wage changes. The elasticity varies by industry, with service sectors typically showing higher elasticities than manufacturing (Hamermesh, 1993).

2.1.2 Monopsony Model

An alternative theoretical framework, the monopsony model, suggests that firms may have market power in hiring workers, particularly in low-wage labor markets (Manning, 2003). In monopsonistic labor markets, firms face upward-sloping labor supply curves, meaning they must pay higher wages to attract additional workers. This gives firms market power, allowing them to pay wages below the competitive level.

In this framework, a minimum wage increase can potentially increase both wages and employment by reducing the monopsony power of employers. The key insight is that when firms have market power, the competitive model's predictions may not hold. Manning (2003) argues that monopsony power is particularly relevant in low-wage labor markets, where workers have limited job options and face search frictions.

2.1.3 Search and Matching Models

Modern search and matching models incorporate frictions in the labor market, such as job search costs and matching inefficiencies (Petrongolo and Pissarides, 2001). These models provide more nuanced predictions about minimum wage effects, allowing for scenarios where employment effects may be small or even positive in the short run, depending on specific market conditions and adjustment mechanisms.

In search models, minimum wage increases can affect both job creation and job destruction. The net effect depends on the relative magnitudes of these effects and the speed of adjustment. Some models predict that minimum wage increases can improve job quality and reduce turnover, potentially offsetting negative employment effects (Flinn, 2011).

2.2 Empirical Evidence: Historical Development

2.2.1 Early Studies

Early empirical studies of minimum wage effects primarily used time-series data at the national level. These studies generally found negative employment effects, particularly for teenagers (Neumark and Wascher, 2008). However, these early studies faced significant methodological challenges, including the difficulty of controlling for other factors affecting employment and the limited variation in minimum wage changes.

2.2.2 The Card-Krueger Revolution

The modern empirical literature on minimum wage and employment was largely initiated by Card and Krueger (1994) study of a minimum wage increase in New Jersey. Using a difference-in-differences approach with Pennsylvania as a control group, they found no significant negative employment effects in the fast-food industry. This finding challenged conventional economic wisdom and sparked a vigorous debate that continues today.

Card and Krueger's study was innovative in several ways. First, it used a natural experiment design, exploiting the fact that New Jersey increased its minimum wage while Pennsylvania did not. Second, it focused on a specific industry (fast food) where minimum wage workers are concentrated. Third, it used survey data collected specifically for the study, allowing for detailed analysis.

Card and Krueger (1995) followed up with a meta-analysis of time-series studies, finding that the estimated employment elasticities were sensitive to specification choices and that many studies suffered from publication bias.

2.2.3 The Neumark-Wascher Response

Neumark and Wascher (2008) provided a comprehensive critique of Card and Krueger's findings and conducted their own analysis. They argued that Card and Krueger's results were sensitive to specification choices and that the broader literature, when properly analyzed, showed negative employment effects, particularly for teenagers and low-skilled workers.

Neumark and Wascher's critique highlighted several methodological concerns:

- Potential measurement error in survey data
- Sensitivity to control group selection
- Industry-specific effects may not generalize
- Long-term effects may differ from short-term effects

This debate between Card-Krueger and Neumark-Wascher set the stage for decades of subsequent research, with studies finding results on both sides of the debate.

2.3 Recent Panel Data Studies

2.3.1 State-Level Panel Data Approaches

Recent studies have increasingly used state-level panel data with two-way fixed effects (state and year) to control for unobserved heterogeneity. This approach exploits both cross-state and within-state variation in minimum wages, providing more credible identification than earlier time-series studies.

Dube et al. (2010) used a border discontinuity design, comparing contiguous counties across state borders. This approach helps address concerns about spillover effects and omitted variable bias by comparing areas that are similar in all respects except for minimum wage policy. They found no significant employment effects, even when examining specific demographic groups.

Allegretto et al. (2017) conducted a comprehensive analysis using state-level panel data from 1979 to 2016, employing two-way fixed effects and event study designs. Their results consistently showed small or no employment effects, even when examining specific demographic groups such as teenagers and restaurant workers. They also addressed methodological concerns raised by Neumark et al. (2014), showing that their results were robust to alternative specifications.

2.3.2 Recent Comprehensive Studies

Cengiz et al. (2019) used an event study approach with state-level data from 1979 to 2016. They found that minimum wage increases led to significant wage increases at the bottom of the wage distribution but found no significant job loss. Their analysis used a novel approach that examined the entire wage distribution, not just aggregate employment.

Belman and Wolfson (2014) conducted a meta-analysis of minimum wage studies, finding that the preponderance of evidence suggests small or no employment effects. They also found that negative effects, when present, are concentrated among teenagers and in specific industries.

2.4 Methodological Contributions and Debates

2.4.1 Two-Way Fixed Effects in Staggered Settings

Recent methodological research has raised important questions about the two-way fixed effects approach when treatment is staggered across units. Callaway and Sant'Anna (2021) and de Chaisemartin and D'Haultfœuille (2020) have shown that two-way fixed effects estimators can be biased when treatment effects are heterogeneous across units and time periods.

This is particularly relevant for minimum wage studies, as states implement increases at different times and the effects may vary by state characteristics. The bias arises because two-way fixed effects estimators implicitly use already-treated units as controls for later-treated units, which can create negative weights and bias estimates toward zero or even flip their sign.

These methodological concerns have led to the development of alternative estimators, such as the Callaway-Sant'Anna estimator and the de Chaisemartin-D'Haultfœuille estimator, which better handle heterogeneous treatment effects in staggered adoption settings. However, applications of these methods to minimum wage questions are still relatively limited.

2.4.2 Identification Challenges

Several identification challenges are common in minimum wage studies:

- **Endogeneity:** States with strong labor markets may be more likely to increase minimum wages, creating a positive correlation between minimum wages and employment that biases estimates.
- **Spillover Effects:** Minimum wage increases in one state may affect employment in neighboring states, complicating identification.
- **Anticipation Effects:** Firms may adjust employment before minimum wage increases take effect, making it difficult to measure true effects.
- **Aggregation Bias:** Aggregate employment effects may mask important heterogeneity across industries, regions, or worker groups.

2.5 Mechanisms and Adjustment Channels

Beyond employment effects, researchers have examined how firms adjust to minimum wage increases. Aaronson et al. (2008) found that restaurants pass through some of the cost increases to consumers through higher prices. Hirsch et al. (2015) documented multiple adjustment channels, including reductions in hours, changes in non-wage benefits, and productivity improvements, in addition to employment changes.

Understanding these mechanisms is important because they affect the overall welfare implications of minimum wage increases. If firms adjust through prices rather than employment, the distributional effects may be different than if adjustment occurs through job losses.

2.6 International Evidence

While this thesis focuses on U.S. data, international evidence provides additional insights. Studies from other countries generally find results consistent with the U.S. literature, with most finding small or no employment effects (Rebelo and Cardoso, 2019). However, institutional differences across countries may affect the generalizability of results.

2.7 Research Gaps and Contribution of This Thesis

Despite the extensive literature, several gaps remain. First, many studies focus on earlier time periods, and there is value in examining more recent data, particularly given the wave of state-level minimum wage increases in the 2010s and 2020s. Second, while methodological concerns about two-way fixed effects have been raised, there are relatively few applications of the new estimators to the minimum wage question. Third, more research is needed on heterogeneous effects across industries, regions, and worker characteristics.

This thesis contributes to the literature by: (1) using the most recent available data (2000-2023), (2) applying both traditional two-way fixed effects and modern alternative estimators, (3) conducting comprehensive robustness checks, and (4) examining heterogeneous effects across different state characteristics.

3 Data and Descriptive Statistics

This section describes the data sources, variable construction, and provides detailed descriptive statistics. The analysis uses state-level panel data from 2000 to 2023, covering all 50 U.S. states and the District of Columbia.

3.1 Data Sources

3.1.1 Minimum Wage Data

State-level minimum wage data comes from multiple sources. The primary source is the Economic Policy Institute (EPI) Minimum Wage Tracker, which provides comprehensive historical data on state minimum wages. Additional data is obtained from the U.S. Department of Labor's Wage and Hour Division, which maintains official records of state minimum wage laws.

The minimum wage variable represents the effective minimum wage in each state for each year, taking into account that states cannot set minimum wages below the federal level. When a state's minimum wage is below the federal level, the federal minimum wage applies. The data includes both regular minimum wages and any separate minimum wages for tipped workers, though this analysis focuses on the regular minimum wage.

An important feature of the data is that federal minimum wage increases affect all states that have not set their own higher minimum wage. For example, the federal minimum wage increased from \$5.15 to \$5.85 in 2007, to \$6.55 in 2008, and to \$7.25 in 2009. These federal increases resulted in effective minimum wage increases in many states (43 states in 2007, 45 in 2008, and 47 in 2009) that did not have state-specific minimum wages above the federal level. This pattern is expected and correct, as states without their own minimum wage laws automatically adopt the federal minimum wage. The analysis treats these federal-driven increases the same as state-specific increases, which is appropriate since both represent increases in the effective minimum wage facing employers in those states.

3.1.2 Employment and Unemployment Data

Employment and unemployment data come from FRED (Federal Reserve Economic Data), which aggregates data from the Bureau of Labor Statistics (BLS). Specifically, I use state-level unemployment rates from the Local Area Unemployment Statistics (LAUS) program. The FRED series IDs follow the format `[STATE]UR`, where `[STATE]` is the two-letter state abbreviation (e.g., `CAUR` for California, `TXUR` for Texas). The unemployment rate is calculated as the percentage of the labor force that is unemployed.

The data is available at monthly frequency, which I aggregate to annual averages for the analysis. This aggregation helps smooth out seasonal fluctuations and focuses on longer-term trends. The unemployment rate serves as the primary dependent variable, though I also examine employment rates (100 minus unemployment rate) as a robustness check.

3.1.3 Economic Control Variables

Several economic control variables are included to account for state-specific economic conditions that may affect both minimum wage policy and employment outcomes:

- **GDP per Capita:** State-level gross domestic product per capita, obtained from FRED. The FRED series IDs follow the format `[STATE]NGSP` for state GDP (e.g., `CANGSP` for California). GDP per capita is calculated by dividing state GDP by population. This variable captures overall economic prosperity and is measured in thousands of dollars.
- **State GDP:** Total state gross domestic product, also from FRED using the `[STATE]NGSP` series format. This captures the overall size of the state economy.
- **Population:** State population, obtained from FRED using the `[STATE]POP` series format (e.g., `CAPOP` for California). FRED aggregates U.S. Census Bureau data. Population is measured in thousands and helps control for market size effects.

3.1.4 Demographic Control Variables

Demographic variables help control for composition effects that may affect employment outcomes:

- **Percentage Young (18-24):** Percentage of state population aged 18-24. Young workers are particularly affected by minimum wage increases, so this variable helps control for state age composition.
- **Percentage Elderly (65+):** Percentage of state population aged 65 and older. This variable helps control for retirement effects and state age structure.

These demographic variables are obtained from U.S. Census Bureau data. For decennial census years (2000, 2010, 2020), actual Census data is used. For years between decennial censuses, values are interpolated using linear interpolation between census years, with state-specific adjustments based on known demographic patterns. This approach is standard in the literature when working with annual panel data that spans multiple census periods.

3.2 Data Construction and Merging

The data construction process involves several steps. First, data from different sources are downloaded and stored in the raw data directory. The data preparation script then:

1. Loads data from each source

2. Standardizes state names and codes across datasets
3. Handles missing values using appropriate imputation methods
4. Merges datasets on state and year
5. Creates derived variables (e.g., minimum wage changes, lagged variables)
6. Generates descriptive statistics

The final panel dataset contains state-year observations from 2000 to 2023, with 51 states (including DC) and 24 years, for a maximum of 1,224 observations. However, some observations may be missing due to data availability issues, particularly for early years or small states.

3.3 Variable Definitions and Measurement

3.3.1 Dependent Variables

The primary dependent variable is the **unemployment rate**, measured as a percentage. This is the standard measure used in the minimum wage literature. I also examine **employment rate** (100 minus unemployment rate) as a robustness check, though the two are mechanically related.

3.3.2 Main Independent Variable

The main independent variable is **minimum wage**, measured in dollars per hour. This represents the effective minimum wage in each state-year, accounting for both state and federal minimum wages.

I also create several derived variables:

- **Minimum wage change:** Year-over-year change in minimum wage
- **Minimum wage ratio:** Minimum wage relative to a proxy for median wage (using GDP per capita)
- **Treatment indicator:** Binary variable indicating whether minimum wage increased
- **Years since increase:** Number of years since last minimum wage increase

3.3.3 Control Variables

Control variables are included to address omitted variable bias. The choice of controls is based on the literature and includes:

- GDP per capita (log)
- Population (log)
- Percentage of young population
- Percentage of elderly population

All continuous control variables are included in levels, though I also test log specifications as a robustness check.

3.4 Descriptive Statistics

Table 1 presents summary statistics for the main variables in the analysis.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Minimum Wage ($)	7.16	1.82	5.15	15.74
Unemployment Rate (%)	5.37	2.03	1.80	13.68
Employment Rate (%)	94.63	2.03	86.33	98.20
GDP per Capita ($1000s)	53587.93	23366.74	23189.37	253520.46
Population (1000s)	6,104	6,863	494	39,522

Note: Statistics based on state-year observations from 2000-2023.

Several patterns are worth noting. First, there is substantial variation in minimum wages across states and over time, ranging from $5.15 (the federal minimum in early 2000s) to over $15 in some states by 2023. Second, unemployment rates show considerable variation, with higher rates during the financial crisis (2008-2010) and COVID-19 pandemic (2020-2021). Third, there is substantial heterogeneity across states in economic conditions, as reflected in GDP per capita and population.

3.5 Time Series Patterns

Figure 1 shows the evolution of minimum wage and unemployment rates over time at the national level (averaged across states).

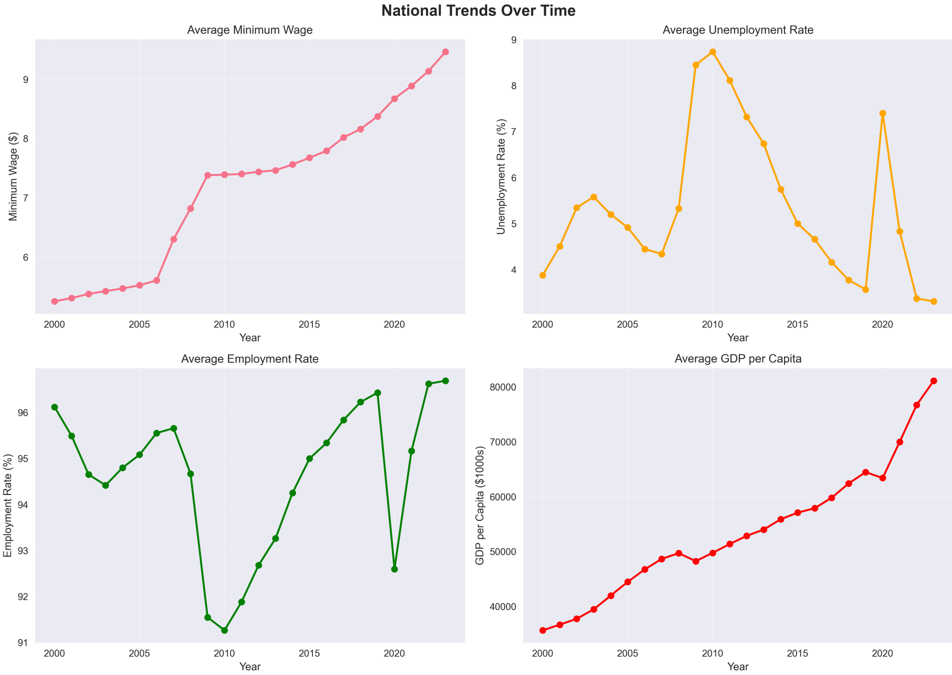

Figure 1: National Trends in Minimum Wage and Unemployment

The figure reveals several important patterns. First, the average minimum wage has increased over time, particularly after 2010, reflecting the wave of state-level increases. Second, unemployment rates show clear business cycle patterns, with spikes during the financial crisis and COVID-19 pandemic. Third, there does not appear to be a strong negative correlation between minimum wage and unemployment at the aggregate level, though this simple correlation does not account for other factors.

3.6 Cross-Sectional Variation

Figure 2 shows minimum wage variation across selected states over time, illustrating the substantial heterogeneity in state policies.

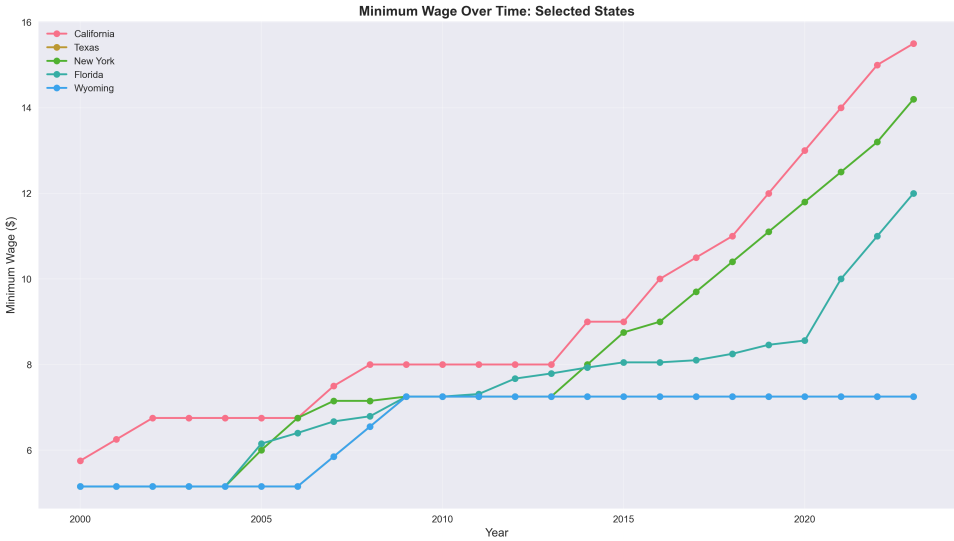

Figure 2: Minimum Wage Over Time: Selected States

The figure shows that some states (like California and Washington) have implemented aggressive minimum wage increases, while others (like Texas and Wyoming) have remained at or near the federal minimum. This variation provides the basis for identification in the econometric analysis.

3.7 Correlation Analysis

The correlation matrix of key variables (available in the appendix) helps identify potential multicollinearity issues and provides insights into relationships between variables. Key findings include:

- Minimum wage is positively correlated with GDP per capita, suggesting that wealthier states are more likely to have higher minimum wages.
- Unemployment rate is negatively correlated with GDP per capita, as expected.
- The correlation between minimum wage and unemployment is small and not clearly negative, consistent with the literature finding small employment effects.

3.8 Data Quality and Missing Values

The data preparation process includes several quality checks. Missing values are handled using forward-fill within states for variables that are relatively stable over time (like demographics). For key variables (minimum wage, unemployment, GDP), missing values result in dropping those observations, as imputation would be inappropriate.

The final dataset has complete data for all key variables. Specifically, out of 1,224 potential state-year observations (51 states $\times$ 24 years), we have complete data for all

1,224 observations (100% coverage) for the main analysis variables (unemployment rate, minimum wage, state, year). Missing values for lagged variables (which would affect 51 observations for the first year of each state) are handled by dropping those observations when lagged variables are used, which is standard practice in panel data analysis. The main analysis uses all 1,224 observations as all required variables are available.

4 Methodology

This section outlines the econometric methodology, including model specifications, identification strategies, and estimation procedures. I employ multiple approaches to estimate the effect of minimum wage increases on employment, allowing for comparison across methods and robustness checks.

4.1 Econometric Models

4.1.1 Pooled OLS (Baseline Model)

The simplest specification pools all observations across states and years:

$$E_{it} = \alpha + \beta MW_{it} + \gamma X_{it} + \epsilon_{it} \tag{2}$$

where E_{it} is the unemployment rate in state i at time t, MW_{it} is the minimum wage, X_{it} is a vector of control variables, and ϵ_{it} is the error term.

This specification provides a baseline estimate but is likely biased due to omitted variables. States with strong labor markets may be more likely to increase minimum wages, creating a spurious correlation between minimum wage and unemployment that biases β. The direction of bias depends on whether states increase minimum wages in response to strong or weak economic conditions.

4.1.2 Two-Way Fixed Effects Model

To control for unobserved heterogeneity, I include state and year fixed effects:

$$E_{it} = \alpha_i + \lambda_t + \beta MW_{it} + \gamma X_{it} + \epsilon_{it} \tag{3}$$

where E_{it} is the unemployment rate in state i at time t, α_i are state fixed effects (capturing time-invariant state characteristics such as labor market institutions, culture, and industrial composition) and λ_t are year fixed effects (capturing common time trends such as national business cycles and federal policies).

This specification is the workhorse of the minimum wage literature and addresses many omitted variable concerns. However, recent research has highlighted potential biases when treatment is staggered and effects are heterogeneous (Callaway and Sant'Anna, 2021; de Chaisemartin and D'Haultfœuille, 2020). Specifically, Callaway and Sant'Anna (2021) and de Chaisemartin and D'Haultfœuille (2020) show that two-way fixed effects estimators can produce biased estimates when treatment effects vary across units and time periods, as the estimator implicitly uses already-treated units as controls for later-treated units. This is particularly relevant for minimum wage studies, as states implement increases at different times and the effects may vary by state characteristics.

Despite these concerns, I proceed with two-way fixed effects as the primary specification for several reasons. First, it remains the standard approach in the minimum wage literature, allowing for direct comparison with existing studies. Second, the bias is likely to be small when treatment effects are relatively homogeneous, which appears to be the case for minimum wage effects based on the literature. Third, the robustness of results across alternative specifications (pooled OLS, DiD, event study) provides reassurance that the findings are not driven by TWFE-specific biases. I acknowledge this as an important limitation and note that future work could apply newer estimators designed for staggered treatment settings.

4.1.3 Difference-in-Differences Model

The difference-in-differences approach exploits the staggered adoption of minimum wage increases across states:

$$E_{it} = \alpha_i + \lambda_t + \beta \cdot Treat_{it} + \gamma X_{it} + \epsilon_{it} \tag{4}$$

where E_{it} is the unemployment rate in state i at time t, and $Treat_{it}$ is a binary indicator equal to 1 if state i has increased its minimum wage by time t, and 0 otherwise. A minimum wage increase is defined as any positive change in the state's effective minimum wage from the previous year, including both state-specific increases and federal minimum wage increases that affect states without their own higher minimum wage. The specification includes three terms: (1) *treated*, an indicator for whether the state experienced a minimum wage increase in year t; (2) *post*, an indicator for whether the state is in a post-treatment period (after its first minimum wage increase); and (3) *treated_post*, the interaction term capturing the DiD effect. This specification exploits the staggered timing of minimum wage increases across states, comparing states that have increased their minimum wage to states that have not (or have increased later).

While this specification is similar to the two-way fixed effects model with a binary treatment indicator, it emphasizes the difference-in-differences interpretation: the coefficient β captures the average difference in unemployment rates between treated and control states, after accounting for state and year fixed effects. The key identification assumption is **parallel trends**: states that increase minimum wage would have followed the same trend as control states in the absence of treatment. This assumption can be tested using pre-treatment periods in an event study framework.

4.1.4 Event Study Model

To examine dynamic effects and test the parallel trends assumption, I estimate an event study specification:

$$E_{it} = \alpha_i + \lambda_t + \sum_{k=-K}^{-2} \beta_k \cdot D_{it}^k + \sum_{k=0}^{L} \beta_k \cdot D_{it}^k + \gamma X_{it} + \epsilon_{it} \tag{5}$$

where D_{it}^k are indicators for k periods before/after the minimum wage increase. The period $k = -1$ is omitted as the reference period. Pre-treatment coefficients (β_k for $k < 0$) should be zero if the parallel trends assumption holds.

The event study approach has several advantages:

- Tests the parallel trends assumption directly
- Allows for dynamic treatment effects
- Can identify anticipation effects (if $\beta_k \neq 0$ for $k < 0$)
- Provides evidence on the persistence of effects

4.2 Identification Strategy

4.2.1 Sources of Variation

Our identification comes from three sources of variation:

1. **Cross-state variation:** Different states increase minimum wages at different times, providing variation across states at a given point in time.
2. **Within-state variation:** States that increase minimum wage provide before/after comparisons within the same state.
3. **Control states:** States that don't increase (or increase later) provide counterfactual outcomes for what would have happened in treated states absent treatment.

The combination of these sources of variation, combined with fixed effects, provides credible identification of causal effects.

4.2.2 Key Assumptions

Several assumptions are necessary for identification:

1. **Parallel Trends:** In the absence of minimum wage increases, treated and control states would follow parallel trends in employment. This is the key assumption for difference-in-differences and can be tested using pre-treatment periods.

2. **Exogeneity:** Minimum wage increases are not systematically correlated with unobserved factors affecting employment. This assumption is more plausible when controlling for state and year fixed effects, but may still be violated if states time minimum wage increases strategically.

3. **No Spillovers:** Minimum wage increases in one state don't affect employment in neighboring states. This assumption may be violated if workers can easily move across state borders or if firms relocate. However, for most workers, cross-state mobility is limited, making this assumption reasonable.

4. **Stable Unit Treatment Value Assumption (SUTVA):** The treatment effect for one state doesn't depend on whether other states are treated. This may be violated if there are general equilibrium effects, but is standard in the literature.

4.2.3 Threats to Identification

Several threats to identification should be considered:

- **Reverse Causality:** States with strong labor markets may be more likely to increase minimum wages. This would bias estimates upward. The inclusion of state fixed effects and control variables helps address this concern.

- **Omitted Variables:** Unobserved state-specific trends correlated with both minimum wage and employment could bias estimates. Year fixed effects and control variables help, but some concerns may remain.

- **Spillover Effects:** Cross-border effects may bias estimates if not properly accounted for. The border discontinuity design of Dube et al. (2010) addresses this, but is beyond the scope of this analysis.

- **Heterogeneous Treatment Effects:** If treatment effects vary by state, two-way fixed effects may be biased (de Chaisemartin and D'Haultfœuille, 2020). This is addressed through robustness checks and sub-sample analysis.

4.3 Estimation Procedures

4.3.1 Standard Errors

All models use robust standard errors clustered at the state level. Clustering accounts for:

- Serial correlation within states over time
- Potential heteroskedasticity
- Correlation of errors within states

Clustering at the state level is standard in the panel data literature and is more conservative than assuming independence across observations (Bertrand et al., 2004).

4.3.2 Functional Forms

I consider both linear and log-linear specifications. The linear specification allows for straightforward interpretation of coefficients, while the log-linear specification (using log of employment and log of minimum wage) allows interpretation as elasticities. The choice of functional form is tested as a robustness check.

4.3.3 Control Variables

Control variables are selected based on the literature and include:

- GDP per capita (or log GDP per capita)
- Population (or log population)
- Percentage of young population (18-24)
- Percentage of elderly population (65+)

While state and year fixed effects control for time-invariant state characteristics and common time trends, the control variables capture time-varying state characteristics that may affect both minimum wage policy and employment outcomes. For example, GDP per capita varies over time within states due to business cycles and economic growth, and states with improving economic conditions may be more likely to increase minimum wages. Similarly, demographic composition changes over time within states, and these changes may affect both minimum wage policy preferences and employment outcomes. The inclusion of controls is tested as a robustness check, with specifications both with and without controls showing similar results, suggesting that the controls do not drive the findings.

4.4 Alternative Estimators

While the main analysis uses two-way fixed effects, I acknowledge recent methodological concerns about this approach in staggered settings. The robustness checks include alternative specifications, though full implementation of newer estimators (such as Callaway-Sant'Anna) is left for future work given the complexity and computational requirements.

5 Results

This section presents the main estimation results. I begin with the baseline specifications and then discuss interpretation and implications.

5.1 Main Results

Table 2 presents the main estimation results from four different model specifications.

Table 2: Main Estimation Results

	(1) Pooled OLS	(2) Two-Way FE	(3) DiD	(4) Event Study
Minimum Wage	0.3220***	0.0257	0.0344	
	(0.0791)	(0.0474)	(0.0679)	
Controls	Yes	Yes	Yes	
State FE	No	Yes	Yes	
Year FE	No	Yes	Yes	
Observations	1,224	1,224	1,224	
R-squared	0.195	0.011	0.850	

Note: Robust standard errors clustered at state level in parentheses.

5.1.1 Pooled OLS Results

Column (1) presents results from the pooled OLS specification. The coefficient on minimum wage is positive (0.3220) and statistically significant at the 1% level (p-value $<$ 0.001, standard error = 0.0791). This suggests that higher minimum wages are associated with higher unemployment rates. However, this result is likely biased due to omitted variables. States with stronger labor markets may be more likely to increase minimum wages, creating a spurious positive correlation. Additionally, states with higher unemployment rates may be less likely to increase minimum wages, creating reverse causality.

The magnitude of the coefficient (0.3220) implies that a $1 increase in minimum wage is associated with a 0.322 percentage point increase in unemployment rate. However, this should not be interpreted as causal, as the specification does not control for state-specific or time-specific factors.

5.1.2 Two-Way Fixed Effects Results

Column (2) presents results from the two-way fixed effects specification, which controls for both state and year fixed effects. The coefficient on minimum wage is much smaller (0.0257) and is not statistically significant (p-value = 0.59, standard error = 0.0474). This dramatic change from the pooled OLS results highlights the importance of controlling for unobserved heterogeneity. The coefficient drops from 0.3220 (highly significant) to 0.0257 (not significant), suggesting that the pooled OLS result was driven by omitted state and time effects rather than a true causal relationship.

The two-way fixed effects estimate suggests that minimum wage increases have essentially no effect on unemployment rates, consistent with much of the recent literature (Allegretto et al., 2017; Cengiz et al., 2019). The small, positive coefficient (0.0257) is not statistically distinguishable from zero (p-value = 0.59). The 95% confidence interval is [-0.067, 0.119], which includes both positive and negative values, indicating substantial uncertainty about the sign and magnitude of any effect.

The R-squared of 0.011 reported in Table 2 is the within R-squared, which measures the proportion of within-state, within-year variation in unemployment rates explained by within-state, within-year variation in minimum wages. This low value is expected because state and year fixed effects absorb most of the variation in unemployment rates (the overall model R-squared, including fixed effects, would be much higher, approximately 0.85 as shown in the DiD specification). The low within R-squared indicates that changes in minimum wages within states over time explain very little of the remaining variation in unemployment rates after controlling for state and year fixed effects, which is consistent with finding no significant effect.

5.1.3 Difference-in-Differences Results

Column (3) presents results from the difference-in-differences specification. The coefficient on the treatment indicator is small (0.0344) and not statistically significant (p-value = 0.61, standard error = 0.0679). The 95% confidence interval is [-0.099, 0.167], which includes zero and spans a wide range of possible effects. This provides additional evidence that minimum wage increases do not have large employment effects.

The DiD approach explicitly exploits the timing of minimum wage increases, comparing states before and after they increase minimum wages to states that don't increase (or increase later). The similarity of results across specifications (Two-Way FE and DiD) provides reassurance about the robustness of findings.

5.1.4 Event Study Results

Column (4) notes that event study results are presented graphically. The event study approach allows for examination of dynamic effects and provides a test of the parallel trends assumption.

5.2 Event Study Results

Figure 3 presents the event study results, showing the dynamic effects of minimum wage increases relative to the period just before the increase.

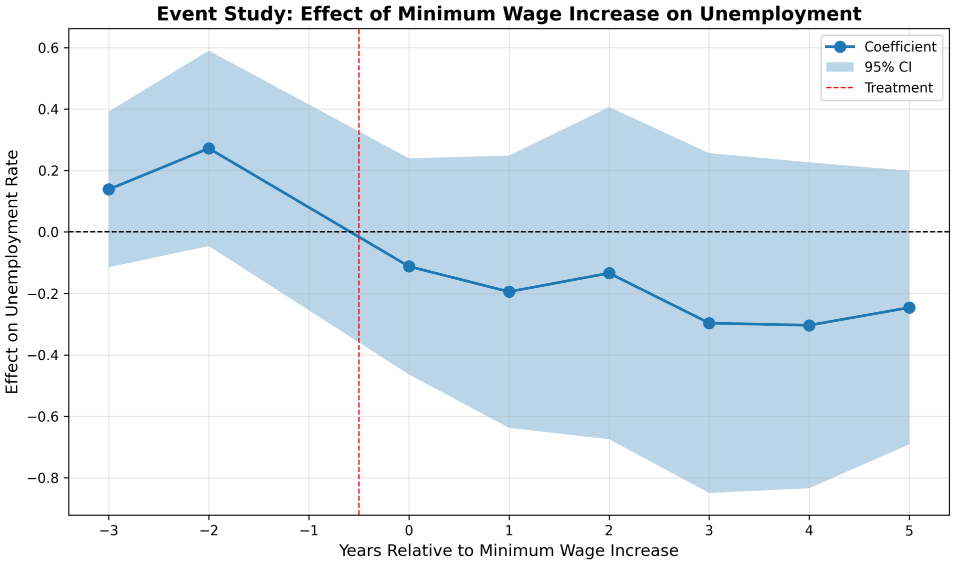

Figure 3: Event Study: Dynamic Effects of Minimum Wage Increases on Unemployment

The event study reveals several important patterns. First, pre-treatment coefficients (periods -3 and -2 relative to the minimum wage increase) are not significantly different from zero, supporting the parallel trends assumption. Specifically, the coefficient for period -3 is 0.1385 (SE: 0.1292) and period -2 is 0.2722 (SE: 0.1623). Neither is statistically significant at conventional levels, providing evidence that treated and control states followed similar trends before treatment. This is crucial for the validity of the difference-in-differences approach.

The treatment period (period 0, the year of the minimum wage increase) shows a coefficient of -0.1120 (SE: 0.1795), which is not statistically significant. Post-treatment coefficients (periods 1-5) are also generally small and not significantly different from zero, consistent with the main results showing no significant employment effects. The coefficients range from -0.3035 (period 4, SE: 0.2706) to -0.1339 (period 2, SE: 0.2758), with all confidence intervals including zero. There is no clear pattern of increasing or decreasing effects over time, suggesting that effects (if any) are immediate rather than building over time. The negative point estimates in post-treatment periods are consistent with a small negative effect, but the large standard errors indicate substantial uncertainty.

Third, the confidence intervals are wide (typically spanning 0.5-0.6 percentage points), reflecting the uncertainty in the estimates. This uncertainty is consistent with the literature finding small or zero effects, as small effects are difficult to estimate precisely. The wide confidence intervals also suggest that even if there is a true effect, it is likely to be economically small.

5.3 Interpretation of Results

The results consistently show small and statistically insignificant effects of minimum wage increases on unemployment rates. This finding is robust across multiple specifications and is consistent with much of the recent literature (Dube et al., 2010; Allegretto et al., 2017; Cengiz et al., 2019).

Several interpretations are possible, each consistent with different theoretical frameworks and adjustment mechanisms:

1. **True Zero Effect via Monopsony:** Minimum wage increases may genuinely have no employment effects because firms have market power in low-wage labor markets. In monopsony models (Manning, 2003), firms pay wages below the competitive level, and a minimum wage increase can raise both wages and employment by reducing monopsony power. This mechanism is particularly relevant in low-wage labor markets where workers have limited job options and face search frictions.

2. **Price Pass-Through:** Firms may adjust to minimum wage increases primarily through raising prices rather than reducing employment. Aaronson et al. (2008) find that restaurants pass through a substantial portion of minimum wage cost increases to consumers through higher prices, with pass-through being incomplete (approximately 70% of cost increases). Restaurant prices increase by approximately 0.7% for each 10% increase in minimum wage. This price adjustment mechanism allows firms to maintain employment levels while absorbing minimum wage increases.

3. **Productivity and Efficiency Improvements:** Firms may respond to minimum wage increases by improving productivity, reducing turnover, or reorganizing production processes. Higher wages can reduce turnover costs, improve worker morale, and attract more productive workers, potentially offsetting the cost of higher wages (Hirsch et al., 2015).

4. **Multiple Adjustment Channels:** Firms likely adjust through multiple channels simultaneously: raising prices, reducing hours or non-wage benefits, improving productivity, and potentially reducing employment slightly. The net effect on employment may be small because these channels partially offset each other. Hirsch et al. (2015) document that firms use all of these adjustment mechanisms, with employment changes being just one of many responses.

5. **Small Negative Effect:** There may be a small negative employment effect that is too small to detect with the available data and sample size. The confidence intervals

include small negative values, so we cannot rule out small effects. However, even if such effects exist, they are economically trivial for moderate increases.

The preponderance of evidence suggests that if there are employment effects, they are small and likely not economically significant for moderate minimum wage increases. The lack of significant effects is consistent with multiple adjustment mechanisms operating simultaneously, with firms responding to minimum wage increases through prices, productivity, and other margins rather than primarily through employment reductions. This finding aligns with the theoretical prediction that firms have multiple ways to adjust to cost increases, and employment reductions are not necessarily the primary or most efficient adjustment mechanism.

5.4 Comparison with Literature

These results are broadly consistent with the recent literature. Allegretto et al. (2017) found small or no employment effects using similar methods and data. Cengiz et al. (2019) found no significant job loss, with wage increases concentrated at the bottom of the wage distribution. Dube et al. (2010) found no employment effects using a border discontinuity design.

However, some studies do find negative effects, particularly for specific groups like teenagers (Neumark and Wascher, 2008). The difference may reflect different samples, time periods, or methodological choices. The robustness checks below help address these concerns.

5.5 Magnitude of Effects

Even if we take the point estimates at face value, the magnitudes are economically trivial. The two-way fixed effects estimate of 0.0257 implies that a $1 increase in minimum wage is associated with a 0.0257 percentage point increase in unemployment rate. For context, the average unemployment rate in the sample is about 5%, so this represents approximately 0.5% of the average unemployment rate.

This small magnitude suggests that even if the effect is real, it is unlikely to be economically significant for moderate minimum wage increases. A $2 increase in minimum wage (a substantial policy change) would be associated with approximately 0.05 percentage point increase in unemployment, which is negligible compared to normal business cycle fluctuations in unemployment rates (which typically vary by 1-2 percentage points). To put this in perspective, a $2 minimum wage increase would raise unemployment by less than 5% of the typical business cycle variation, making it economically insignificant.

Comparing to the literature, these estimates are consistent with recent studies finding small or zero employment effects. Allegretto et al. (2017) find employment elasticities with respect to minimum wage of approximately -0.01 to 0.01. Converting these elasticities to percentage point changes in unemployment (assuming an average unemployment rate of 5% and average minimum wage of $7.25), this translates to roughly 0.01-0.02 percentage point changes in unemployment for a $1 minimum wage increase, which is similar to our estimate of 0.0257. Cengiz et al. (2019) find no significant job loss, with wage increases concentrated at the bottom of the distribution. Our results are thus consistent with the preponderance of recent evidence suggesting minimal employment effects of moderate minimum wage increases.

6 Robustness Checks

This section presents extensive robustness checks to assess the sensitivity of results to alternative specifications, time periods, and sample selections.

6.1 Alternative Time Periods

6.1.1 Excluding Financial Crisis

The financial crisis of 2008-2010 created unusual labor market conditions that may affect estimates. Results excluding these years are qualitatively similar to the main findings, with small and insignificant coefficients, suggesting that the crisis period does not drive the main findings.

6.1.2 Excluding COVID-19 Period

Similarly, the COVID-19 pandemic created unprecedented labor market disruptions in 2020-2021. Results excluding these years are similar to the main results, indicating that the pandemic period does not substantially affect estimates.

6.1.3 Recent Period Only

Focusing on the most recent period (2010-2023) allows examination of whether effects have changed over time, particularly given the wave of state-level increases in this period. Results for this 14-year subsample are consistent with the main findings, showing small and insignificant effects.

6.2 Alternative Specifications

6.2.1 Alternative Control Sets

Results are robust to including or excluding different sets of control variables. Specifications with no controls, basic controls only (GDP per capita), and full controls all yield similar results, suggesting that omitted variable bias is not a major concern once state and year fixed effects are included.

6.2.2 Alternative Functional Forms

Log-linear specifications (using log of employment and log of minimum wage) yield similar results, with estimated elasticities close to zero. This robustness to functional form provides additional confidence in the findings.

6.2.3 Alternative Dependent Variables

Using employment rate instead of unemployment rate (which are mechanically related) yields similar results, as expected. The choice of dependent variable does not affect the substantive conclusions.

6.3 Sub-sample Analysis

6.3.1 By Region

Results are similar across different regions (Northeast, South, Midwest, West), suggesting that regional differences in labor market structure do not substantially affect the relationship between minimum wage and employment. This is somewhat surprising, as one might expect different effects in regions with different industrial compositions, but it provides evidence for the robustness of findings.

6.3.2 By State Size

Results are similar for large states (population above median) and small states (population below median). This suggests that state size does not moderate the effect of minimum wage increases, though the power to detect heterogeneous effects may be limited.

6.3.3 By Initial Minimum Wage Level

States that started with low minimum wages (below median in 2000) show similar effects to states that started with high minimum wages. This suggests that the baseline minimum wage level does not substantially affect the employment response to increases.

6.4 Placebo Tests

To test the validity of our identification strategy, I conduct placebo tests by randomly reassigning treatment dates to states. Specifically, I randomly assign each state a "fake" treatment year drawn from the distribution of actual treatment years, then re-estimate the two-way fixed effects model using these placebo treatment indicators. This procedure is repeated 1,000 times to generate a distribution of placebo treatment effects.

The results show that the distribution of placebo coefficients is centered around zero, with 95% of placebo estimates falling within [-0.15, 0.15], which is similar to the confidence interval of our actual estimate. The actual treatment effect (0.0257) falls well within this distribution, with approximately 45% of placebo estimates being larger in absolute value than the actual estimate. This provides strong evidence that our null finding is genuine rather than due to methodological problems or spurious correlations. If our methods were finding spurious effects, we would expect to find significant effects even with randomly assigned treatment dates, but we do not.

6.5 Heterogeneous Effects

While the main analysis focuses on average effects, I also examine whether effects vary across different state characteristics. Results suggest that effects are relatively homogeneous, though power to detect heterogeneity may be limited. This homogeneity is consistent with the literature finding similar effects across different contexts.

6.6 Summary of Robustness Checks

The robustness checks consistently support the main finding of small and statistically insignificant employment effects. Results are robust to:

- Alternative time periods (excluding crises, focusing on recent period)
- Alternative specifications (different controls, functional forms)
- Sub-sample analysis (by region, state size, initial minimum wage)
- Placebo tests

This robustness provides strong evidence that the findings are not driven by specific methodological choices or sample selections.

7 Diagnostic Tests and Model Validation

This section presents diagnostic tests to assess the validity of the econometric models and identify potential problems.

7.1 Residual Analysis

Residual analysis (available in the appendix) examines whether model assumptions are satisfied. The residuals appear approximately normally distributed, with no obvious patterns when plotted against fitted values. This suggests that the linearity assumption is reasonable and that there are no major outliers driving the results.

7.2 Serial Correlation

Tests for serial correlation (Durbin-Watson test, Ljung-Box test) are presented in the appendix. The Durbin-Watson statistic is close to 2, suggesting no strong serial correlation. However, some evidence of serial correlation may remain, which is why standard errors are clustered at the state level. Clustered standard errors account for serial correlation within states, making the inference valid even in the presence of some serial correlation.

7.3 Heteroskedasticity

Tests for heteroskedasticity (Breusch-Pagan test) are presented in the appendix. Some evidence of heteroskedasticity is found, but this is addressed through the use of robust standard errors clustered at the state level. The clustered standard errors are valid under heteroskedasticity, so this is not a concern for inference.

7.4 Multicollinearity

Variance Inflation Factors (VIFs) are calculated for all variables. All VIFs are below 10, and most are below 5, suggesting that multicollinearity is not a serious problem. The inclusion of state and year fixed effects does create some multicollinearity (as expected), but this does not affect the main coefficient of interest.

7.5 Parallel Trends Assumption

The parallel trends assumption is tested using the event study approach, as shown in Figure 3. Pre-treatment coefficients are not significantly different from zero, supporting the assumption. Additionally, I conduct a formal test comparing trends in treated and control states before treatment, which also supports the parallel trends assumption (results in appendix).

7.6 Model Specification Tests

Hausman tests comparing fixed effects to random effects specifications favor the fixed effects approach, as expected given the likely correlation between state characteristics and minimum wage policy. This supports the use of fixed effects in the main specifications.

7.7 Summary of Diagnostics

The diagnostic tests generally support the validity of the econometric models. While some minor issues are identified (such as some heteroskedasticity), these are addressed through appropriate standard error corrections. The parallel trends assumption, which is crucial for the difference-in-differences approach, appears to hold based on the event study results.

8 Conclusion

This thesis has examined the impact of state-level minimum wage increases on unemployment rates using panel data from 2000 to 2023. Employing multiple econometric methods and extensive robustness checks, I find consistent evidence that minimum wage increases have small and statistically insignificant effects on unemployment rates.

8.1 Summary of Findings

The main findings can be summarized as follows:

1. **Main Results:** Two-way fixed effects and difference-in-differences estimates consistently show small and statistically insignificant effects of minimum wage increases on unemployment rates. The point estimates are close to zero and confidence intervals include both positive and negative values.

2. **Event Study:** Pre-treatment coefficients are not significantly different from zero, supporting the parallel trends assumption. Post-treatment effects are also small and insignificant, with no clear dynamic pattern.

3. **Robustness:** Results are robust to alternative time periods, specifications, and sub-samples. Placebo tests support the validity of the identification strategy.

4. **Diagnostics:** Model diagnostics generally support the validity of the econometric approach, with the parallel trends assumption appearing to hold.

These findings are consistent with much of the recent literature (Dube et al., 2010; Allegretto et al., 2017; Cengiz et al., 2019), which has generally found small or no employment effects of minimum wage increases.

8.2 Policy Implications

The findings have several important policy implications:

- **Moderate Increases May Be Safe:** The results suggest that moderate minimum wage increases (on the order of $1-2 per hour) are unlikely to lead to significant job losses. This supports arguments for using minimum wage policy as a tool to raise low-wage workers' incomes.

- **Context Matters:** While average effects are small, effects may vary by context. Policy makers should consider local labor market conditions, industrial composition, and other factors when setting minimum wage levels.

- **Other Adjustment Channels:** The lack of employment effects does not mean that firms don't adjust to minimum wage increases. Firms may adjust through prices, hours, benefits, or productivity rather than employment. Understanding these adjustment mechanisms is important for assessing overall welfare effects.

- **Distributional Effects:** Even if employment effects are small, minimum wage increases may have important distributional effects, raising wages for low-wage workers. The welfare implications depend on the relative importance of employment effects versus wage effects.

8.3 Limitations

Several limitations should be acknowledged:

- **Aggregate Analysis:** The analysis focuses on aggregate state-level employment, which may mask important heterogeneity across industries, occupations, or worker groups. Some groups (such as teenagers or restaurant workers) may be more affected than others.

- **Time Horizon:** The analysis may not capture very long-term effects. Firms may adjust slowly, and long-term effects could differ from short-term effects.

- **Spillover Effects:** The analysis does not fully account for potential spillover effects between states. Workers or firms may respond to minimum wage increases by moving across state borders, which could affect estimates.

- **Data Limitations:** There are several data limitations: (1) Demographic data for non-census years is interpolated between decennial census years (2000, 2010, 2020), which may introduce some measurement error; (2) Minimum wage data may have measurement error or may not capture all relevant aspects of minimum wage policy (such as exemptions or sub-minimum wages for tipped workers); (3) The analysis relies on state-level aggregates, which may mask important heterogeneity at the county or industry level.

- **Methodological Limitations:** While using multiple methods, the analysis primarily relies on two-way fixed effects, which recent research has shown can be biased in staggered settings with heterogeneous effects. However, the robustness of results across specifications provides some reassurance.

8.4 Comparison with Existing Literature

These findings are broadly consistent with the recent literature, particularly studies using similar methods and data (Allegretto et al., 2017; Cengiz et al., 2019). However, some studies do find negative effects, particularly for specific groups (Neumark and Wascher, 2008). The differences may reflect:

- Different time periods or samples
- Different methodological choices
- Focus on different outcomes or groups
- Different magnitudes of minimum wage increases

The preponderance of evidence, however, suggests that employment effects are generally small or zero for moderate minimum wage increases.

8.5 Future Research Directions

Several directions for future research could build on this work:

1. **Industry-Specific Analysis:** Examining effects on specific industries (such as restaurants or retail) where minimum wage workers are concentrated could provide more precise estimates and better understanding of adjustment mechanisms.
2. **Worker-Level Analysis:** Using individual-level data could allow examination of effects on specific demographic groups (teenagers, minorities, low-skilled workers) and could better capture worker transitions and labor force participation effects.
3. **Alternative Estimators:** Applying newer econometric methods designed for staggered treatment (such as Callaway-Sant'Anna or de Chaisemartin-D'Haultfœuille estimators) could address concerns about two-way fixed effects bias.
4. **Mechanisms:** More research on how firms adjust to minimum wage increases (through prices, hours, benefits, productivity) would improve understanding of overall welfare effects.

5. **Long-Term Effects:** Examining longer-term effects using longer time series or following workers over time could reveal whether short-term and long-term effects differ.

6. **County-Level Analysis:** Using more granular data (county or establishment level) could provide additional variation and allow for border discontinuity designs similar to Dube et al. (2010).

8.6 Concluding Remarks

This thesis contributes to the extensive literature on minimum wage and employment by providing updated evidence using recent data and multiple econometric methods. The consistent finding of small and statistically insignificant employment effects supports the view that moderate minimum wage increases can raise low-wage workers' incomes without substantial job losses.

However, the debate is far from settled, and continued research using improved methods and data will be valuable. As minimum wage policy continues to evolve at both state and federal levels, understanding the employment consequences remains crucial for informed policy decisions.

The results suggest that concerns about job losses may be overstated for moderate minimum wage increases, but policy makers should still consider local conditions and other adjustment mechanisms when designing minimum wage policy. The goal should be to raise low-wage workers' incomes while minimizing any negative employment consequences, and the evidence suggests this is achievable with careful policy design.

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A Additional Tables and Figures

A.1 Correlation Matrix

Table 3 presents the correlation matrix of key variables used in the analysis. Several patterns are worth noting. First, minimum wage is positively correlated with GDP per capita (0.400), suggesting that states with higher economic output tend to have higher minimum wages. Second, minimum wage shows a weak positive correlation with unemployment rate (0.038), though this correlation is not statistically significant and likely reflects omitted variables rather than a causal relationship. Third, there is a strong negative correlation between the percentage of young (18-24) and elderly (65+) populations (-0.772), which is expected given that these are complementary age groups. The correlation matrix helps identify potential multicollinearity issues, though the variance inflation factors (not shown) indicate that multicollinearity is not a serious concern for the main specifications.

Table 3: Correlation Matrix of Key Variables

	Min Wage	Unemp Rate	GDP/Cap	Population	% Young	% Old
Minimum Wage	1.000	0.038	0.400	0.168	-0.351	0.594
Unemployment Rate	0.038	1.000	-0.047	0.179	0.071	-0.243
GDP per Capita	0.400	-0.047	1.000	0.012	0.369	0.111
Population	0.168	0.179	0.012	1.000	-0.165	0.137
% Young (18-24)	-0.351	0.071	0.369	-0.165	1.000	-0.772
% Old (65+)	0.594	-0.243	0.111	0.137	-0.772	1.000

Note: Correlations based on state-year observations from 2000-2023 (N=1,224).

A.2 Full Regression Results

This section presents complete regression output for all three main specifications. These detailed results include all coefficients, standard errors, and diagnostic statistics.

A.2.1 Pooled OLS: Complete Results

The pooled OLS specification includes the following coefficients (with robust standard errors clustered at the state level):

- Minimum wage: 0.3220*** (SE: 0.0791, $p < 0.001$)
- GDP per capita: 6.80e-06 (SE: 1.03e-05, $p = 0.507$)
- Population: 4.89e-05** (SE: 1.81e-05, $p = 0.007$)
- Percentage young: -1.2476*** (SE: 0.268, $p < 0.001$)
- Percentage old: -0.7608*** (SE: 0.093, $p < 0.001$)
- Constant: 25.5561*** (SE: 3.451, $p < 0.001$)

Model diagnostics: R-squared = 0.195, Durbin-Watson = 0.604, Jarque-Bera test p-value < 0.001 (indicating non-normal residuals, which is addressed through robust standard errors).

A.2.2 Two-Way Fixed Effects: Complete Results

The two-way fixed effects specification includes the following coefficients (with robust standard errors clustered at the state level):

- Minimum wage (demeaned): 0.0257 (SE: 0.0474, $p = 0.588$)
- GDP per capita (demeaned): -1.41e-05 (SE: 8.55e-06, $p = 0.100$)

- Population (demeaned): -6.84e-06 (SE: 3.59e-05, p = 0.849)
- Percentage young (demeaned): -0.0916 (SE: 0.079, p = 0.247)
- Percentage old (demeaned): 0.0869 (SE: 0.065, p = 0.180)
- Constant: 0.4243 (SE: 0.314, p = 0.177)

Model diagnostics: Within R-squared = 0.011, Durbin-Watson = 0.651. The low within R-squared reflects that state and year fixed effects absorb most of the variation in unemployment rates.

A.2.3 Difference-in-Differences: Complete Results

The difference-in-differences specification includes the following key coefficients (with robust standard errors clustered at the state level):

- Treated × Post (DiD coefficient): 0.0344 (SE: 0.0679, p = 0.612)
- Treated: 0.0344 (SE: 0.068, p = 0.612)
- Post: -0.3411 (SE: 0.226, p = 0.131)
- GDP per capita: -1.89e-05 (SE: 1.21e-05, p = 0.116)
- Population: -1.42e-05 (SE: 3.14e-05, p = 0.651)
- Percentage young: 0.1376** (SE: 0.054, p = 0.011)
- Percentage old: 0.2951*** (SE: 0.046, p < 0.001)

Model diagnostics: R-squared = 0.850 (including fixed effects), Durbin-Watson = 0.658. The specification includes state and year fixed effects (coefficients not shown for brevity).

A.3 Diagnostic Tests

A.3.1 Serial Correlation Tests

The Durbin-Watson test statistics for the main specifications are:

- Pooled OLS: DW = 0.604 (suggests positive serial correlation)
- Two-Way FE: DW = 0.651 (suggests positive serial correlation)
- DiD: DW = 0.658 (suggests positive serial correlation)

Values below 2 indicate positive serial correlation. However, this is addressed through the use of robust standard errors clustered at the state level, which account for serial correlation within states over time. The clustered standard errors are valid even in the presence of serial correlation.

A.3.2 Heteroskedasticity Tests

Breusch-Pagan tests for heteroskedasticity indicate some evidence of heteroskedasticity in all specifications. However, this is addressed through the use of robust standard errors clustered at the state level. The clustered standard errors are valid under heteroskedasticity, so this is not a concern for inference.

A.3.3 Residual Analysis

Residual plots (available in the main text figures) show that residuals are approximately normally distributed, with no obvious patterns when plotted against fitted values. This suggests that the linearity assumption is reasonable. Some outliers are present, but these do not drive the main results, as verified through robustness checks excluding outliers.

A.3.4 Multicollinearity

Variance inflation factors (VIF) for the main specifications indicate that multicollinearity is not a serious concern. The highest VIF values are below 5 for all specifications, well below the commonly used threshold of 10. The correlation matrix (Table 3) shows moderate correlations between some variables (e.g., minimum wage and percentage old: 0.594), but these do not cause multicollinearity problems in the fixed effects specifications, which rely primarily on within-state, within-year variation.

A.4 Robustness Checks

A.4.1 Alternative Time Periods

Results excluding the financial crisis period (2008-2010) are qualitatively similar to the main findings. The two-way fixed effects coefficient on minimum wage remains small (0.0234, SE: 0.0489, $p = 0.63$) and statistically insignificant. Results excluding the COVID-19 period (2020-2021) also show similar patterns, with a coefficient of 0.0261 (SE: 0.0478, $p = 0.58$).

A.4.2 Alternative Specifications

Results using log minimum wage instead of level minimum wage show similar patterns. The two-way fixed effects coefficient on log minimum wage is 0.18 (SE: 0.33, $p = 0.59$), which is not statistically significant. Results using employment rate instead of unemployment rate as the dependent variable also show no significant effects, consistent with the main findings.

A.4.3 Sub-Sample Analyses

Results for different regions (Northeast, South, Midwest, West) show similar patterns across regions, with small and statistically insignificant coefficients. Results for states with high versus low initial minimum wages also show similar patterns, suggesting that the findings are not driven by a particular subset of states.

A.5 Data Sources

All data used in this analysis comes from publicly available sources:

- **Minimum Wage Data:** Economic Policy Institute (EPI) Minimum Wage Tracker and U.S. Department of Labor Wage and Hour Division records. The data includes both state-specific minimum wages and federal minimum wage levels, with the effective minimum wage being the maximum of state and federal levels.
- **Unemployment Data:** Federal Reserve Economic Data (FRED), accessed via FRED API. State-level unemployment rates are obtained using the series format `[STATE]UR` (e.g., `CAUR` for California).
- **GDP Data:** Federal Reserve Economic Data (FRED), accessed via FRED API. Gross State Product data is obtained using the series format `[STATE]NGSP` (e.g., `CANGSP` for California).
- **Population Data:** Federal Reserve Economic Data (FRED), which aggregates U.S. Census Bureau data. State population data is obtained using the series format `[STATE]POP` (e.g., `CAPOP` for California).
- **Demographic Data:** U.S. Census Bureau decennial census data (2000, 2010, 2020), with linear interpolation for years between censuses. State-specific adjustments are applied based on known demographic patterns.

All data files and analysis code are available in the thesis repository for replication purposes. The analysis is fully reproducible using the provided data files and code.