

Powering Rural Prosperity: The Local Economic Impact of Utility-Scale Wind and Solar Developments

Adrienne Ohler^{a, b, *}

Austin Landini^{b, †}

Michael Sykuta^{a, b, ‡}

^a*Division of Applied Social Science*

^b*Center for Rural Energy Security*

University of Missouri

Mumford Hall

Columbia, MO 65211

Abstract

A growing literature documents a relationship between renewable energy development and local economic outcomes. Yet, important gaps remain in understanding how these effects manifest in rural economies, across technologies, and within specific sectors. Using county-level data on U.S. energy installations between 2001-2023, we examine how renewable energy adoption shapes sector-specific economic activity, focusing on GDP, employment, and wages in rural counties. We extend prior work in three ways. First, we focus explicitly on rural outcomes, where utility-scale renewable development is concentrated but where economic structures may limit local benefits. Second, we incorporate solar adoption alongside wind, enabling a comparison of technology-specific impacts. Third, we move beyond aggregate measures to conduct a sectoral analysis, identifying how effects vary across industries. Wind development is associated with significant GDP gains concentrated in the utilities sector, while solar development is associated with modest wage and employment gains driven largely by utilities and construction. For very large utility-scale solar (e.g. 5MW or 20MW) agriculture, construction, and utility GDP increase with solar adoption. Neither technology is associated with detectable declines in agricultural GDP, employment, or wages, providing little evidence of substantial disruption to agricultural production or related labor markets. These findings provide a more nuanced understanding of the local economic consequences of the energy transition and highlight the importance of technology type and sectoral composition in shaping rural development outcomes.

Keywords: Wind energy; solar energy; economic development; rural development; difference-in-differences; renewable energy; agriculture

JEL Codes: Q42; R11; Q56

Acknowledgements: This research was supported by funding from the University of Missouri's Financial Research Institute and the Center for Rural Energy Security

CRedit Contributions: Adrienne Ohler: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. Austin Landini: Data curation, Investigation, Writing – review & editing. Michael Sykuta: Conceptualization, Funding acquisition, Writing – review & editing, Policy analysis.

Conflict of Interest Statement: The authors have no other financial or proprietary interests in any material discussed in this article.

*Email: Adrienne.ohler@missouri.edu, corresponding author

†Email: Austin.landini@missouri.edu

†Email: sykutam@missouri.edu

Powering Rural Prosperity: The Local Economic Impact of Utility-Scale Wind and Solar Developments

Abstract

A growing literature documents a relationship between renewable energy development and local economic outcomes. Yet, important gaps remain in understanding how these effects manifest in rural economies, across technologies, and within specific sectors. Using county-level data on U.S. energy installations between 2001-2023, we examine how renewable energy adoption shapes sector-specific economic activity, focusing on GDP, employment, and wages in rural counties. We extend prior work in three ways. First, we focus explicitly on rural outcomes, where utility-scale renewable development is concentrated but where economic structures may limit local benefits. Second, we incorporate solar adoption alongside wind, enabling a comparison of technology-specific impacts. Third, we move beyond aggregate measures to conduct a sectoral analysis, identifying how effects vary across industries. Wind development is associated with significant GDP gains concentrated in the utilities sector, while solar development is associated with modest wage and employment gains driven largely by utilities and construction. For very large utility-scale solar (e.g. 5MW or 20MW) agriculture, construction, and utility GDP increase with solar adoption. Neither technology is associated with detectable declines in agricultural GDP, employment, or wages, providing little evidence of substantial disruption to agricultural production or related labor markets. These findings provide a more nuanced understanding of the local economic consequences of the energy transition and highlight the importance of technology type and sectoral composition in shaping rural development outcomes.

Keywords: Wind energy; solar energy; economic development; rural development; difference-in-differences; renewable energy; agriculture

JEL Codes: Q42; R11; Q56

Conflict of Interest Statement: The authors have no other financial or proprietary interests in any material discussed in this article.

1. Introduction

The infrastructure demands of the energy transition are largely borne by rural communities. Technoeconomic factors, such as resource quality and access to open undeveloped spaces, are the main drivers of wind and solar siting in the U.S. (O'Shaughnessy et al. 2022). Fossil fuel power plant siting occurs largely in an urban fringe and suburban context, while solar and wind projects are located largely in rural areas. In the Midwest, most utility-scale solar (70%) and wind farms (94%) are situated on cropland, and in the West, 60% and 69% of solar and wind farms, respectively, are located on pasture or rangeland (Maguire et al. 2024).

This study investigates the economic impacts of utility-scale wind and solar developments in rural U.S. counties. Using a difference-in-differences framework and county-level data on renewable energy installations, GDP, employment, and wages, we estimate the effects of renewable energy development on local economies at both the aggregate and sectoral levels. We focus on rural counties and this approach allows us to compare the local economic consequences of wind and solar development across communities that are most likely to host utility-scale renewable energy projects.¹

We contribute to the literature in three important ways. First, we focus specifically on rural counties, where renewable energy development is often promoted as an economic development strategy, but where empirical evidence on its local economic effects remains limited. This focus is important because rural counties host many utility-scale projects and often face slower economic growth, population decline, and limited opportunities for economic

¹ Rural is defined by the USDA Rural-Urban Classification Codes (RUCC > 3). In a supplemental analysis, we examine county rurality based on agricultural production, defining rural counties as those in which agricultural GDP accounts for more than 10% of total GDP. Results are available in the online Supplemental S1.

diversification (Brown et al. 2012; Shoeib, Renski, and Hamin Infield 2022; Haggerty, Haggerty, and Rasker 2014). Previous research also suggests that the economic effects of renewable energy development differ substantially between rural and non-rural areas. For example, Shoeib, Renski, and Hamin Infield (2022) find positive effects of wind development on income, employment, and poverty reduction when considering all counties, but only farm income gains when the analysis is restricted to rural counties.

Second, we provide a direct comparison of utility-scale wind and solar development. Although both technologies are frequently sited in rural areas and often compete for agricultural land, they differ substantially in land-use intensity and compatibility with agricultural production (Maguire et al. 2024). Understanding whether these differences translate into distinct local economic outcomes remains an important gap in the literature.

Third, we extend prior work by examining sector-specific effects on GDP, employment, and wages. Building on Brunner and Schwegman (2022), we investigate impacts across sectors including agriculture, construction, and utilities, providing insight into the mechanisms through which renewable energy development affects local economies and whether there is substitution or displacement of economic activity across sectors, particularly given land use concerns in agriculture.

The results show economically meaningful but technology-specific effects: wind development produces larger GDP gains, especially in the utilities sector, while solar development produces smaller labor-market gains concentrated in utilities and construction. Across both technologies, we find little evidence of declines in agricultural GDP, employment, and wages. When restricting solar adoption to larger utility-scale projects (e.g. $\geq 5\text{MW}$ or $\geq 20\text{MW}$), we find modest effects across the agriculture, construction, and utility sectors. These

findings inform siting debates by distinguishing technology-specific economic effects from generalized claims about renewable energy development.

The remainder of the paper proceeds as follows. Section 2 reviews the drivers of utility-scale wind and solar development and the mechanisms through which renewable energy investments may affect local economic outcomes, including potential trade-offs with agricultural land use. Section 3 describes the data and empirical strategy, including county-level renewable energy, GDP, employment, and wage data and the staggered-adoption difference-in-differences (DiD) framework. Section 4 presents descriptive trends in renewable energy deployment and economic activity across rural U.S. counties. Section 5 reports the main results from the Callaway and Sant'Anna estimator, including sector-specific effects. Section 6 discusses the implications of the findings for rural economic development and renewable energy policy and concludes.

2. Background on Utility-Scale Renewable Developments

Local expectations about economic benefits are central to community support and siting decisions (Carley et al. 2020; Slattery et al. 2012). These expectations are especially salient where projects intersect with agricultural land use. With any new infrastructure, local governments and residents often anticipate new jobs, increased tax revenues, lease payments to landowners, and broader economic development, particularly in rural communities facing population decline or limited economic opportunities. Whether these expected benefits materialize has important implications for public decision-making because perceptions of local economic gains can influence zoning decisions, permitting outcomes, and long-term community support for renewable energy development. However, actual economic outcomes depend not only on the projects themselves but also on where projects are located and the characteristics of host communities.

2.1 Project Siting and Local Economic Context

The location of utility-scale wind and solar projects is determined by a combination of physical, institutional, and social factors. Resource quality, transmission access, population density, and state and federal policies all influence project siting decisions (Schumacher and Yang 2018). Counties with more landowners tend to have lower levels of wind development (Winikoff and Parker 2023), while local ordinances and zoning regulations can either facilitate or constrain renewable energy development (Lerner 2021). At the farm level, adoption of renewable energy systems is more common among livestock operations, larger farms, operators with internet access, and organic producers (Borchers, Xiarchos, and Beckman 2014), suggesting that renewable development may be correlated with underlying agricultural and socioeconomic characteristics.

Community acceptance and local permitting processes further shape renewable energy development. Public support is influenced by perceptions of visual impacts, economic benefits, trust in developers and regulators, and the degree of public participation in the siting process (Carley et al. 2020; Firestone et al. 2017; Roddis et al. 2018). Opposition is often greater in areas with strong amenity values and preservation-oriented land use preferences (Bessette and Mills 2021; Giordono et al. 2018). Recent work suggests that permitting outcomes are often driven as much by local implementation, stakeholder engagement, and community opposition as by the specific language of ordinances themselves (O'Shaughnessy, Nilson, and Rand 2025). Local regulatory decisions may also have broader economic implications; Hicks et al. (2026) find that counties adopting wind and solar restrictions experienced lower manufacturing-related GDP and employment growth.

These factors imply that renewable energy projects are not randomly located. Counties that adopt wind or solar development differ systematically from those that do not in ways that may also influence economic outcomes. For example, counties with strong wind resources, available transmission infrastructure, supportive regulatory environments, or large amounts of agricultural land may already be on different economic trajectories than otherwise similar counties without these characteristics. Consequently, simple cross-sectional comparisons between adopting and non-adopting counties risk confounding the effects of renewable energy development with pre-existing differences across locations.

This nonrandom siting motivates the quasi-experimental DiD approach used below, which compares changes in adopting counties with changes in not-yet-adopting counties.

2.2 Empirical Evidence on Local Economic Impacts

To estimate the economic consequences of renewable energy development, researchers have relied on two broad approaches. Ex ante studies typically use input-output models such as JEDI and IMPLAN to forecast employment, wage, and tax effects from proposed projects (Bae and Dall'erba 2016; Jenniches 2018). These studies generally predict positive economic impacts but estimate gross rather than net effects and often focus on state or national economies. Because they do not directly observe realized outcomes, they are less suited for evaluating opportunity costs, including foregone agricultural production, changes in land values, or displacement of existing economic activity (De Silva, McComb, and Schiller 2016).

To address these limitations, a growing literature uses ex post econometric approaches, most commonly DiD designs, to estimate the realized economic impacts of renewable energy development. These ex post studies generally find positive but modest local economic effects

from wind development. Brown et al. (2012) estimate increases of roughly 0.2% in county personal income and 0.4% in employment, largely concentrated during the construction phase. Using Texas counties, De Silva, McComb, and Schiller (2016) similarly find positive effects on income and employment, although the magnitude of these gains varies with project size. More recently, Brunner and Schwegman (2022) find increases in county GDP per capita, income per capita, and median home values, while Gilbert, Hoen, and Gagarin (2024) document persistent gains in earnings and employment among workers located near wind projects.

Recent work also suggests that impacts vary substantially across locations. Using matching methods and longitudinal models, Shoeib, Renski, and Hamin Infield (2022) find positive associations between wind development and income, employment, and poverty reduction when considering all U.S. counties, but much weaker effects when restricting attention to rural counties. Brunner and Schwegman (2022) similarly find larger economic gains in less-populated rural communities. These results raise important questions about whether findings from national samples generalize to the rural agricultural counties where most utility-scale renewable projects are located.

Beyond income and employment, a growing literature examines effects on housing and agricultural land markets. Evidence for solar development is mixed, with Gaur and Lang (2023) finding negative housing price effects in rural Northeastern communities, while Hao and Michaud (2024) find positive effects in the Midwest. Studies of agricultural land values generally find limited impacts. Abashidze and Taylor (2023) report no direct effect of solar development on agricultural land values in North Carolina, while Tanner et al. (2024) find little effect of wind development on agricultural land without buildings but negative effects on agricultural properties containing buildings.

Three gaps motivate this study. Existing ex post evidence remains weighted toward wind, relies largely on aggregate outcomes, and provides limited evidence for rural agricultural counties. We address these gaps by comparing wind and solar adoption and estimating sector-specific effects in rural counties where utility-scale projects are most commonly sited.

2.3 Agricultural Land Use and Rural Economic Trade-offs

Utility-scale renewable energy development is deeply connected to rural land use. In the U.S., more than 90% of large-scale wind and 80% of solar farms in rural areas have been installed on cropland, pasture, or rangeland (Maguire, Tanner, and Winikoff 2024; Maguire et al. 2024). This concentration on agricultural land has raised concerns that renewable energy development may compete with food and fiber production, especially in rural counties where agriculture remains an important part of the local economy. Recent evidence suggests that solar development may also influence agricultural land markets; in New York, solar suitable parcels near substations sold for 15-18% more following the adoption of community-solar policies (Li, Zhang, and Ortiz-Bobea 2026). These concerns are particularly salient for utility-scale solar, which often requires larger contiguous land areas and may remove land from agricultural production from the duration of the project lease.

The extent of this trade-off likely differs between wind and solar development. Wind turbines generally occupy a relatively small physical footprint, allowing farming or grazing to continue around turbines and access roads. In some cases, wind development may even have limited positive effects on crop productivity; using a DiD approach, (Kaffine 2019) finds a small (~1%) increase in corn, soybean, and hay yields near a 100MW wind facility, potentially due to local microclimate effects. Solar development presents a different set of concerns because the land-use footprint is more spatially extensive and may more directly substitute energy production

for agricultural production. Agrivoltaics has been proposed as one strategy to reduce this tension, but widespread adoption remains limited (Dohlman et al. 2024).

Whether renewable energy development affects agricultural economies, however, cannot be inferred from land conversion alone. The local economic effects depend on how energy development changes landowner income, land values, rental markets, local labor demand, and the organization of agricultural production. Lease payments may provide a new and stable source of income for participating landowners, but project siting may also alter the availability and price of farmland for producers who rent land. These effects are shaped by local zoning policies, siting restrictions (Lerner 2021; O'Shaughnessy, Nilson, and Rand 2025), soil productivity, and whether projects are steered toward marginal or highly productive farmland (Maguire, Tanner, and Winikoff 2024; Owusu-Obeng et al. 2026).

These considerations raise a central empirical question: do renewable energy projects generate local economic gains alongside continued agricultural economic activity? We examine agricultural GDP, employment, and wages to assess whether renewable development complements, displaces, or restructures agricultural economic activity in rural counties, and whether those effects differ between wind and solar technologies.

3. Data and Methods

We construct a county-level panel dataset for the contiguous U.S. from 2001 through 2023 to estimate the local economic effects of utility-scale renewable energy developments in rural communities. The unit of observation is the county-year, which allows us to link the timing and scale of wind and solar installations to annual measures of local economic activity, including GDP, employment, and wages. Consistent with the recent ex post studies of renewable energy

development (Brunner and Schwegman 2022; Gilbert, Hoen, and Gagarin 2024; Shoeib, Renski, and Hamin Infield 2022), we focus on observed changes rather than modeled input-output projects, exploiting variation in the timing of project adoption across counties. The primary analysis is restricted to nonmetropolitan counties, defined using USDA Rural-Urban Continuum Codes (RUCC) of 4 or greater, because large-scale renewable energy projects are disproportionately sited in rural and agricultural landscapes and because the economic channels through which these projects affect local communities may differ from those in more urban economies. We supplement this rural classification with an agricultural-economy definition based on the county-share of GDP from agriculture to assess whether results are robust for counties where agriculture production is a central component of the local economic base. The resulting panel combines federal data on power plant location, technology, capacity, and operating year with county-level economic outcomes and demographic characteristics, providing a framework to compare pre- and post-development trends in counties that adopt wind or solar energy with otherwise comparable counties that do not.²

3.1 Power Plant Locations and Rural Classifications

Data on renewable energy development are constructed from the U.S Energy Information Administration's annual Form EIA-860, which reports generator-level information on electric power plants, including technology type, operating status, nameplate capacity, initial operating

² Due to inconsistencies in county definitions and reporting, most Virginia counties and independent cities are excluded. Virginia's independent city structure creates inconsistencies across datasets that report either counties or county-equivalents, complicating harmonization with BEA and other federal data sources.

year, and plant location.³ We merge plant-level location records with generator-level capacity and technology data to identify the county, timing, and scale of wind and solar development. Counties are assigned using the state and county reported for each plant and are linked to the remaining panel using five-digit Federal Information Processing Standards (FIPS) codes.

Wind and solar generators are identified using the generator's reported primary energy source. Generator-level observations are aggregated to the plant level. We then exclude wind plants with total nameplate capacity below 50 MW and solar plants with total nameplate capacity below 1 MW (Abashidze and Taylor 2023; Wiser et al. 2023).⁴ For each county, we define the adoption year as the first year in which a qualifying wind or solar plant becomes operational.⁵ Once a county adopts a technology, treatment status remains equal to one in all subsequent years. Counties that do not host a qualifying plant during the sample period serve as comparison counties, subject to the sample restrictions described below. Wind and solar adoption are coded separately, allowing counties to enter the wind and solar treatment groups in different years.

The primary analysis focuses on rural counties. We classify counties as rural using the U.S. Department of Agriculture's 2013 Rural-Urban Continuum Codes (RUCC), defining nonmetropolitan counties as those with RUCC values of 4 or greater. This restriction is motivated by the spatial pattern of utility-scale renewable energy development, which is

³ Required respondents to the EIA-860 form if the plant's total nameplate capacity is 1MW or greater and plant's generator(s) are connected to the local or regional electric power grid, and has the ability to draw from and deliver power to the grid.

⁴ Smaller wind projects are rare and larger projects benefit from economies of scale. For solar, this exclusion criterion removes many of the commercial or public rooftop solar projects that do not impact land use. We find broadly similar results when the threshold for solar is 5MW and 20MW with stronger statistical significance. These results are available in Appendix A.

⁵ Generators within qualifying plants generally enter operation in the same year, so differences between first operation and the year in which total operating capacity reaches the threshold are uncommon.

disproportionately located in lower-density rural areas where agricultural and other undeveloped land is more abundant. Because rurality may also reflect the structure of the local economy rather than only metropolitan status, we conduct a supplemental analysis using an agricultural-economy definition. In this robustness sample, counties are classified as “agriculturally rural” if agriculture accounts for at least 10% of county GDP.⁶ This alternative definition allows us to test whether estimated effects are sensitive to using an economic measure of agricultural dependence rather than an urban-rural classification alone.

Table 1 reports baseline characteristics for adopting and non-adopting counties using data from the 2000 Decennial Census. Several differences emerge across adoption groups. Wind-adopting counties tend to be smaller, older, and have lower poverty rates than non-adopting counties, with slightly higher levels of educational attainment and lower shares of non-White residents. In contrast, solar-adopting counties are substantially larger, younger, more educated, have lower poverty rates, and more racially diverse than non-adopting counties. These patterns suggest that wind and solar development are not randomly distributed across rural areas but instead occur in counties with different demographic and socioeconomic characteristics.

3.2 Economic Outcomes: GDP, Wages, and Employment

Economic outcomes are measured at the county-year level using data from the U.S. Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics’ Quarterly Census of Employment and Wages (QCEW). We examine three complementary measures of local economic activity: gross domestic product (GDP), employment, and wages. County-level GDP and GDP by

⁶ Results are broadly similar when rurality is defined as having an agricultural GDP share equal to or greater than 10%. GDP growth is largely driven by the utility sector, but impacts on employment are diminished in the effect size and significance. These results are available in the online Supplemental S1.

industry are drawn from the BEA and measure the value-added produced within the county. Employment and wages outcomes are constructed from the QCEW, which reports annual average employment and total annual wages by county, ownership, and North American Industry Classification System (NAICS) industry.⁷ For QCEW outcomes, employment and wages are summed across federal, state, local, and private ownership categories, allowing sectoral measures to capture both public and private covered employment where applicable. Demographic and population characteristics are sourced from the U.S. Census Bureau's 2000 Decennial Census. The datasets are combined into a county-year panel based on FIPS codes. All outcomes are analyzed in logs, with GDP expressed as log GDP per capita.

Our primary outcomes are total county GDP per capita, total employment, and total annual wages. These aggregate measures capture the overall scale of local economic activity and allow us to test whether utility-scale renewable energy development produces measurable countywide changes beyond a narrow project-specific footprint. Because renewable energy projects may affect local economies through several channels, including construction activity, utility-sector production, land-use changes, lease payments, tax revenue, and local demand for goods and services, we also estimate sector-specific effects.

The primary sectoral analysis focuses on agriculture, construction, and utilities. Agriculture captures the existing land-based economic base of many host counties. For GDP, this sector reflects value added from crop and livestock production and related agricultural activities. For QCEW employment and wages, it captures covered wage-and-salary jobs in agriculture though it may understate the full agricultural labor force because many farm proprietors, family

⁷ NAICS sectors used in the analysis include agriculture, forestry, fishing, and hunting (11); utilities (22); construction (23); manufacturing (31–33); wholesale trade (42); transportation and warehousing (48–49); real estate and rental and leasing (53); and public administration (92).

workers, and self-employed operators are not fully represented in QCEW employment. This sector is central to the analysis because renewable projects are often sited on agricultural land and may affect farm economies through land leases, changes in land use, or interactions with ongoing agricultural production.

Construction captures the short-run development and installation phase of renewable energy projects. In rural counties, construction-sector GDP, employment, and wages may include site preparation, road building, grading, foundations, electrical work, transmission interconnection, and related contracting activity. Because the construction phase is labor-intensive but temporary, construction outcomes help distinguish short-run project development effects from longer-run operating effects.

Utilities capture the sector most directly connected to electricity generation, transmission, and distribution. For GDP, the utilities sector is important because electric power generation is capital intensive and can generate substantial value added even when local employment effects are modest. For QCEW employment and wages, the utilities sector may include plant operations, maintenance technicians, grid and substation workers, and administrative or technical staff.

In supplemental sectoral analyses, we also examine transportation and warehousing, public administration, real estate and rental and leasing, manufacturing, and wholesale trade. These sectors are not the primary expected channels, but they provide evidence on broader local spillovers and help identify whether renewable energy development affects the composition of rural economic activity. We interpret these supplemental estimates as exploratory because the sectors capture broad local activity rather than renewable-specific supply chains.

BEA GDP measures value added, while QCEW employment and wages measure covered wage-and-salary labor market activity. As a result, capital-intensive sectors such as utilities or real estate may show changes in GDP without large employment effects, while sectors such as construction may show temporary employment and wage responses with smaller long-run effects. In addition, sector-level QCEW data are subject to disclosure suppression and missingness, particularly in small rural counties and narrowly defined industries. We therefore emphasize total outcomes and the primary sectors of agriculture, construction, and utilities in the main analysis, and report the remaining sectoral results as supplemental evidence in Appendix B. Sector-specific estimates are interpreted cautiously where disclosure suppression reduces the number of available county-year observations.

3.3 Econometric Approaches

We estimate the causal effects of utility-scale wind and solar development using the staggered-adoption DiD framework developed by Callaway and Sant'Anna (2021). This approach is designed for settings in which treatment occurs at different times across units and avoids the negative-weighting problems that arise in traditional two-way fixed effects estimators when treatment effects are heterogeneous across cohorts. The estimator compares counties that adopt renewable energy in different years to counties that have not yet adopted the relevant technology, thereby recovering cohort-specific treatment effects that are subsequently aggregated into overall average treatment effects.

Let Y_{it} denote an economic outcome for county i in year t , such as GDP, employment or wages. Let G_i denote the first year in which county i receives treatment (wind and solar development are modelled separately), with $G_i = \infty$ for never-treated counties. The parameter of interest is the group-time average treatment effect:

where $Y_t(1)$ and $Y_t(0)$ represent the potential outcomes under treatment and no treatment, respectively. The estimator compares counties first treated in year g to counties that have not yet been treated by year t . Following Callaway and Sant'Anna (2021), identification relies on a conditional parallel trends assumption, under which treated counties would have followed the same outcome trends as counties not yet treated in the absence of renewable energy development.

We define treatment timing, (G_i) , as the first year in which a qualifying wind or solar project becomes operational in county (i) . Using the year of operation provides a clearly observed and consistently measured treatment date across projects and captures the point at which renewable energy generation formally begins. As a robustness check, we consider alternative treatment timing that accounts for the construction period prior to operation, when some local economic effects may begin to emerge. These specifications, reported in Online Supplemental S2, yield broadly similar results.

Event-study estimates are reported for a window spanning five years before and five years after the initial adoption of utility-scale wind or solar development. These estimates allow treatment effects to evolve flexibly over time and provide a visual assessment of pre-treatment trends and post-treatment impacts. Identification relies on comparison between treated counties and counties that have not yet received treatment. To assess the plausibility of the parallel trends assumption, we conduct formal pre-treatment tests using the joint significance test of event-time coefficients for the five years preceding treatment. Standard errors are clustered at the county level to account for serial correlation within counties over time.

Following the set of baseline county characteristics considered by Brunner and Schwegman (2022), we estimate supplemental covariate-adjusted specifications that condition on pre-treatment county characteristics. These specifications are presented as robustness checks and do not alter the main conclusions. The baseline county characteristics measured prior to treatment are drawn from the 2000 Decennial Census and include population, the homeownership rate, the share of the population age 65 and older, the share of adults with a bachelor's degree or higher, the poverty rate, and racial composition as reported in Table 1. We include these variables as baseline level controls because specifications with covariate-specific trends more frequently failed pre-trend tests.

The pre-treatment tests assess the null hypothesis that all pre-treatment event-time effects are jointly equal to zero:

$$H_0: ATT(g, g + e) = 0 \quad \forall e \in \{-5, -4, -3, -2, -1\}$$

Failure to reject the null hypothesis provides evidence consistent with parallel trends. We also aggregate the group-time treatment effects by event time, $e = t - g$, and report the $ATT(e)$ for $e \in [-5, 5]$. These estimates allow us to examine both anticipatory effects prior to treatment and the evolution of impacts following renewable development.

4. Trends in Renewable Installations and Economic Outcomes

This section describes the spatial distribution of utility-scale wind and solar development and compares economic trends between counties that eventually adopt renewable energy and those that do not.

Figure 1 maps the location of wind and solar development across the U.S., illustrating the geographic distribution of utility-scale development through 2023. Wind development is

concentrated in the Great Plains, Midwest, and portions of the Mountain West, reflecting the spatial distribution of high-quality wind resources. Solar development is more geographically dispersed but is concentrated in the Southwest, Texas, and along portions of the Atlantic seaboard. These patterns suggest that wind and solar development occur in different economic and geographic contexts, reflecting differences in resource availability, land requirements, transmission access, and state policy environments.

Figure 2 highlights important differences in renewable adoption for rural and non-rural counties. Across all counties, a total of 378 counties adopted utility-scale wind and 1,105 counties adopted utility-scale solar during the study period, while 121 counties adopted both technologies. Wind adoption is substantially more common in rural counties, whereas solar adoption is more prevalent in urban counties under our 1-MW threshold. Wind development is also more common in counties with a greater dependence on agricultural production. Average project size is generally larger in rural counties ($RUCC \geq 4$), particularly for solar installations. Together, these patterns underscore the importance of focusing on rural communities when evaluating the local economic impacts of renewable energy development.

Figure 3 compares average GDP, employment, and wage trends for rural counties that eventually adopt wind or solar with rural counties that never adopt during the sample period. Several differences in baseline economic conditions are evident. Counties that eventually adopt wind energy tend to have higher overall levels of GDP, lower employment and wages, and a greater concentration of agricultural activity, reflecting the tendency for wind projects to locate in agricultural regions (See Appendix C for sector specific trends). In contrast, counties that eventually adopt solar exhibit consistently higher levels of employment and wages throughout

the sample period. While these counties also begin with higher levels of GDP, the gap relative to non-adopting counties narrow substantially after 2010.

Because renewable adoption is staggered across counties, there is no single pre-treatment period that can be used to assess the identifying assumptions of the DiD model from these figures alone. Instead, Figure 3 is intended as a descriptive comparison of aggregate economic trends among adopting and non-adopting counties over the sample period. The figures suggest that differences between the groups are largely characterized by persistent differences in levels rather than pronounced divergence in trends. Appendix C presents analogous comparisons for GDP, employment, and wages across the major industry sectors. Formal event-study estimates and statistical tests of parallel trends are reported in the DiD results next.

5. Results

This section presents the estimated effects of utility-scale wind and solar adoption on economic activity in rural counties. We first examine impacts on overall GDP per capita, employment, and wages, followed by sector-specific effects in agriculture, construction, and utilities, before assessing the robustness of the results to alternative specifications and sample definitions.

5.1 Main Economic Effects of Wind and Solar Development

5.1.1 Assessment of Pre-Treatment Trends

Table 2 reports joint tests of the pre-treatment event-time coefficients. For the majority of specifications, the null hypothesis that the pre-treatment coefficients are jointly equal to zero cannot be rejected, providing support for the identifying assumptions underlying the event-study design. A small number of sectoral outcomes do exhibit evidence of pre-treatment differences and should therefore be interpreted more cautiously.

5.1.2 Gross Domestic Product

Figure 4 presents the estimated effects of wind and solar adoption on county-level GDP in rural counties. For wind adoption, the event-study estimates indicate positive and statistically significant increases in overall GDP per capita that emerge after adoption and persist throughout the post-adoption period. The results suggest that by the third year of operation GDP per capita is 7.22% [95% CI: 3.45% to 11.13%, p-value<0.001] higher than it would have been in the absence of wind adoption.⁸ The timing of these effects is consistent with the gradual expansion of economic activity associated with large-scale wind development. Examination of sector-specific results in Figure 5 suggests that these gains are driven primarily by increases in utility-sector GDP. Wind adoption is also associated with modest positive effects in the agricultural sector when covariates are included, with the magnitude varying somewhat across specifications (see online Supplemental S3).

In contrast, there is little statistical evidence that solar adoption substantially increases overall GDP per capita. While point estimates are generally positive in the post-adoption period, the effects are smaller and less precisely estimated than those observed for wind development. Sectoral results indicate that the economic impacts of solar development are concentrated largely within the utilities sector, with some evidence of positive effects in construction-related activity. However, these gains are not sufficient to generate the same magnitude or persistence of overall GDP growth observed following wind adoption. By the fifth year after solar adoption, overall GDP per capita is estimated to increase by less than 0.01% [95% CI: -1.78% to 1.78%, p-value=0.990], compared with 7.32% [95% CI: 2.61% to 12.26%, p-value=0.002] following wind

⁸ For log-transformed outcomes, reported percentage effects are obtained by transforming estimated coefficients as $100 \times (e^{\beta} - 1)$; confidence interval bounds are transformed analogously.

adoption. When smaller-scale solar installations are excluded (e.g. using 5MW or 20MW thresholds), the estimated effects become more pronounced, with positive effects emerging in the agriculture and construction sectors (see Appendix A).

5.1.3 Employment

Figure 6 presents the estimated effects of wind and solar adoption on county-level employment in rural counties. Compared with the GDP results, employment responses are generally smaller in magnitude and less persistent. For wind adoption, there is little evidence of a substantial increase in overall employment following development. While some positive post-adoption effects are observed, the estimates are generally modest, suggesting that wind development does not generate broad-based labor market expansion. For example, by the fifth year of operation, total employment is estimated to be only 1.53% [95% CI: -1.88% to 5.06%, p-value=0.384] higher than comparable counties that had not yet adopted wind energy, and these effects are not statistically significant across the post-adoption period. Sector-specific results fail to indicate any significant employment gains in the agricultural, construction, and utilities sectors following wind adoption.

Solar adoption is associated with somewhat stronger employment effects than wind, although the estimated impacts remain modest. Positive post-adoption employment effects emerge after development and are concentrated primarily within the construction and utilities sectors. Results are more pronounced when higher capacity thresholds (5MW and 20MW) are used to define utility-scale solar adoption. As shown in Appendix A, these alternative specifications yield larger and statistically significant estimated employment and wages effects in the construction and utilities sectors, suggesting that including very small solar facilities attenuates the estimated impacts of utility-scale development.

The employment results suggest that renewable energy development produces more limited labor market effects than output effects. The concentration of gains within utilities, and to a lesser extent construction, indicates that much of the economic activity generated by renewable energy development occurs through relatively capital-intensive sectors that require comparatively few long-term workers.

5.1.4 Wages

Figure 7 presents the estimated effects of wind and solar adoption on wages in rural counties. For wind adoption, wage estimates are generally positive in the post-adoption period, but none are statistically significant. By the fifth year of operation, the estimated treatment effect implies that real total wages are approximately 2.93% [95% CI: -0.06% to 6.62%, p-value=0.107] higher than in comparable not-yet-treated counties, but again with statistically insignificant results over the post-treatment period. Consistent with the broader wage results, sector-specific estimates provide little evidence of persistent wage effects in agriculture, construction, or utilities following wind adoption.

Solar adoption is associated with positive wage effects that emerge following adoption and persist through much of the post-adoption period. Estimated overall wage gains increase from approximately 0.35% in the first year of operation to 1.26% by the third year, remaining positive thereafter, but are not statistically significant. However, sectoral estimates indicate gains that are significant and concentrated primarily in the utilities sector, with additional improvements observed in construction wages.

Overall, the results suggest that renewable energy development contributes more strongly to wage growth than to employment growth. This pattern is consistent with economic activity

being concentrated in relatively high-paying utility and construction occupations rather than through large increases in total employment.

5.2 Robustness Checks

5.2.1 Inclusion of Covariates

Online Supplemental S3 presents event-study estimates from specifications that incorporate baseline demographic and socioeconomic controls, including population homeownership, educational attainment, poverty, age structure, and racial composition. Overall, the inclusion of these covariates produces results that are highly consistent with the baseline estimates reported in Figures 4–7. The main signs, magnitudes, and timing remain similar, indicating that the findings are not sensitive to observable baseline county characteristics.

5.2.2 Alternative Definition of Rural Counties

We define agriculturally intensive counties as those where agriculture represented at least 10 percent of county GDP in 2023. This alternative definition of rural targets counties with a stronger agricultural economic base and provides a more stringent test of whether the results are driven by the rural classification. Because the smaller sample reduces the number of treated observations, we employ the regression-adjusted estimator in place of the doubly robust estimator used in the main analysis. Results are reported in the online Supplemental S1.

The results are qualitatively consistent with the main analysis. Wind development continues to generate positive GDP effects, with gains concentrated in the utilities sector. Solar development remains associated with comparatively modest economic effects in employment and wages. Overall, the findings are not sensitive to the definition of rurality.

5.3 Sectoral Heterogeneity

While the primary analysis focuses on agriculture, construction, and utilities, renewable energy development may also affect other sectors through indirect and induced economic channels.

Appendix B reports trends and event-study estimates for transportation, public administration, real estate, manufacturing, and wholesale trade.

5.3.1 Additional GDP Effects

The sectoral GDP results reveal several additional channels through which renewable energy development affects rural economies. For wind development, the public administration also experience positive gains, with sectoral GDP increasing by approximately 2.67% [95% CI: 0.62% to 4.76%, p-value=0.010] by the fifth year after adoption. Increased public administration activity may reflect growth in local government revenues and expenditures associated with renewable energy development, including increased tax collections and public service provision.

Solar development exhibits a different pattern. Positive GDP effects are observed in the transportation sector, potentially reflecting increased demand for transportation, logistics, and equipment movement associated with solar construction and operation. While the magnitude of these effects is substantial, 15.52% [95% CI: 5.07% to 27.02%, p-value=0.003] by the fifth year, the results suggest that transportation-related activities may benefit disproportionately from utility-scale solar development.

5.3.2 Additional Employment and Wage Effects

The employment and wage results similarly indicate greater sectoral spillovers from solar development than from wind development. Solar adoption is associated with positive long-run effects in transportation employment and wages, suggesting sustained demand for transportation-

related services after projects become operational. In contrast, wind development exhibits positive but insignificant effects on employment and wages for the transportation sector.

5.4 Discussion of Economic Mechanisms

The results suggest that the economic impacts of renewable energy development in rural counties are shaped by both the characteristics of the technologies themselves and the sectors through which benefits are transmitted. Across both wind and solar development, the utilities sector consistently exhibits the largest and most persistent effects. This pattern reflects the fact that renewable facilities become part of the local electricity-generation infrastructure. In addition, utility investments may generate indirect demand for supporting services and infrastructure, contributing to spillover effects in other sectors.

The larger GDP gains associated with wind development relative to solar likely reflect differences in project scale, land requirements, and the economic linkages generated by each technology. Wind projects often involve larger geographic footprints, longer development timelines, and substantial lease payments to landowners. These factors may increase the extent to which economic benefits circulate within local economies. The broader sectoral spillovers observed for wind development, particularly in public administration, are consistent with this interpretation. Solar development, however, produces a notably larger positive effect in the transportation sector than wind, suggesting that its local economic impacts may be more concentrated in logistics, equipment movement, and related transportation activity.

The contrast between GDP effects and employment effects also highlights the capital-intensive nature of utility-scale renewable energy development. Both wind and solar projects require substantial upfront investment in equipment and infrastructure but relatively few long-

term workers once operational. As a result, increases in economic output are generally larger than increases in employment, while wage gains are concentrated within a limited number of sectors.

Finally, our results do not provide evidence of economic displacement across important agricultural measures. Agricultural GDP, employment, and wages remain largely unchanged after adoption, with modest positive effects for solar in some very large-scale specifications. This pattern suggests that although solar development may displace production on the land directly converted to solar use, these land-use changes do not appear to translate into substantial declines in agricultural economic activity at the county level.

6. Conclusion

Utility-scale wind and solar development is disproportionately located in rural communities, where siting decisions often weigh expected economic benefits against competing land uses and other local priorities. Using a staggered DiD framework, this study finds that utility-scale wind development is associated with significant increases in county GDP, driven primarily by growth in the utilities sector with additional spillovers into public administration. In contrast, solar development generates more modest economic effects that are concentrated in employment and wages rather than aggregate output. Importantly, neither wind nor solar development is associated with declines in agricultural GDP, employment, or wages, suggesting that renewable energy development does not substantially disrupt agricultural economic activity in rural counties.

The analysis extends prior ex post studies by comparing wind and solar directly, by focusing on rural counties, and by tracing effects across economic sectors within those counties.

The results also have important implications for local economic development policy. Economic benefits from renewable energy development should not be assumed to be uniform across technologies or communities. Wind development appears more likely to generate measurable gains in local economic output, while the benefits of solar development are generally smaller but more clearly create spillover effects into the construction and transportation sectors. Consequently, local governments should be cautious when relying on generic economic impact projections during siting and permitting decisions.

The agricultural results are particularly important for rural siting debates: within the county-level outcomes examined here, neither technology shows evidence of reducing agricultural GDP, employment, or wages.

A few limitations should be considered when interpreting these findings. First, the analysis focuses on county-level outcomes and therefore cannot fully identify how economic benefits and costs are distributed among households, landowners, workers, and local governments within a county. Second, we do not have information on what type of land a project was built on; for instance, whether it had been in agricultural production or unused, or whether it was high or low quality agricultural land. Differences in previous land use and quality may affect our results. Third, while the estimates capture net changes in local economic activity, they do not directly measure several potentially important dimensions of renewable energy development that have been examined elsewhere in the literature, including impacts on land use and property values (Abashidze and Taylor 2023), the opportunity costs of alternative land uses, or the costs associated with transmission and related infrastructure investments. As with all difference-in-difference designs, our estimates rely on a conditional parallel trends assumption that cannot be directly verified. Although event-study estimates and formal pre-trend tests provide little

evidence of differential pre-treatment trends, unobserved time-varying factors correlated with both renewable energy development and local economic outcomes could still bias estimates. Finally, the results reflect observed outcomes for projects developed during the study period and may not fully generalize to future renewable energy deployment as technologies, market conditions, and policy environments continue to evolve.

Future research should examine the persistence of these effects as projects age, the distribution of benefits across workers, landowners, and local governments, and interactions with land markets, transmission infrastructure, and alternative land uses. Additional ex post studies of utility-scale solar development are especially needed given the technology's rapid expansion and the comparatively limited evidence on its realized local impacts.

Overall, the results indicate that renewable energy development can generate measurable economic benefits for rural communities, but the magnitude and form of those benefits vary across technologies and local economic contexts. Wind development is associated with broader gains in economic output, while solar development produces modest and sector-specific effects. As renewable energy infrastructure continues to expand across rural landscapes, understanding these differences will be important for designing policies and siting decisions that balance energy production, agricultural land use, and rural economic development objectives.

References

- Abashidze, Nino, and Laura O. Taylor. 2023. "Utility-Scale Solar Farms and Agricultural Land Values." *Land Economics* 99 (3): 327–342.
<https://doi.org/10.3368/le.99.3.102920-0165R>.
- Bae, Jinwon, and Sandy Dall'erba. 2016. "The economic impact of a new solar power plant in Arizona: Comparing the input-output results generated by JEDI vs. IMPLAN." *Regional Science Policy & Practice* 8 (1-2): 61–74.
- Bessette, Douglas L., and Sarah B. Mills. 2021. "Farmers vs. Iakers: Agriculture, amenity, and community in predicting opposition to United States wind energy development." *Energy Research & Social Science* 72.
<https://doi.org/10.1016/j.erss.2020.101873>.
- Borchers, Allison M., Irene Xiarchos, and Jayson Beckman. 2014. "Determinants of wind and solar energy system adoption by U.S. farms: A multilevel modeling approach." *Energy Policy* 69: 106–115.
<https://doi.org/10.1016/j.enpol.2014.02.014>.
- Brown, Jason P., John Pender, Ryan Wiser, Eric Lantz, and Ben Hoen. 2012. "Ex post analysis of economic impacts from wind power development in U.S. counties." *Energy Economics* 34 (6): 1743–1754.
<https://doi.org/10.1016/j.eneco.2012.07.010>.
- Brunner, Eric J., and David J. Schwegman. 2022. "Commercial wind energy installations and local economic development: Evidence from U.S. counties." *Energy Policy* 165. <https://doi.org/10.1016/j.enpol.2022.112993>.
- Callaway, Brantly, and Pedro HC Sant'Anna. 2021. "Difference-in-differences with multiple time periods." *Journal of econometrics* 225 (2): 200–230.
- Carley, Sanya, David M. Konisky, Zoya Atiq, and Nick Land. 2020. "Energy infrastructure, NIMBYism, and public opinion: a systematic literature review of three decades of empirical survey literature." *Environmental Research Letters* 15 (9). <https://doi.org/10.1088/1748-9326/ab875d>.
- De Silva, Dakshina G, Robert P McComb, and Anita R Schiller. 2016. "What Blows in with the Wind?" *Southern Economic Journal* 82 (3): 826–858.
- Dohlman, Erik, Karen Maguire, Wilma V Davis, Megan Husby, John Bovay, Catharine Weber, and Yoonjung Lee. 2024. *Trends, insights, and future prospects for production in controlled environment agriculture and agrivoltaics systems*.
- Firestone, Jeremy, Ben Hoen, Joseph Rand, Debi Elliott, Gundula Hübner, and Johannes Pohl. 2017. "Reconsidering barriers to wind power projects: community engagement, developer transparency and place." *Journal of Environmental Policy & Planning* 20 (3): 370–386.
<https://doi.org/10.1080/1523908x.2017.1418656>.
- Gaur, Vasundhara, and Corey Lang. 2023. "House of the rising sun: The effect of utility-scale solar arrays on housing prices." *Energy Economics* 122: 106699.
- Gilbert, Ben, Ben Hoen, and Hannah Gagarin. 2024. "Distributional Equity in the Employment and Wage Impacts of Energy Transitions." *Journal of the Association of Environmental and Resource Economists* 11 (S1): S261–S298.
<https://doi.org/10.1086/732186>.

- Giordono, Leanne S, Hilary S Boudet, Anna Karmazina, Casey L Taylor, and Brent S Steel. 2018. "Opposition "overblown"? Community response to wind energy siting in the Western United States." *Energy Research & Social Science* 43: 119–131.
- Haggerty, Julia H, Mark Haggerty, and Ray Rasker. 2014. "Uneven local benefits of renewable energy in the US west: property tax policy effects." *Western Economics Forum*.
- Hao, Simeng, and Gilbert Michaud. 2024. "Assessing property value impacts near utility-scale solar in the Midwestern United States." *Solar Compass* 12. <https://doi.org/10.1016/j.solcom.2024.100090>.
- Hicks, Michael J, Dagney Faulk, Sarah Orzechowski, and Seth Payton. May 20, 2026. *Towards the Economic Effects of Renewable Energy Restrictions*. Center for Business and Economic Research, Ball State University (Muncie, IN).
- Jenniches, Simon. 2018. "Assessing the regional economic impacts of renewable energy sources – A literature review." *Renewable and Sustainable Energy Reviews* 93: 35–51. <https://doi.org/10.1016/j.rser.2018.05.008>.
- Kaffine, Daniel T. 2019. "Microclimate effects of wind farms on local crop yields." *Journal of Environmental Economics and Management* 96: 159–173.
- Lerner, Michael. 2021. "Local power: Understanding the adoption and design of county wind energy regulation." *Review of Policy Research* 39 (2): 120–142. <https://doi.org/10.1111/ropr.12447>.
- Li, Zhiyun, Wendong Zhang, and Ariel Ortiz-Bobea. 2026. "Impacts of Large-Scale Solar-Enabling Legislation on Farmland Values." *Land Economics* 102 (2): 163–181.
- Maguire, Karen, Sophia J Tanner, Justin B Winikoff, and Ryan Williams. 2024. *Utility-Scale Solar and Wind Development in Rural Areas: Land Cover Change (2009–20)*.
- Maguire, Karen, Sophia Tanner, and Justin Winikoff, 2024, "Agricultural Land Near Solar and Wind Projects usually Remained in Agriculture After Development," <https://www.ers.usda.gov/amber-waves/2024/september/agricultural-land-near-solar-and-wind-projects-usually-remained-in-agriculture-after-development>.
- O'Shaughnessy, Eric, Robi Nilson, and Joseph Rand. 2025. "Go slow to go fast? A review of the impacts of permitting on large-scale solar project development." *Energy Research & Social Science* 127: 104318.
- O'Shaughnessy, Eric, Ryan Wiser, Ben Hoen, Joseph Rand, and Salma Elmallah. 2022. "Drivers and energy justice implications of renewable energy project siting in the United States." *Journal of Environmental Policy & Planning* 25 (3): 258–272. <https://doi.org/10.1080/1523908x.2022.2099365>.
- Owusu-Obeng, Papa Yaw, Mai Shi, Max Vanatta, and Michael T Craig. 2026. "Beyond prime farmland: solar siting tradeoffs for cost-effective decarbonization." *Environmental Research: Energy* 3 (1): 015014.
- Roddiss, Philippa, Stephen Carver, Martin Dallimer, Paul Norman, and Guy Ziv. 2018. "The role of community acceptance in planning outcomes for onshore wind and solar farms: An energy justice analysis." *Applied Energy* 226: 353–364. <https://doi.org/10.1016/j.apenergy.2018.05.087>.
- Schumacher, Kim, and Zhuoxiang Yang. 2018. "The determinants of wind energy growth in the United States: Drivers and barriers to state-level development."

- Renewable and Sustainable Energy Reviews* 97: 1–13.
<https://doi.org/10.1016/j.rser.2018.08.017>.
- Shoeib, Eman Ahmed Hamed, Henry C. Renski, and Elisabeth Hamin Infield. 2022. "Who benefits from Renewable Electricity? The differential effect of wind power development on rural counties in the United States." *Energy Research & Social Science* 85. <https://doi.org/10.1016/j.erss.2021.102398>.
- Slattery, Michael C., Becky L. Johnson, Jeffrey A. Swofford, and Martin J. Pasqualetti. 2012. "The predominance of economic development in the support for large-scale wind farms in the U.S. Great Plains." *Renewable and Sustainable Energy Reviews* 16 (6): 3690–3701. <https://doi.org/10.1016/j.rser.2012.03.016>.
- Tanner, Sophia, Wesley Burnett, Karen Maguire, and Justin Winikoff. 2024. "Blown Away: The Influence of Wind Farms on Agricultural Land Values." 2024 Agricultural and Applied Economics Association Annual Meeting, New Orleans, LA.
- Winikoff, Justin B., and Dominic P. Parker. 2023. "Farm size, spatial externalities, and wind energy development." *American Journal of Agricultural Economics* 106 (4): 1518–1543. <https://doi.org/10.1111/ajae.12438>.
- Wiser, Ryan, Mark Bolinger, Ben Hoen, Dev Millstein, Joseph Rand, Galen Barbose, Naïm Darghouth, Will Gorman, Seongeun Jeong, and Eric O'Shaughnessy. 2023. "Land-based wind market report: 2023 edition."

Table 1. Baseline Characteristics by Adoption Status

	Wind			Solar		
	Non-adopters	Adopters	P-value	Non-adopters	Adopters	P-value
N	1,637 (85.0%)	289 (15.0%)		1,421 (73.7%)	508 (26.3%)	
Population	23,338 (20,444)	19,486 (21,012)	0.003	18,951 (17,518)	33,354 (24,393)	<0.001
Homeownership Rate (%)	75.20 (6.06)	74.25 (5.79)	0.014	75.40 (6.21)	74.13 (5.41)	<0.001
Population Age 65+ (%)	15.88 (3.79)	17.20 (4.16)	<0.001	16.47 (4.01)	14.99 (3.25)	<0.001
Bachelor's Degree or Higher (%)	14.12 (5.87)	15.38 (4.61)	<0.001	14.15 (5.64)	14.75 (5.88)	0.042
Poverty Rate (%)	15.91 (6.87)	13.84 (5.77)	<0.001	15.91 (6.93)	14.72 (6.16)	<0.001
Non-White Population (%)	17.30 (19.28)	15.57 (19.58)	0.163	15.39 (18.49)	21.61 (20.81)	<0.001

Entries report means with standard deviations in parentheses. Baseline characteristics are measured using data from the 2000 Decennial Census. Differences between adopters and non-adopters are assessed using two-sample t-tests; reported p-values correspond to tests of equality in group means.

Table 2. Joint Tests of Pre-Treatment Event-Time Coefficients

Outcome	Wind	Wind with Covariates	Solar	Solar with Covariates
GDP				
Overall	2.850	1.611	2.746	1.685
Agriculture	5.454	6.819	3.589	4.351
Construction	6.839	4.034	2.408	1.559
Utilities	2.398	5.102	8.908	9.815*
Employment				
Overall	3.613	2.998	1.530	1.441
Agriculture	1.847	5.108	6.414	5.286
Construction	2.763	7.549	3.057	2.515
Utilities	4.821	9.690*	3.249	2.490
Wages				
Overall	6.927	3.506	2.034	1.273
Agriculture	1.480	5.953	6.466	6.594
Construction	3.318	7.513	3.842	2.803
Utilities	4.554	6.948	3.571	3.640

Notes: Entries report χ^2 statistics from joint tests that the pre-treatment event-time coefficients ($t = -5$ through $t = -1$) are jointly equal to zero. *, **, and *** denote rejection of the null hypothesis at the 10%, 5%, and 1% significance levels, respectively.

Appendix A. Utility-Scale Solar Defined as 5MW and 20MW

Figure A1. Effect of Renewable Adoption

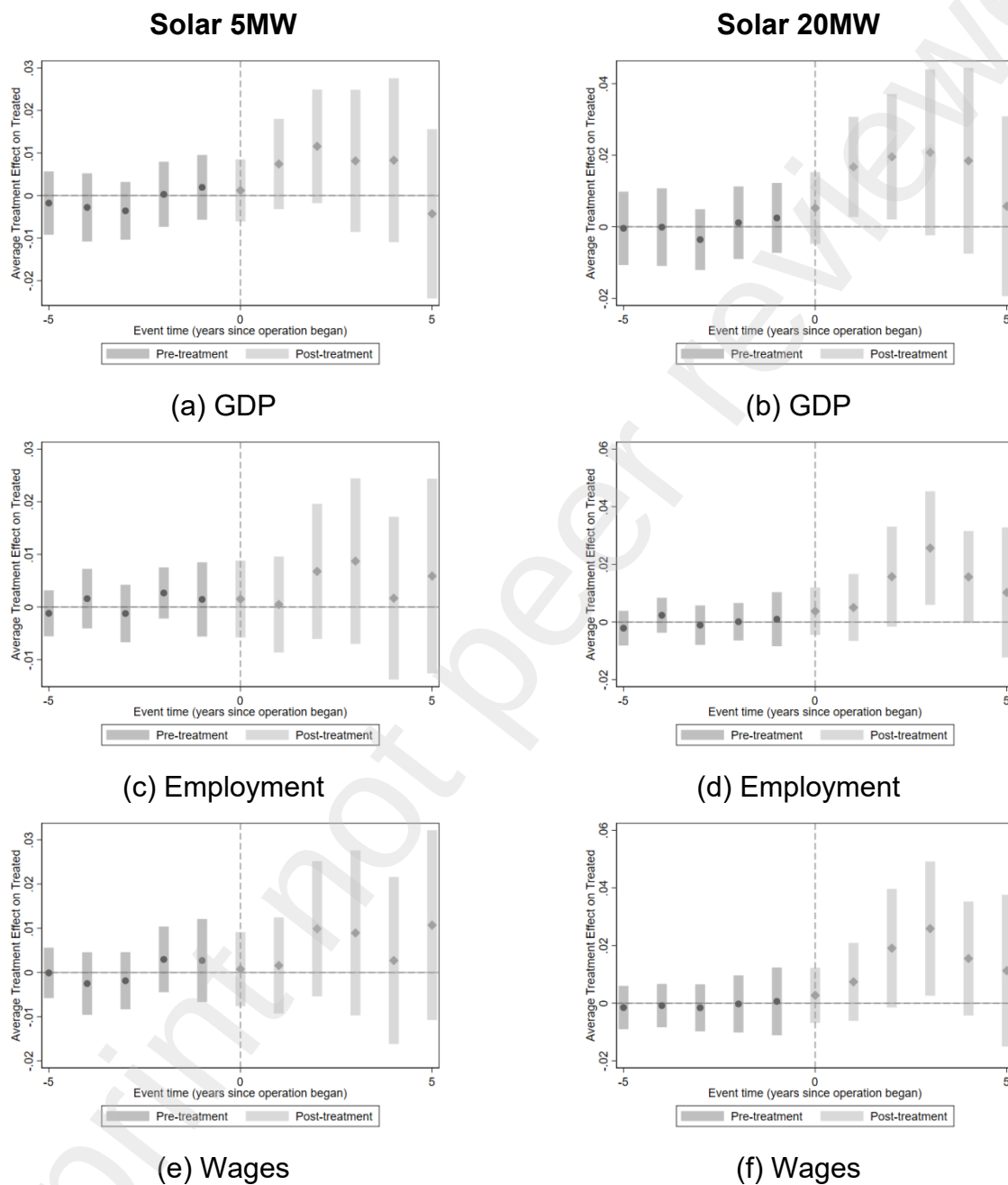
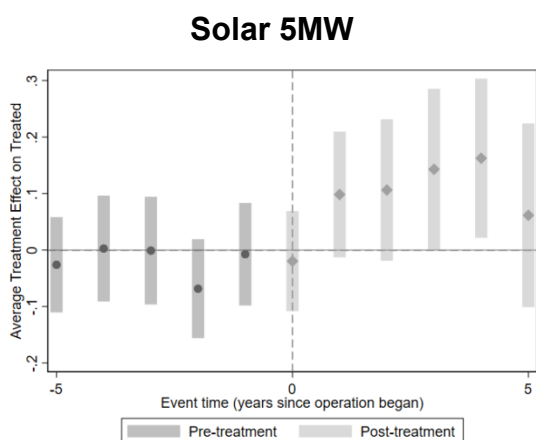
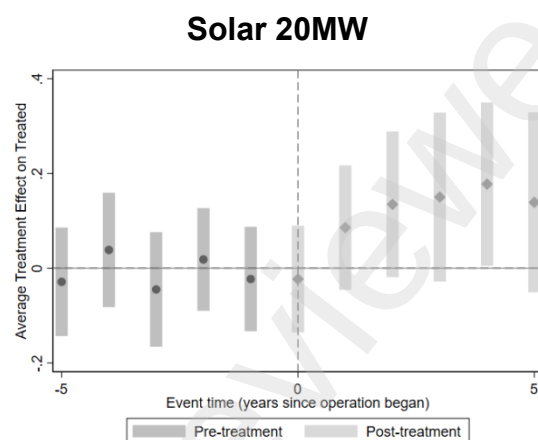


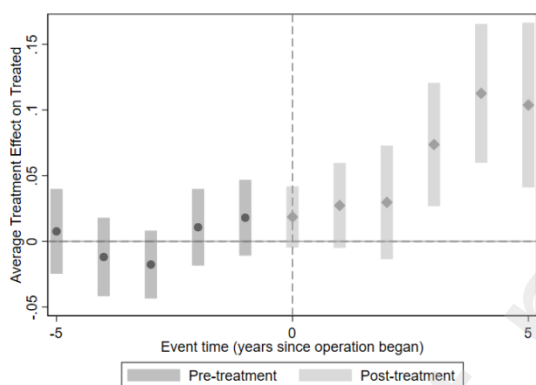
Figure A2. Renewable Adoption's Effect on GDP by Sector



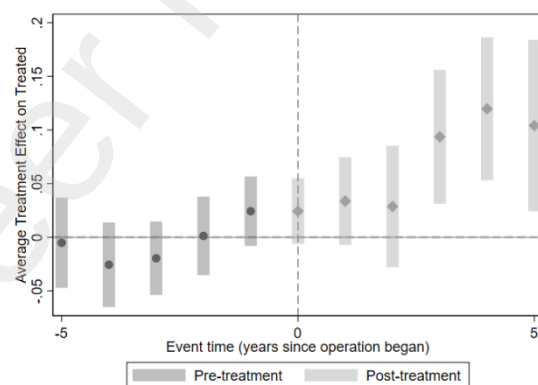
(a) Agriculture



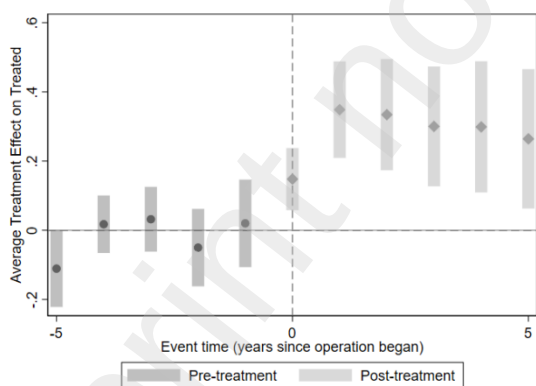
(b) Agriculture



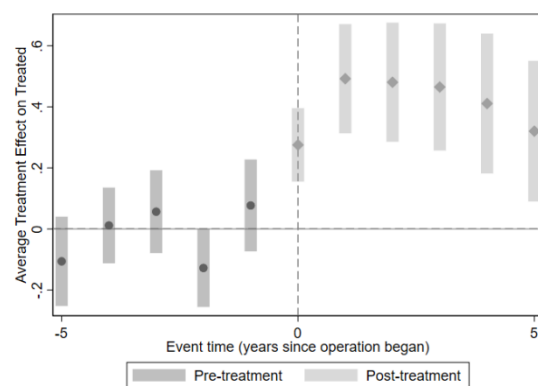
(c) Construction



(d) Construction



(e) Utilities



(f) Utilities

Figure A3. Renewable Adoption's Effect on Employment by Sector

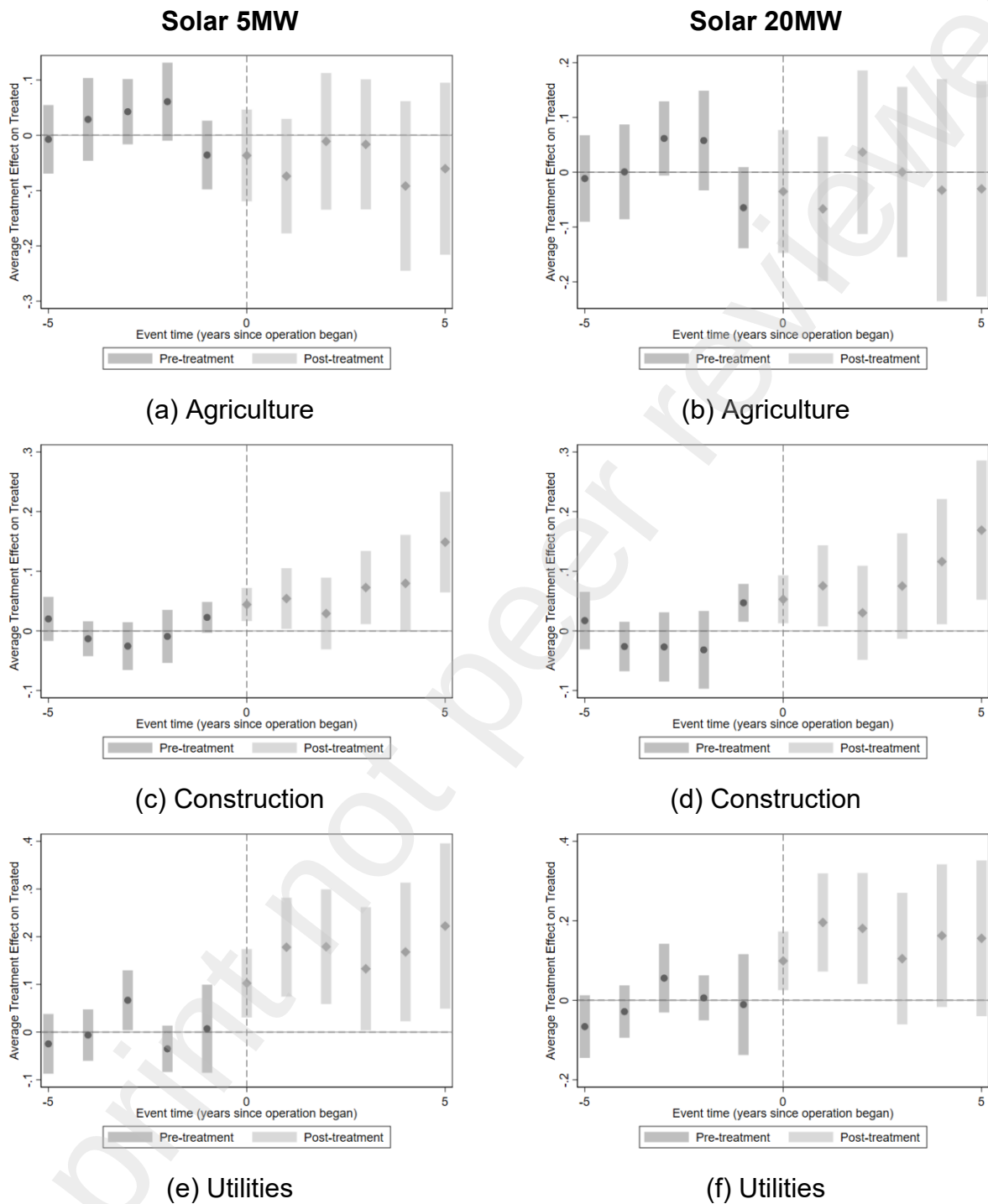


Figure A4. Renewable Adoption's Effect on Wages by Sector

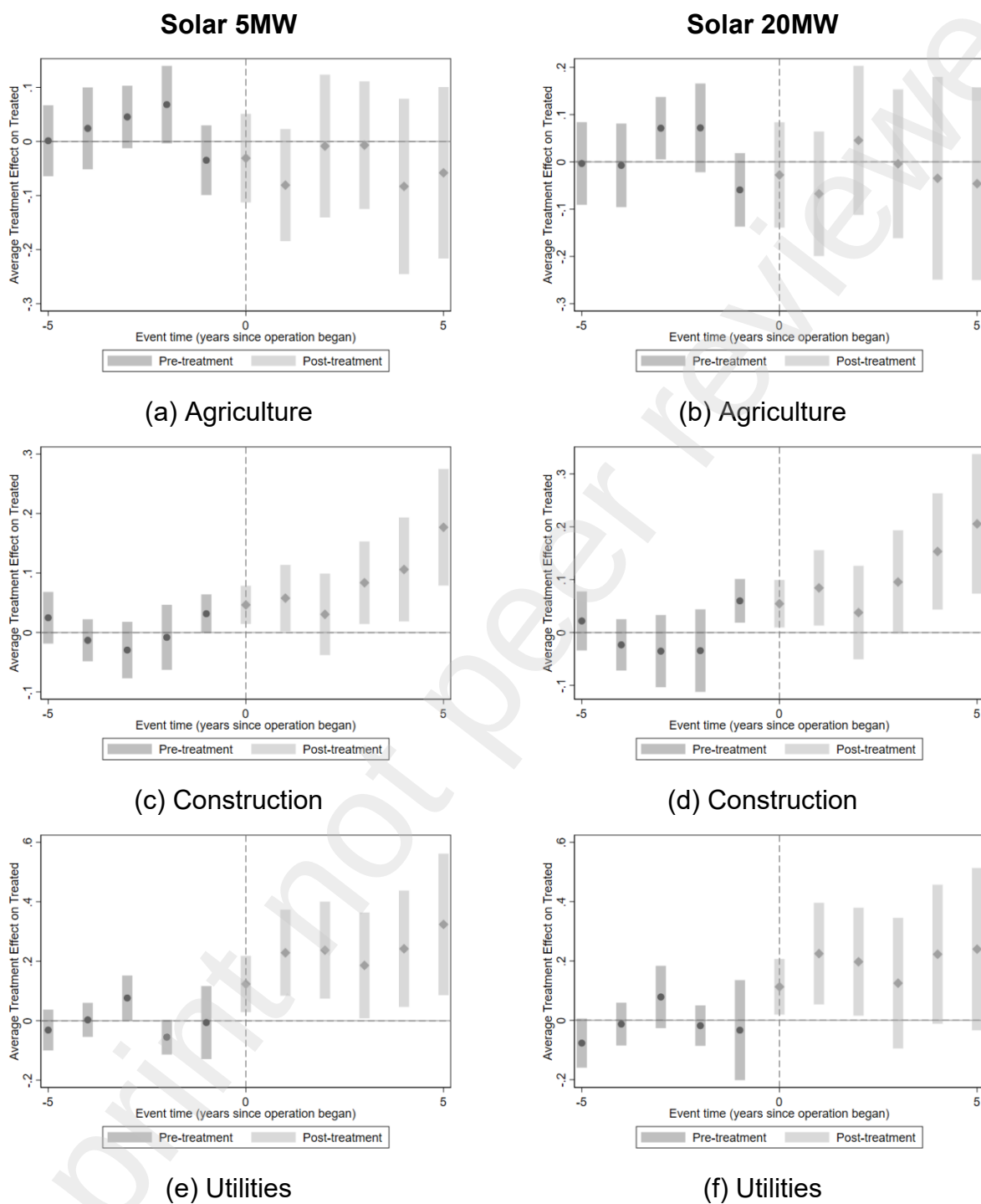


Figure A5. Renewable Adoption's Effect on GDP by Sector with Covariates

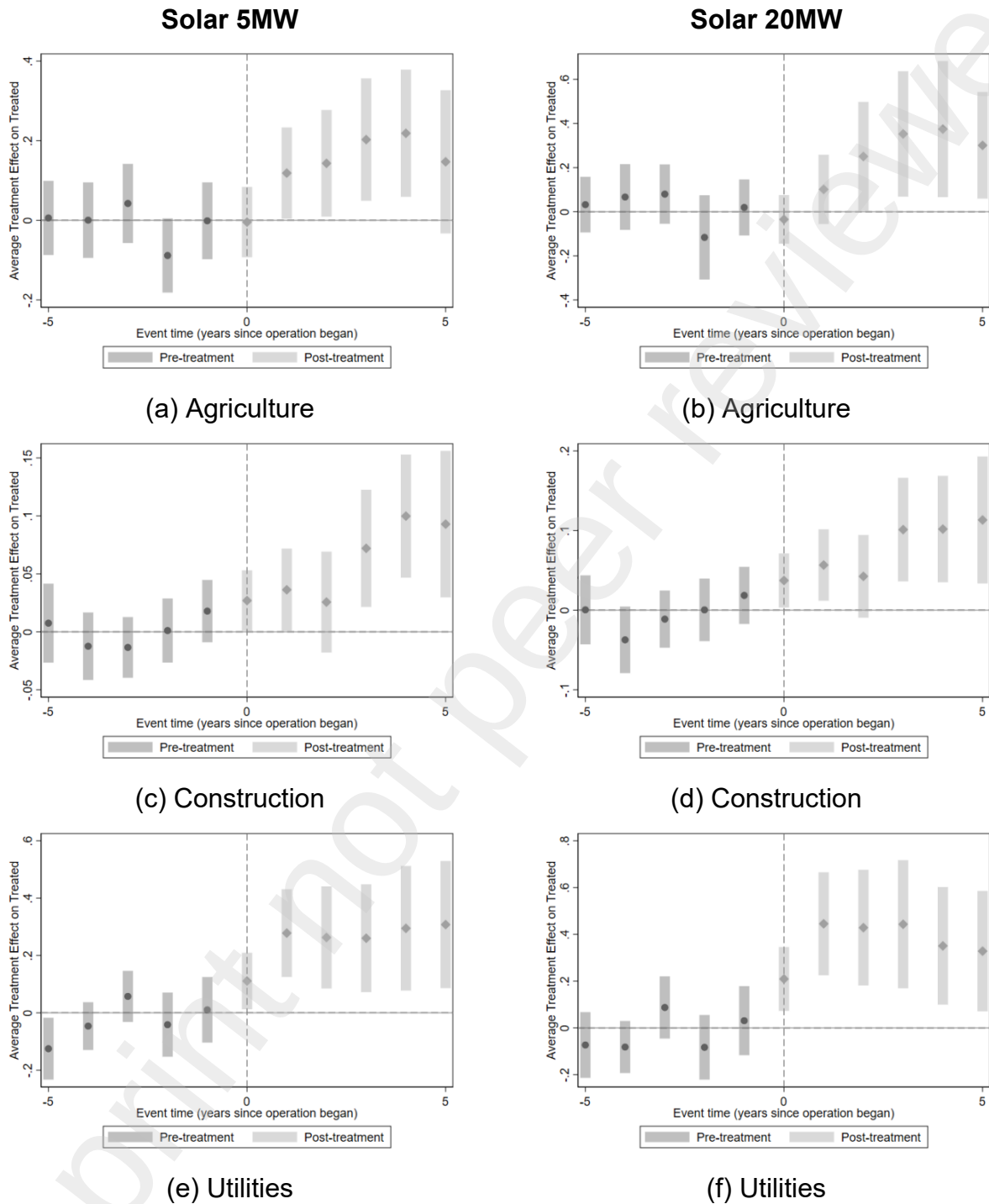


Figure A6. Renewable Adoption's Effect on Employment by Sector with Covariates

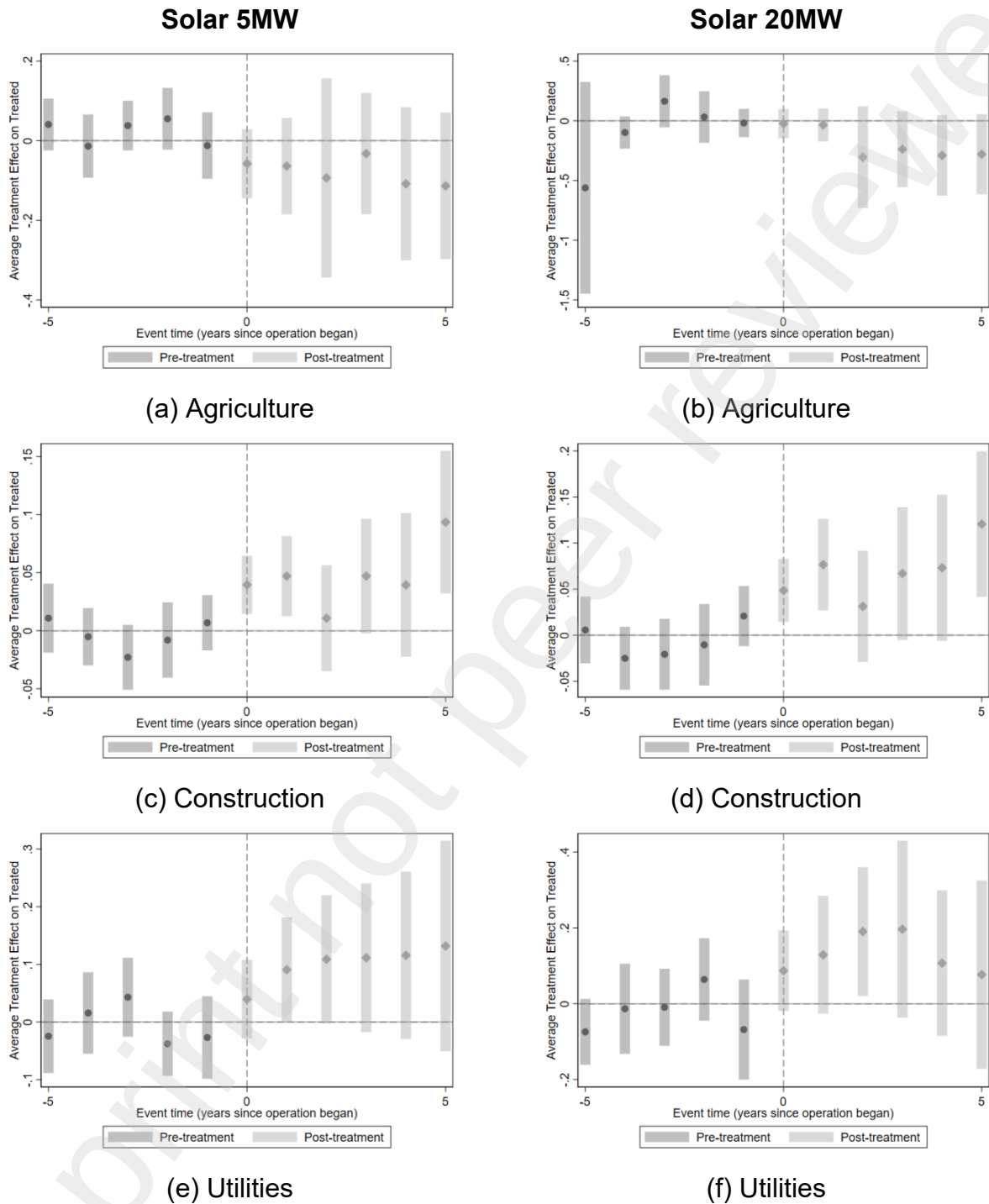
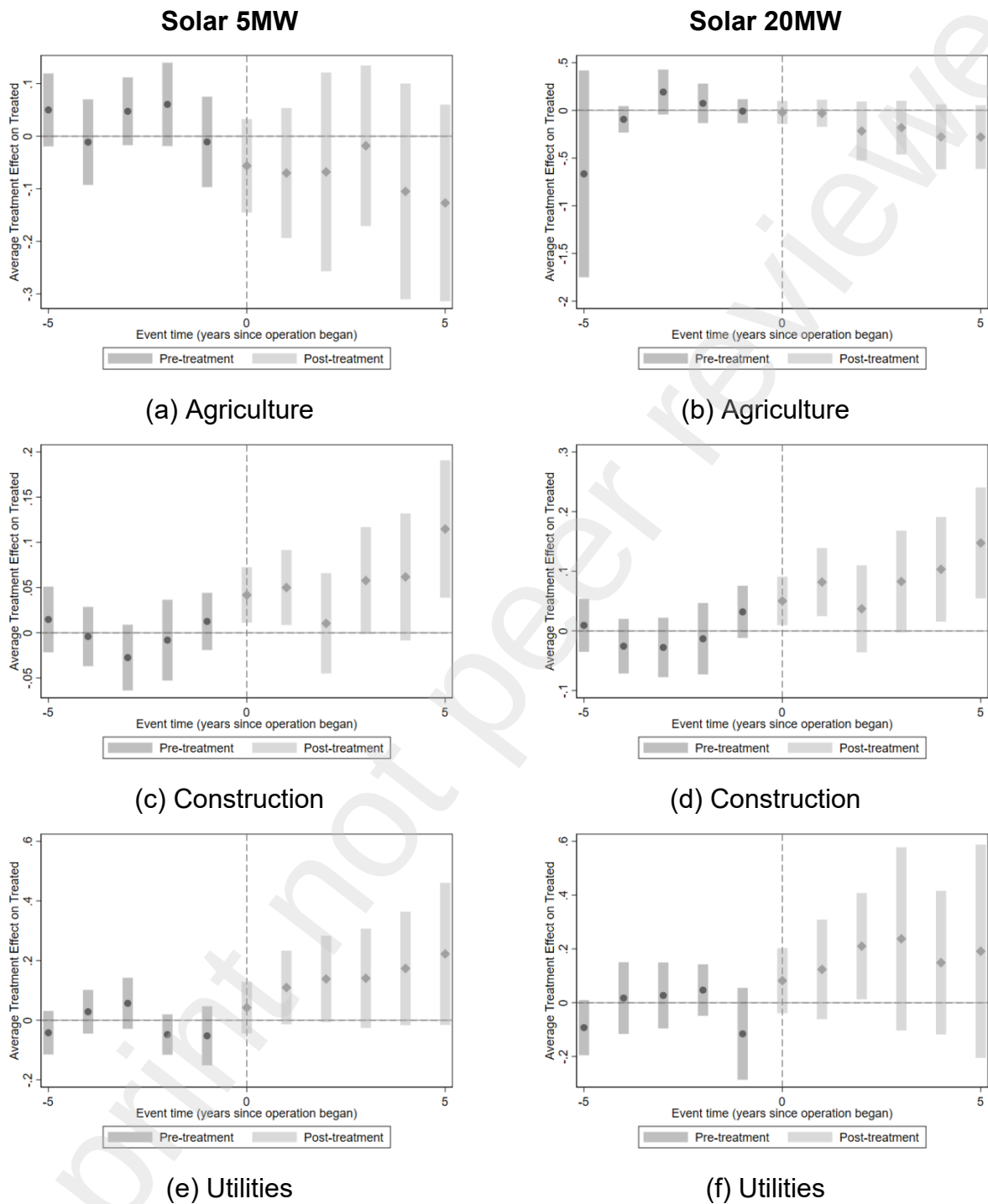
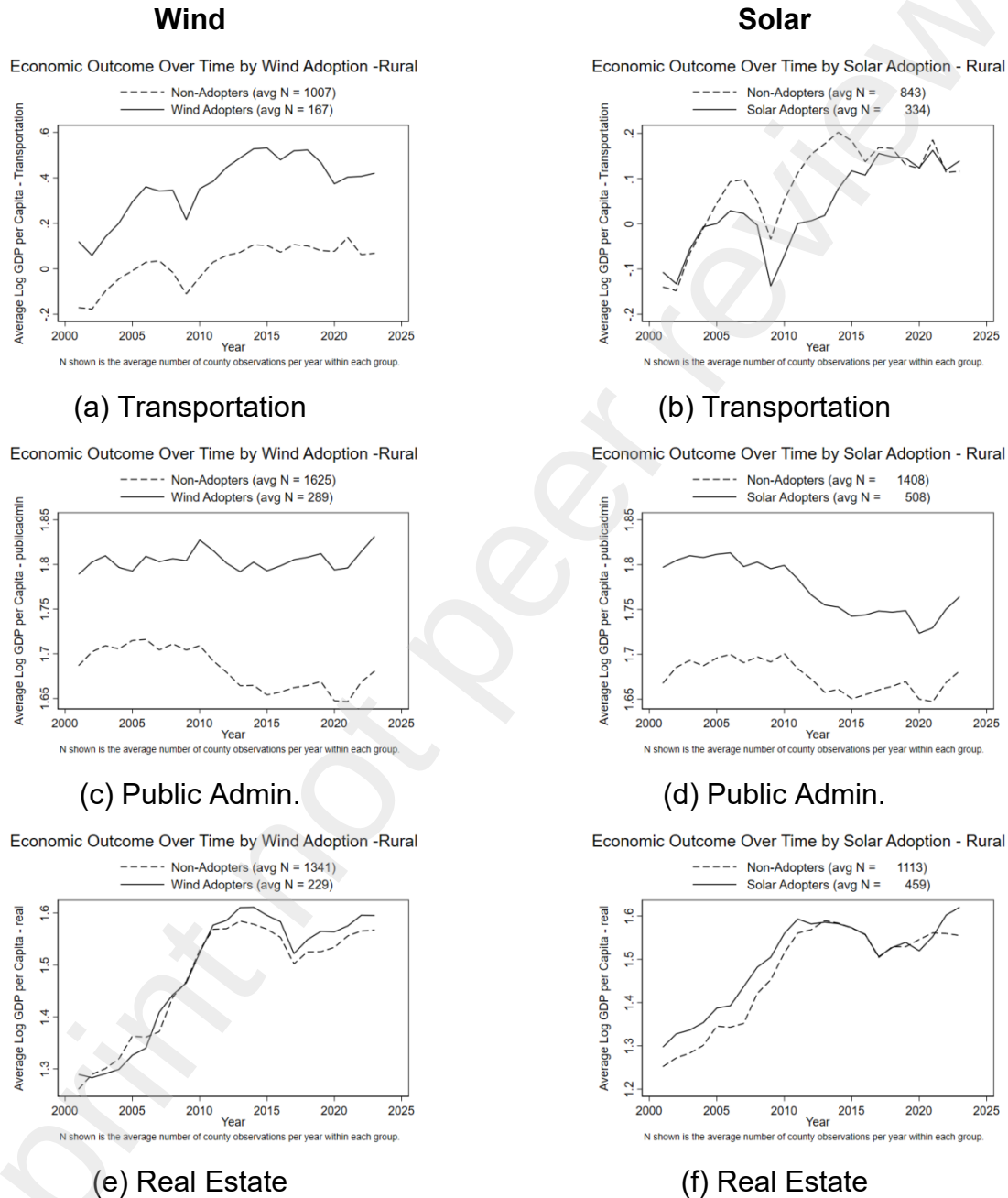


Figure A7. Renewable Adoption's Effect on Wages by Sector with Covariates

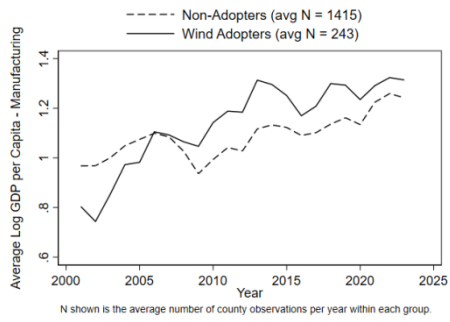


Appendix B. Results for Sectors Transportation, Public Administration, Real Estate, Manufacturing, Wholesale Trade

Figure B1. Trends in GDP by Technology Adoption for Rural Counties

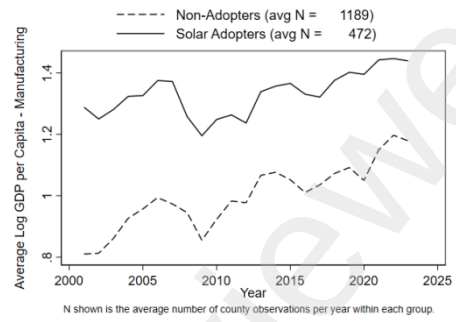


Economic Outcome Over Time by Wind Adoption -Rural



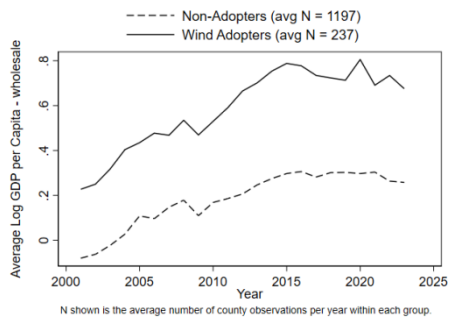
(g) Manufacturing

Economic Outcome Over Time by Solar Adoption - Rural



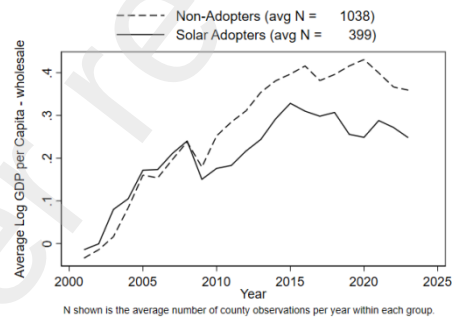
(h) Manufacturing

Economic Outcome Over Time by Wind Adoption -Rural



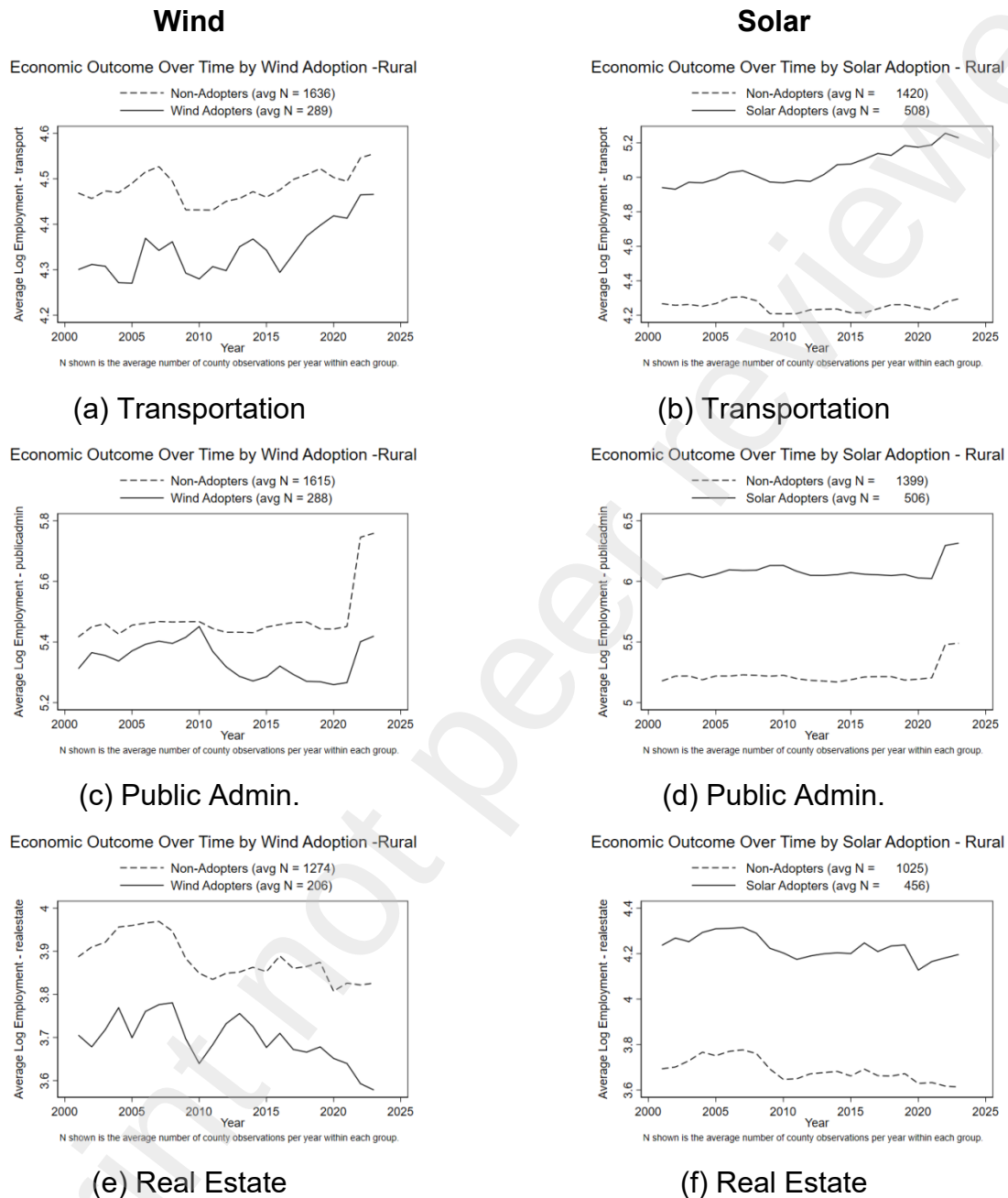
(i) Wholesale

Economic Outcome Over Time by Solar Adoption - Rural

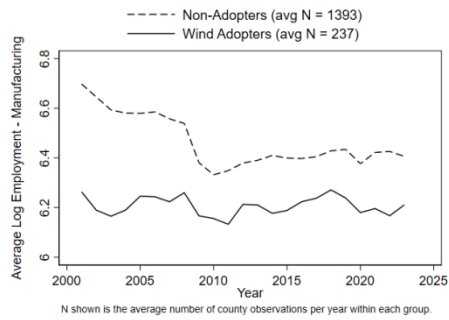


(j) Wholesale

Figure B2. Trends in Employment by Technology Adoption for Rural Counties

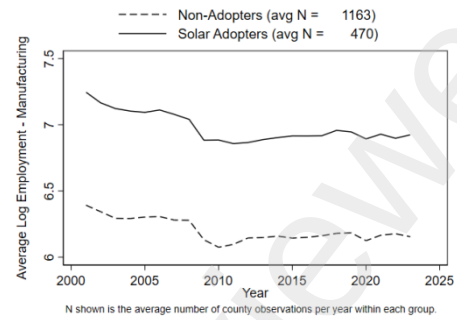


Economic Outcome Over Time by Wind Adoption -Rural



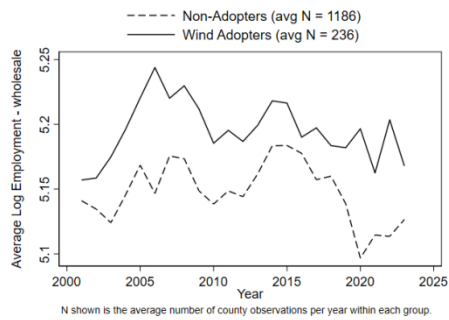
(g) Manufacturing

Economic Outcome Over Time by Solar Adoption - Rural



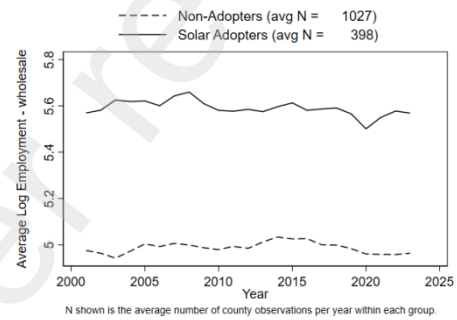
(h) Manufacturing

Economic Outcome Over Time by Wind Adoption -Rural



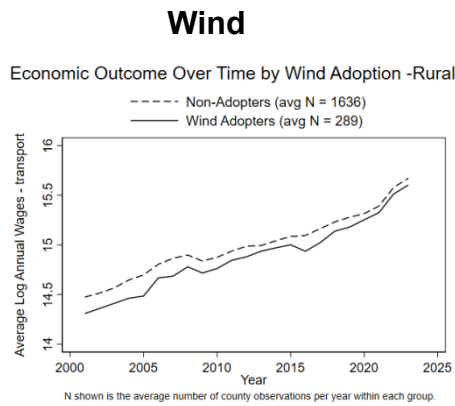
(i) Wholesale

Economic Outcome Over Time by Solar Adoption - Rural

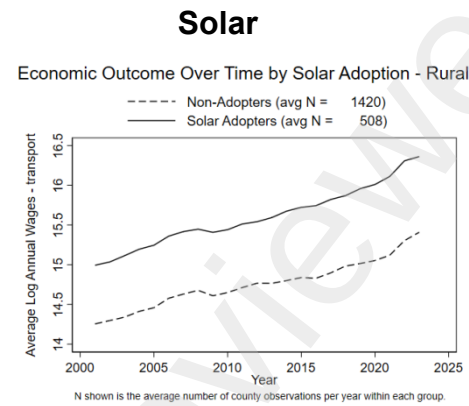


(j) Wholesale

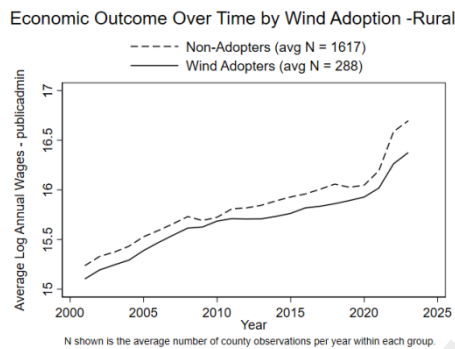
Figure B3. Trends in Wages by Technology Adoption for Rural Counties



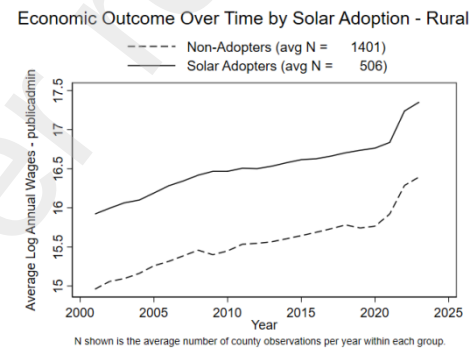
(a) Transportation



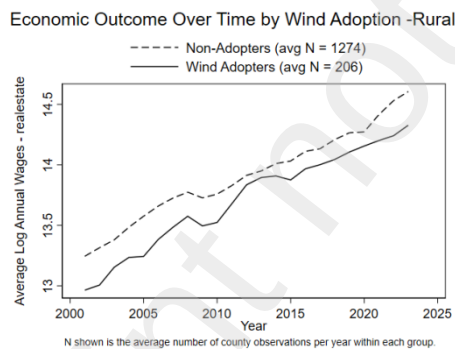
(b) Transportation



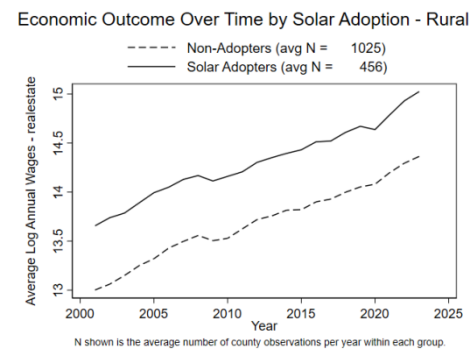
(c) Public Admin.



(d) Public Admin.

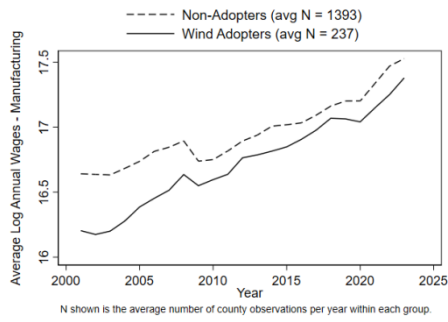


(e) Real Estate



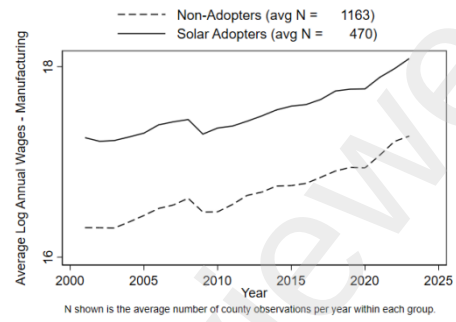
(f) Real Estate

Economic Outcome Over Time by Wind Adoption -Rural



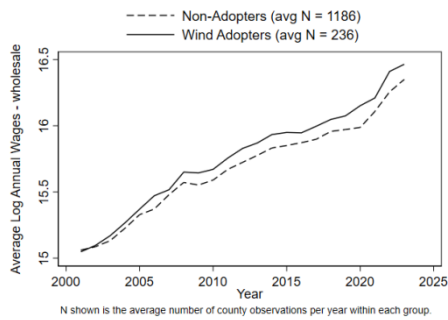
(g) Manufacturing

Economic Outcome Over Time by Solar Adoption - Rural



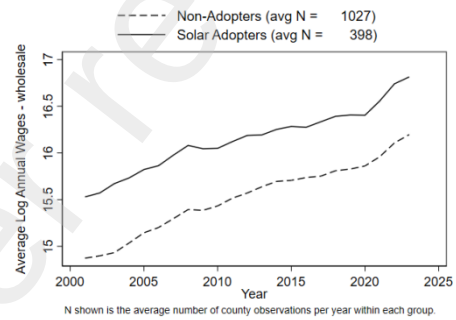
(h) Manufacturing

Economic Outcome Over Time by Wind Adoption -Rural



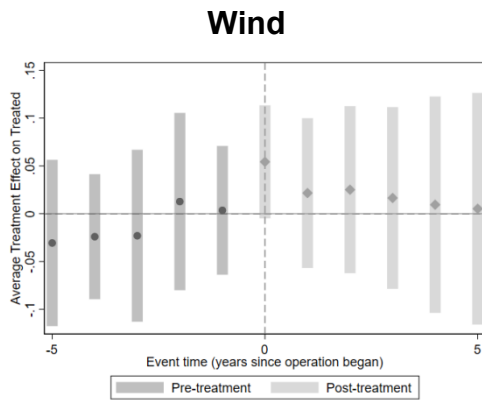
(i) Wholesale

Economic Outcome Over Time by Solar Adoption - Rural

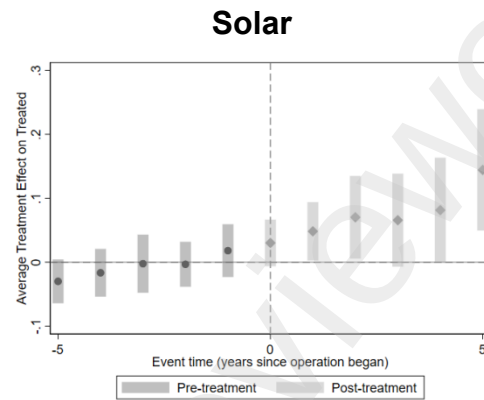


(j) Wholesale

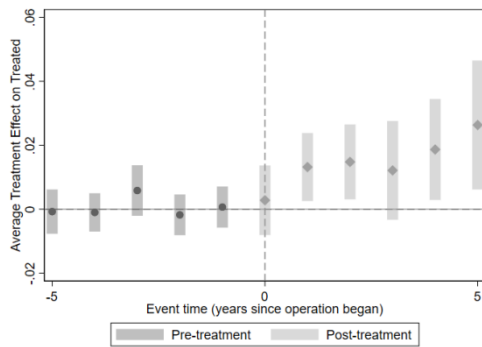
Figure B4. Effect in GDP from Technology Adoption for Rural Counties



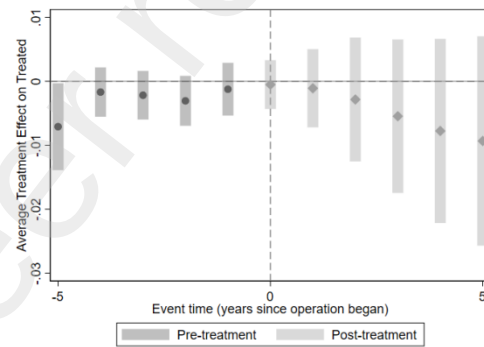
(a) Transportation



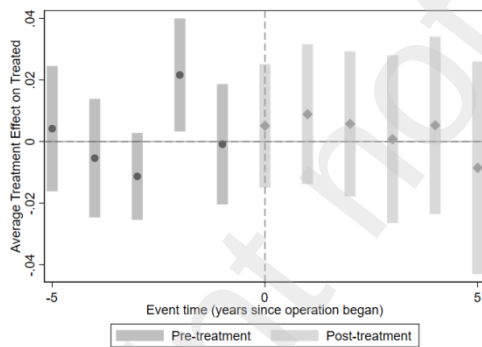
(b) Transportation



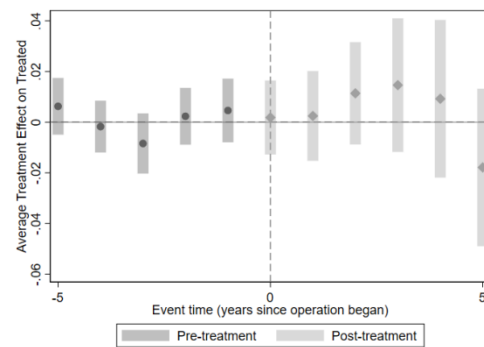
(c) Public Admin.



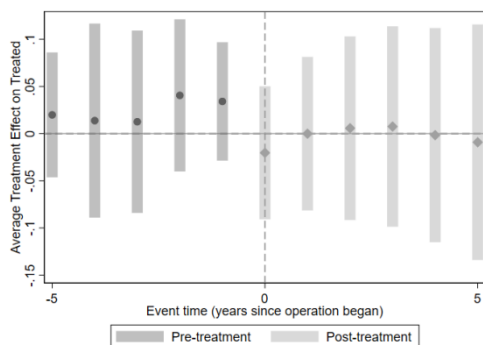
(d) Public Admin.



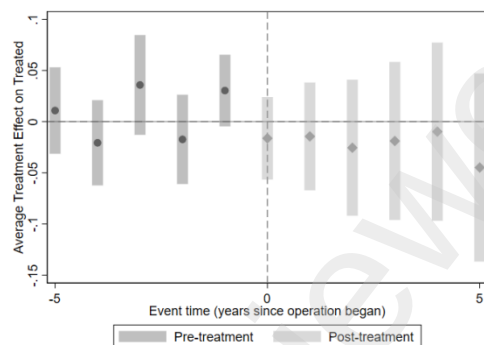
(e) Real Estate



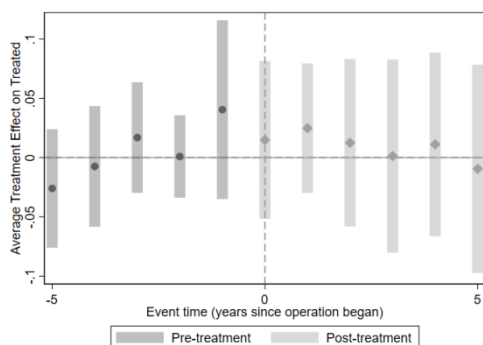
(f) Real Estate



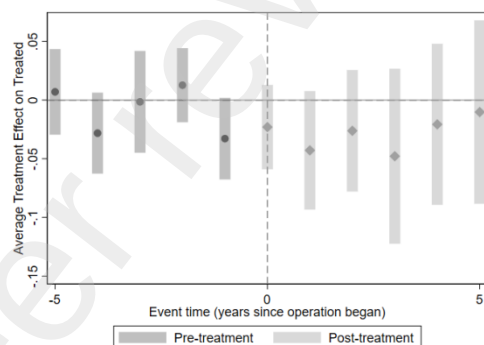
(g) Manufacturing



(h) Manufacturing

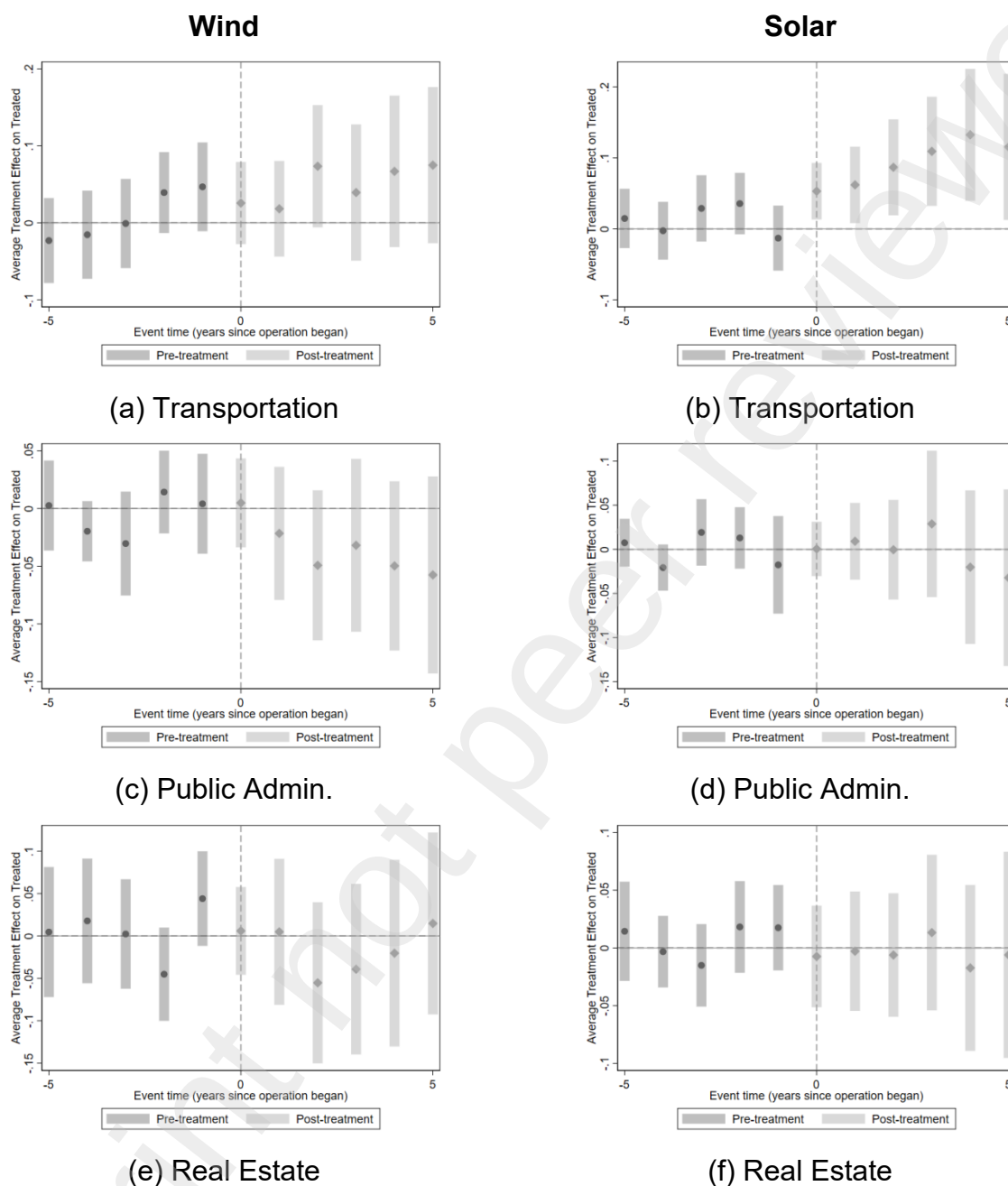


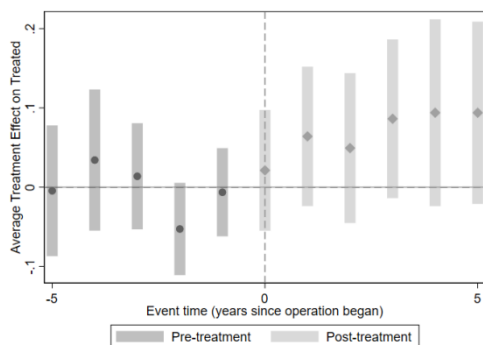
(i) Wholesale



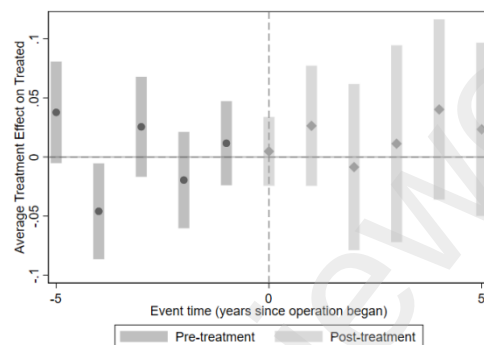
(j) Wholesale

Figure B5. Effects in Employment from Technology Adoption for Rural Counties

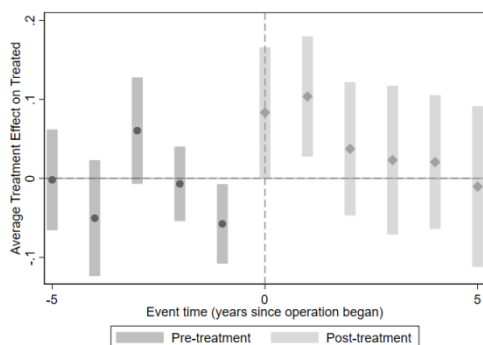




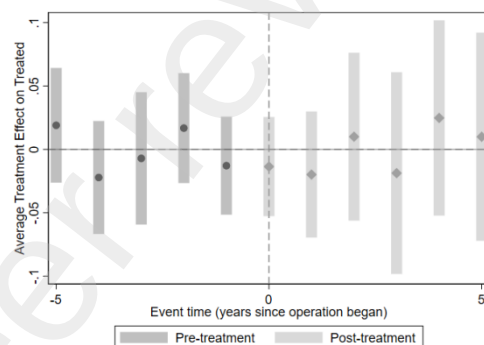
(g) Manufacturing



(h) Manufacturing

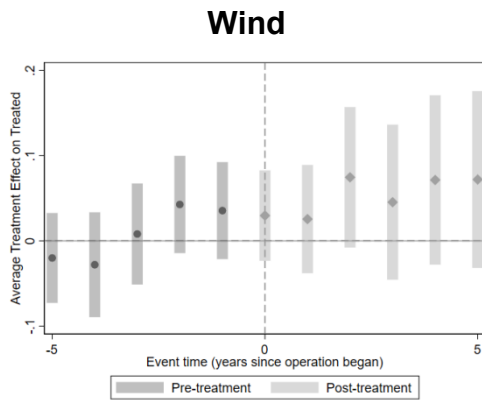


(i) Wholesale

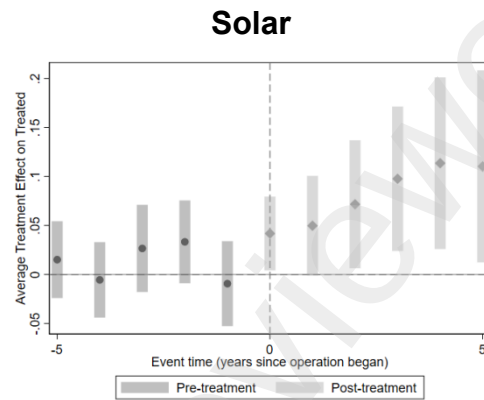


(j) Wholesale

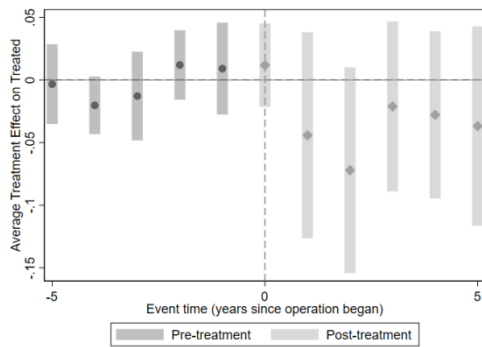
Figure B6. Effects in Wages from Technology Adoption for Rural Counties



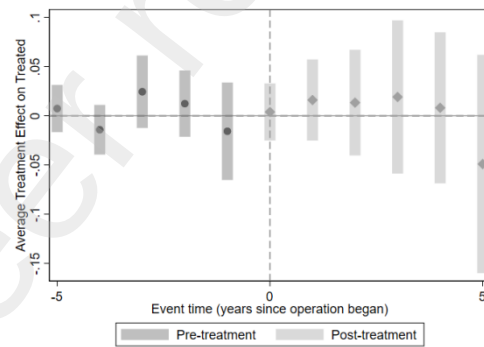
(a) Transportation



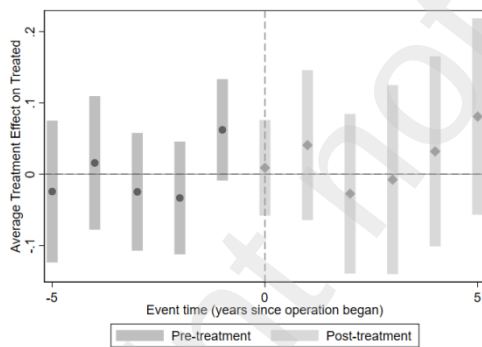
(b) Transportation



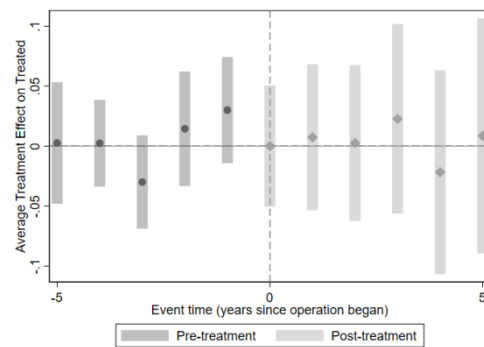
(c) Public Admin.



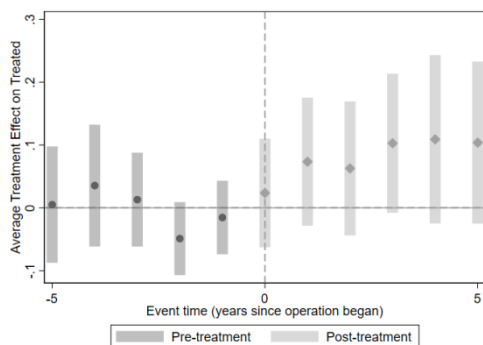
(d) Public Admin.



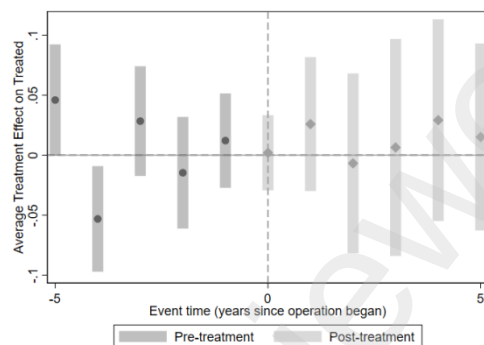
(e) Real Estate



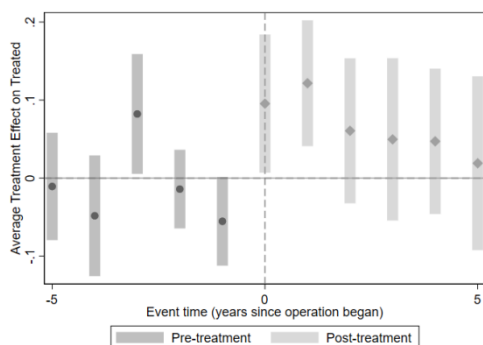
(f) Real Estate



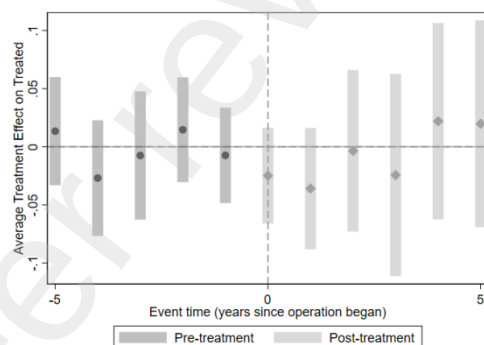
(g) Manufacturing



(h) Manufacturing

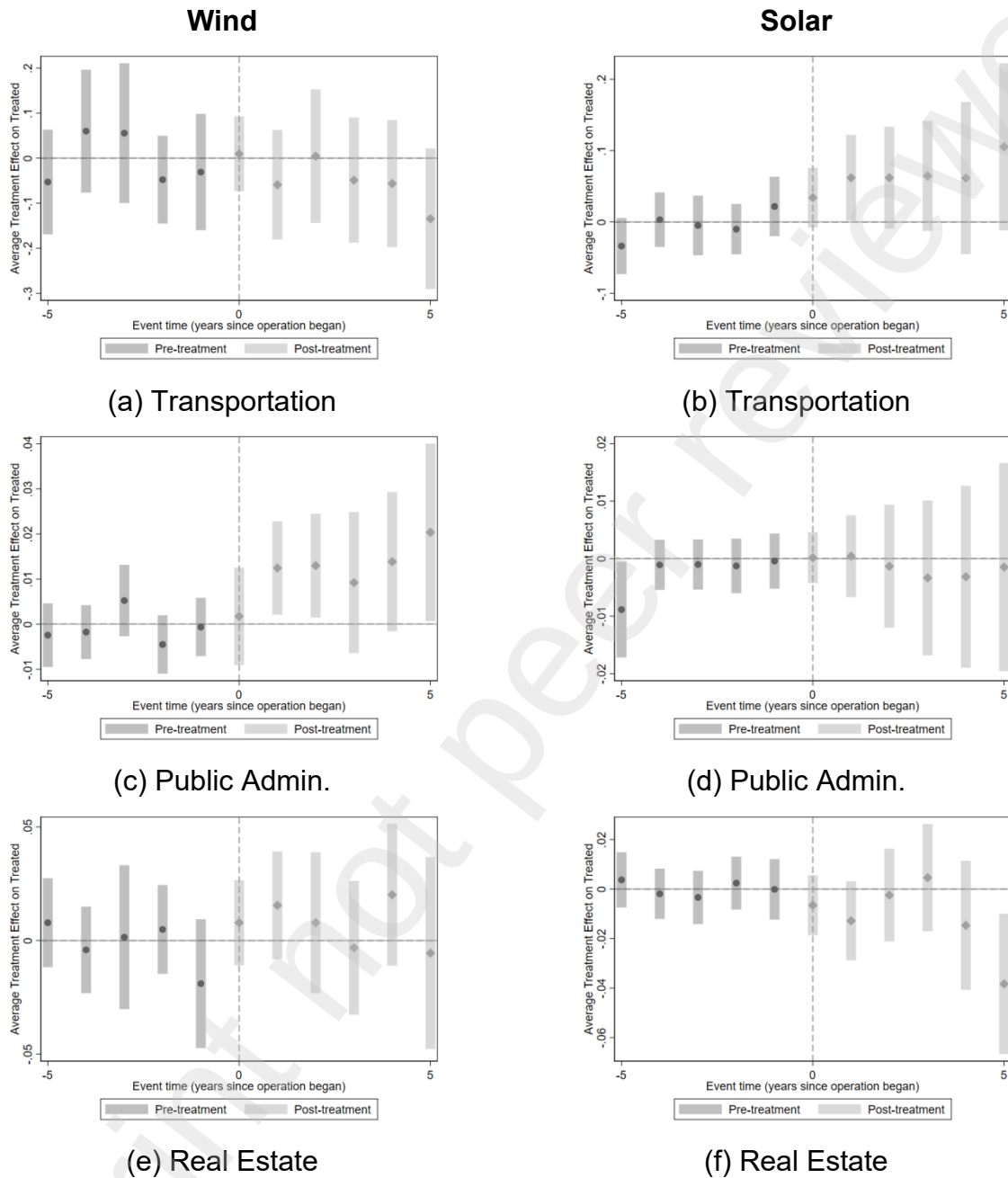


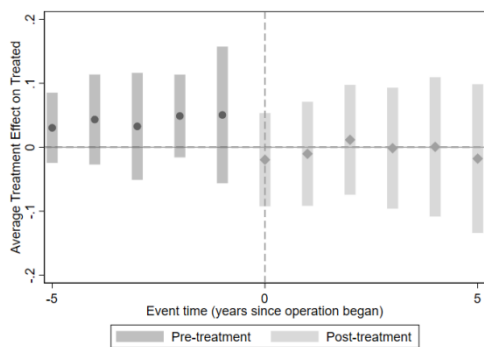
(i) Wholesale



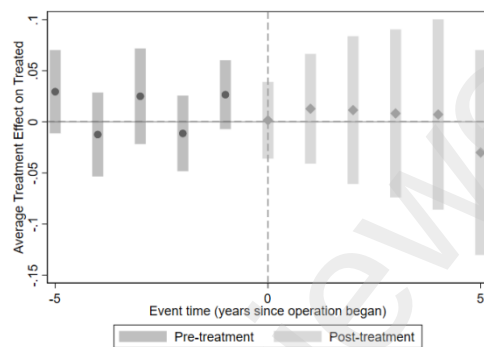
(j) Wholesale

Figure B7. Effect in GDP from Technology Adoption with Covariates

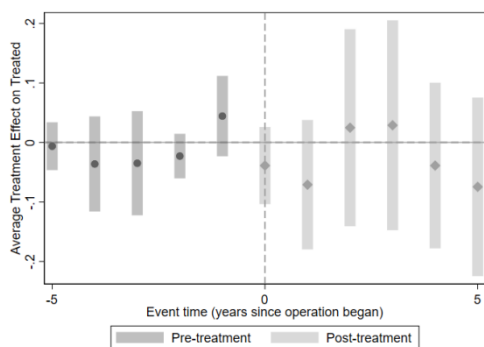




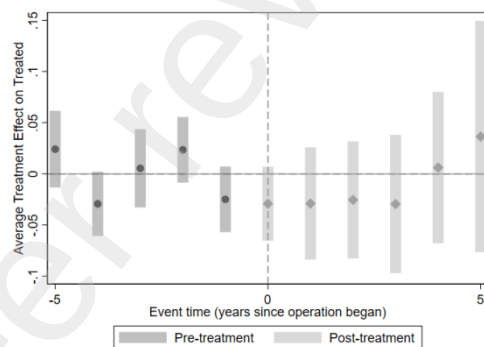
(g) Manufacturing



(h) Manufacturing

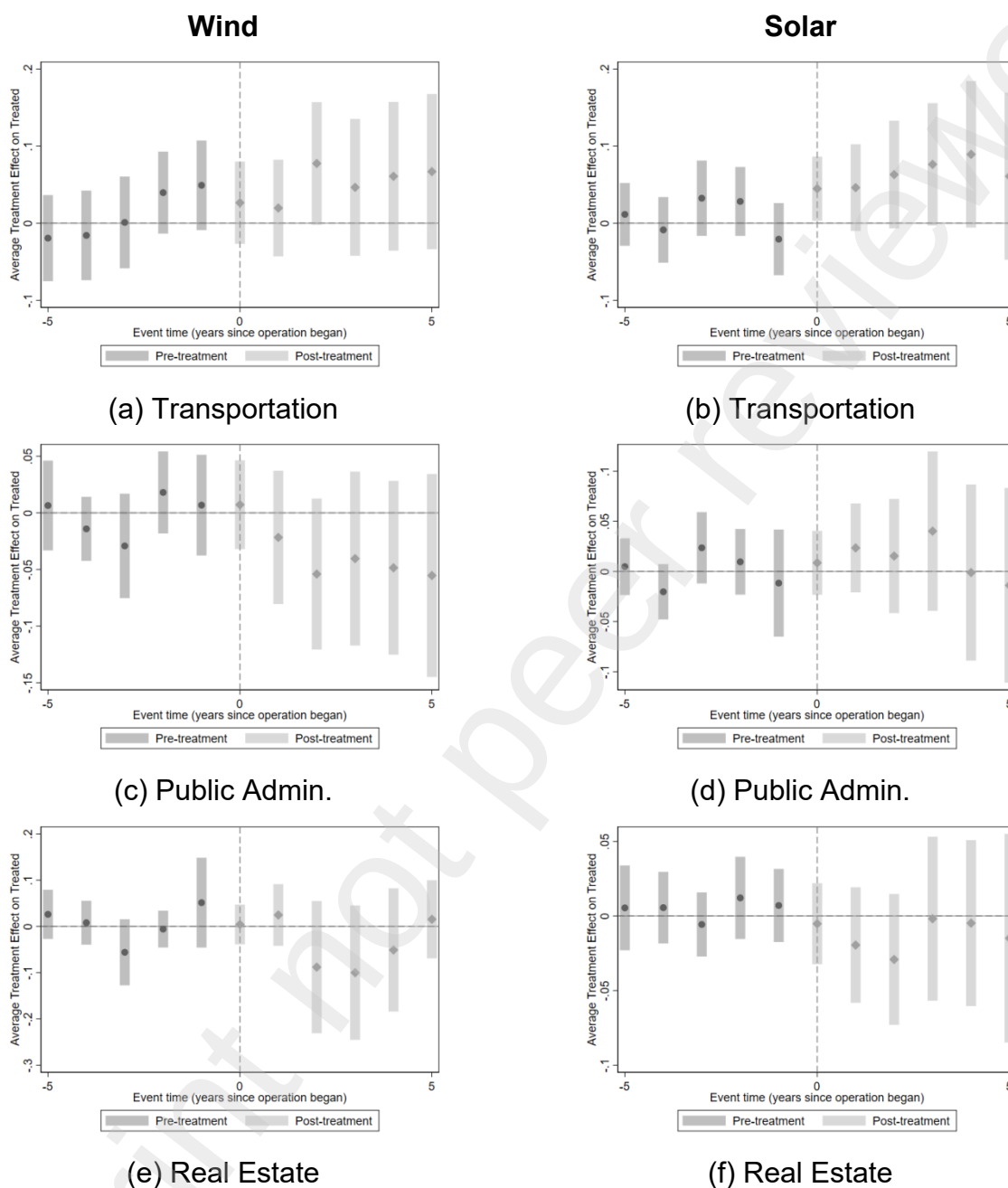


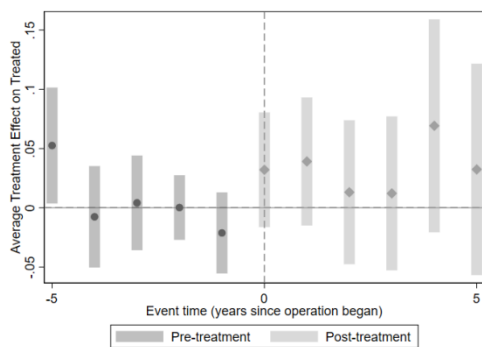
(i) Wholesale



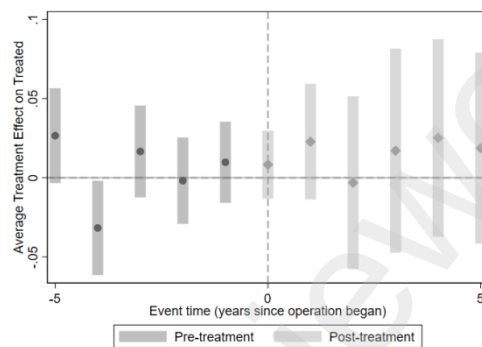
(j) Wholesale

Figure B8. Effects in Employment from Technology Adoption with Covariates

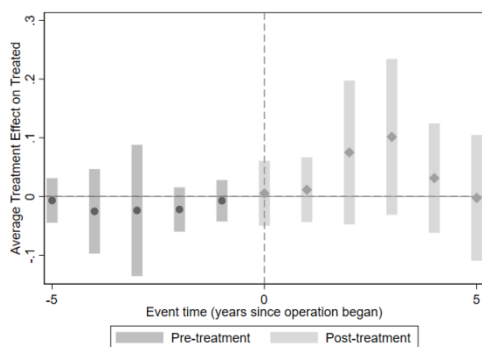




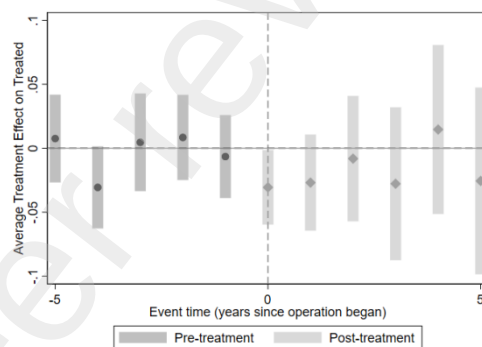
(g) Manufacturing



(h) Manufacturing

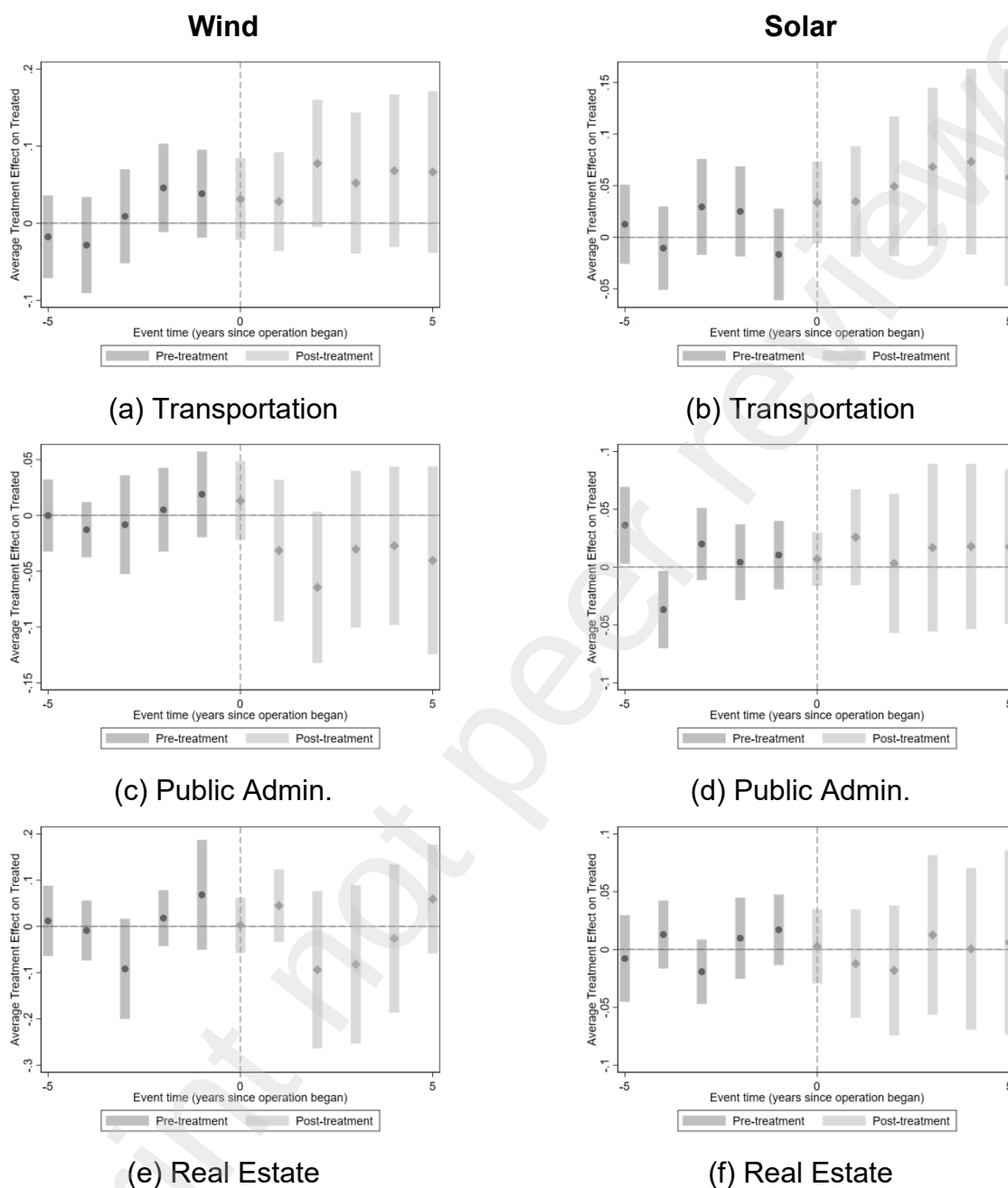


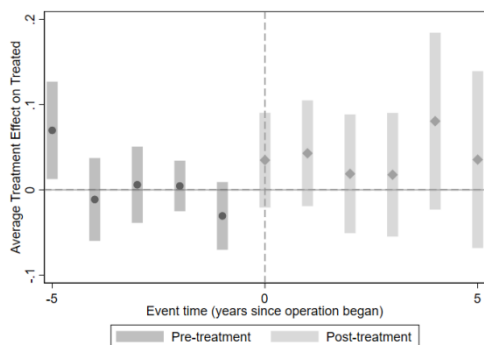
(i) Wholesale



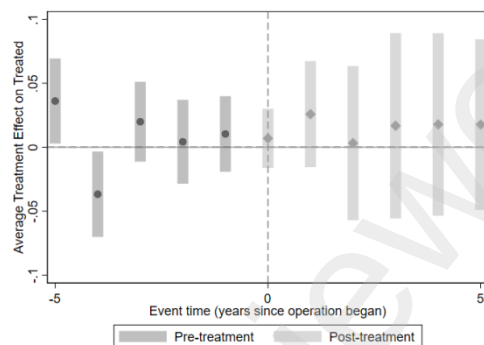
(j) Wholesale

Figure B9. Effects in Wages from Technology Adoption with Covariates

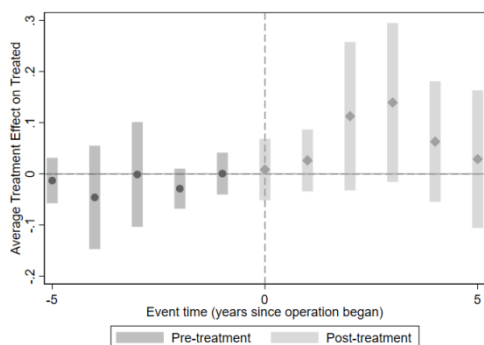




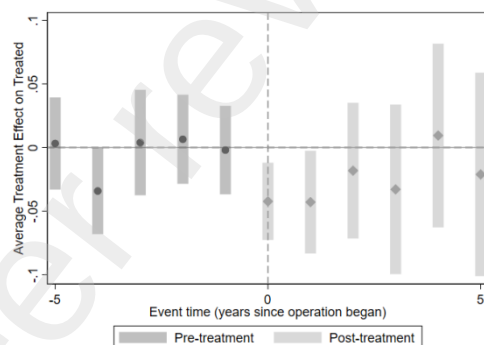
(g) Manufacturing



(h) Manufacturing



(i) Wholesale



(j) Wholesale

Appendix C. Sector Specific Trends

Figure C1. Trends in Sector Specific GDP by Technology Adoption for Rural Counties

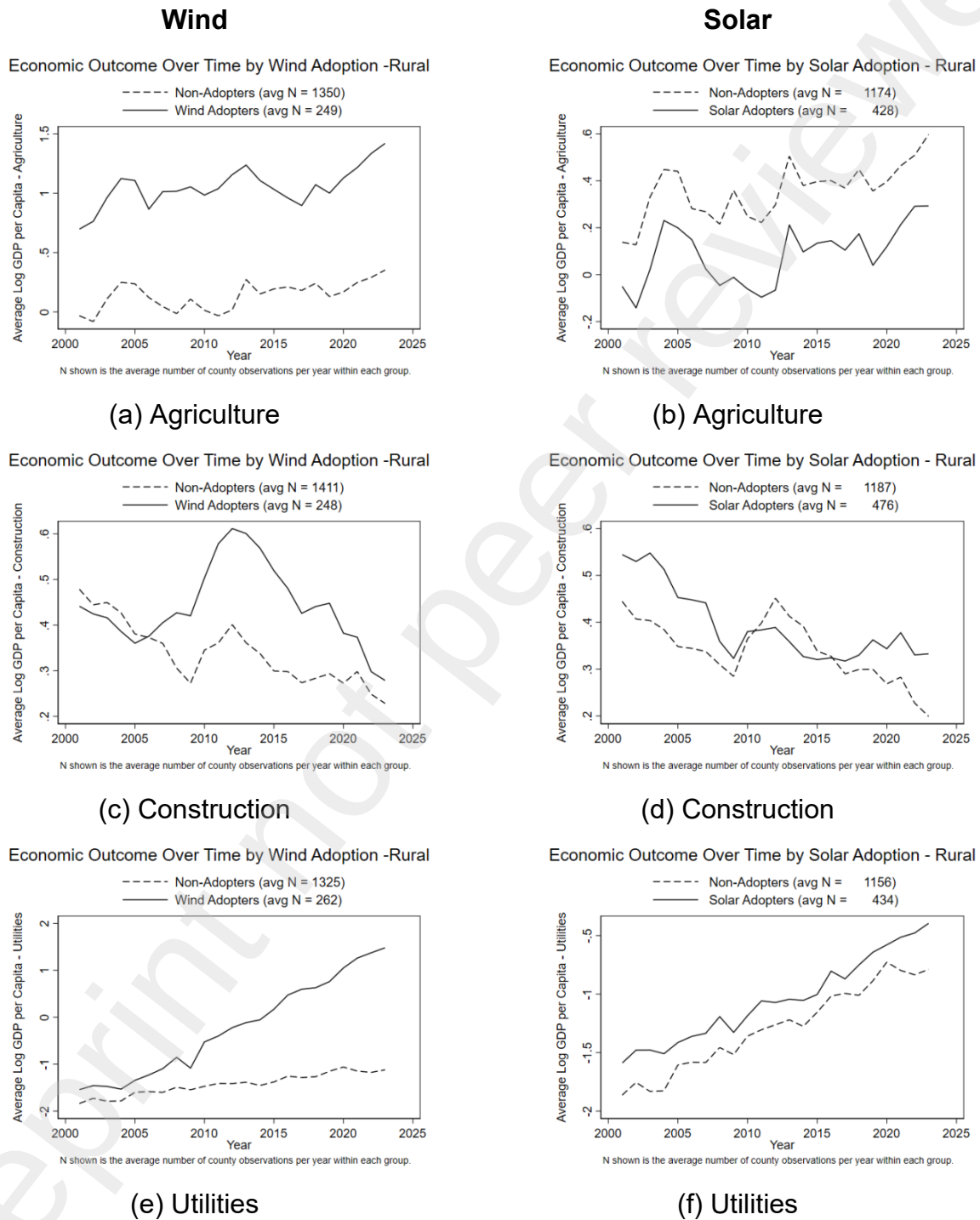


Figure C2. Trends in Sector Specific Employment by Technology Adoption for Rural Counties

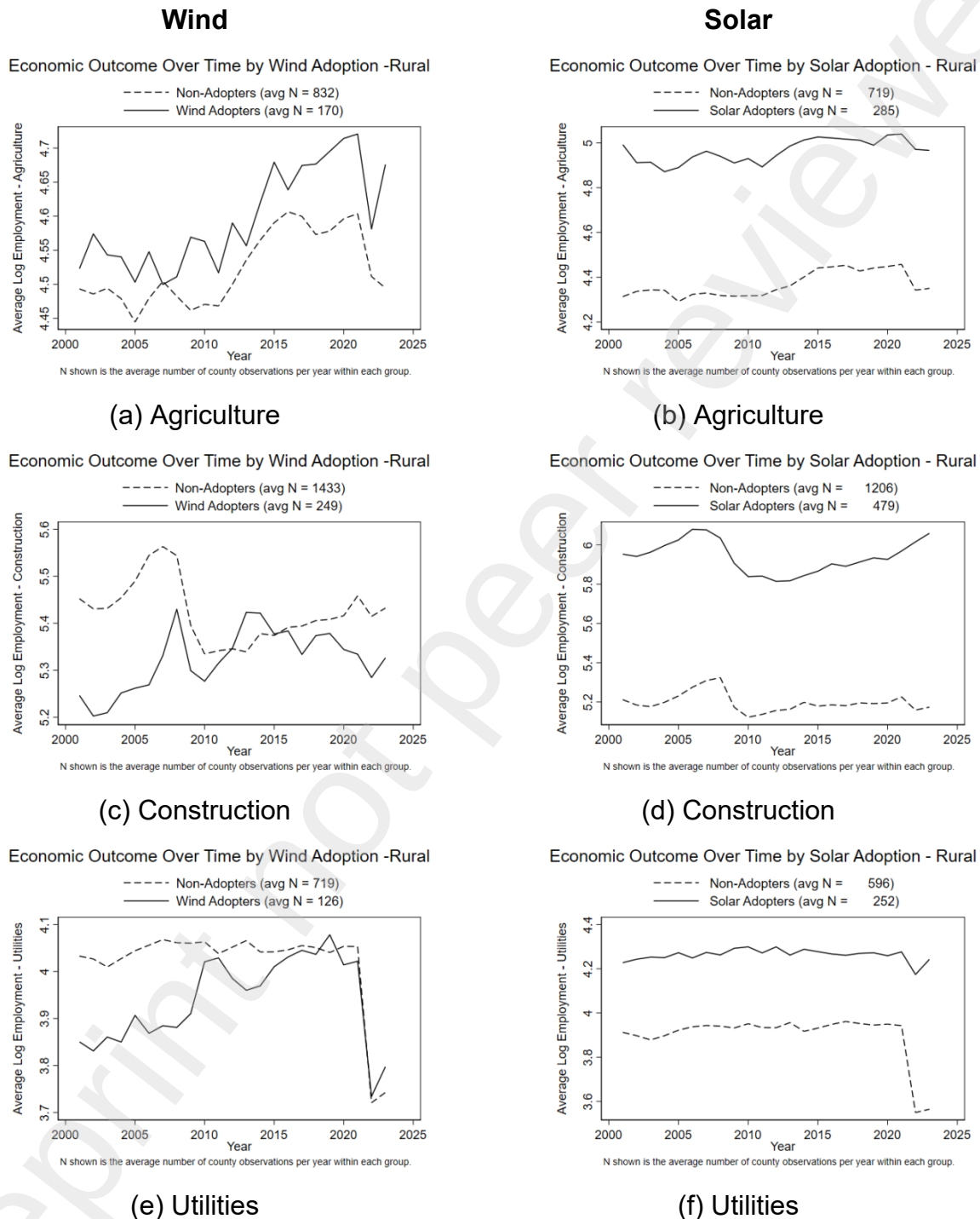
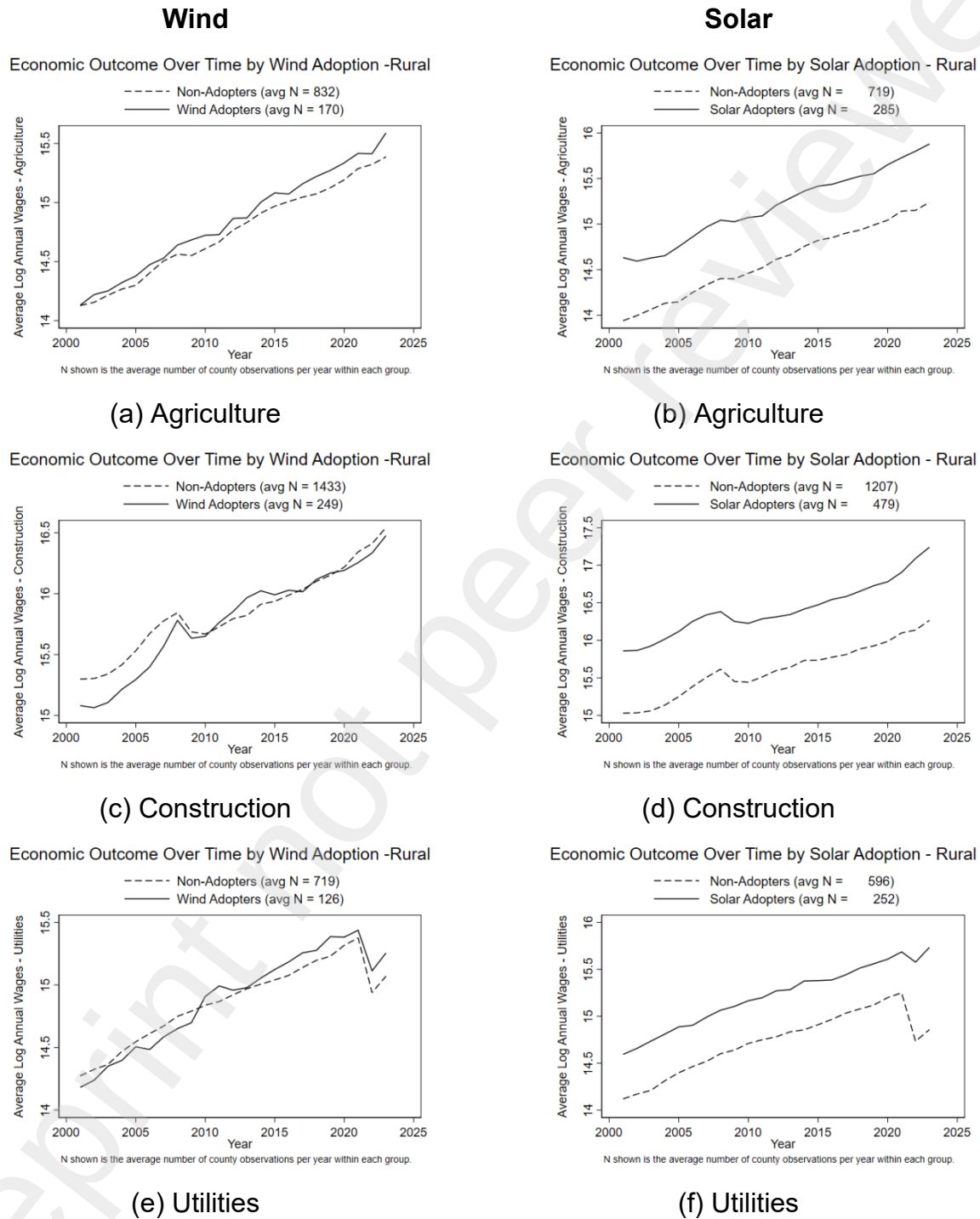


Figure C3. Trends in Sector Specific Wages by Technology Adoption for Rural Counties



Online Supplemental Appendix S1. Counties with 10% or Greater Agricultural GDP

Figure S1.1. Effect of Renewable Adoption

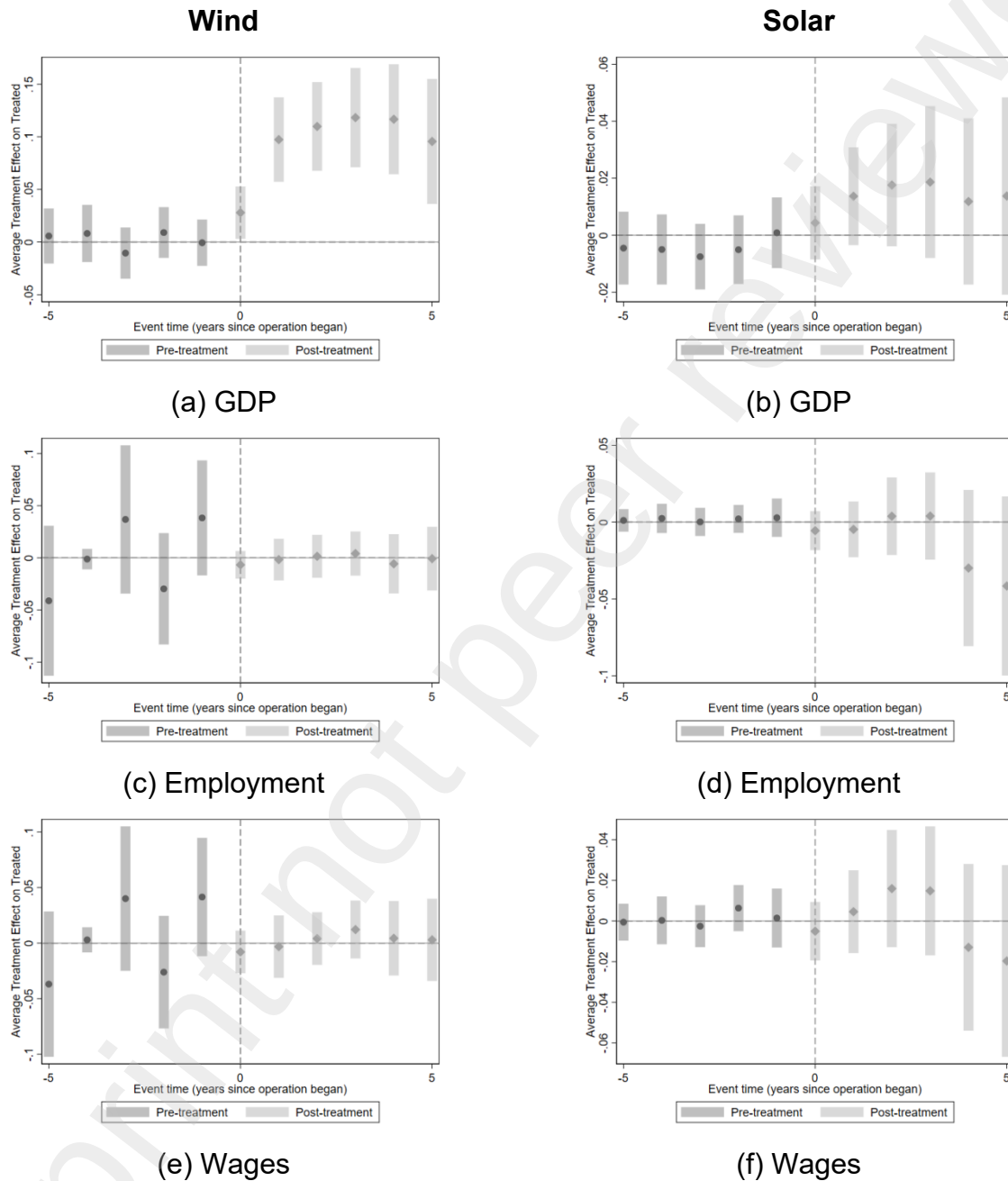
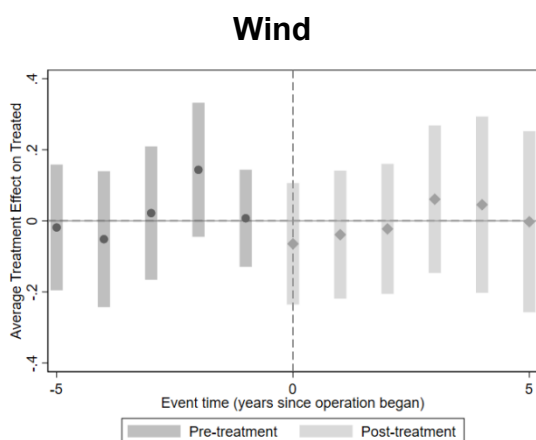
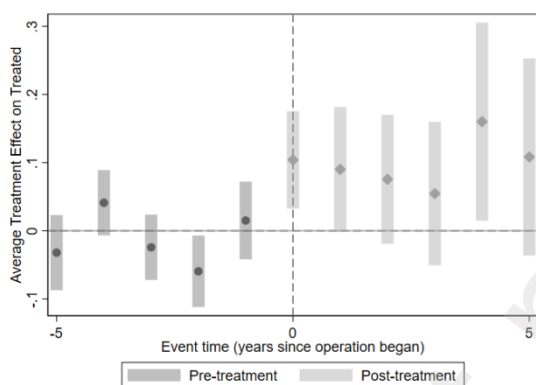


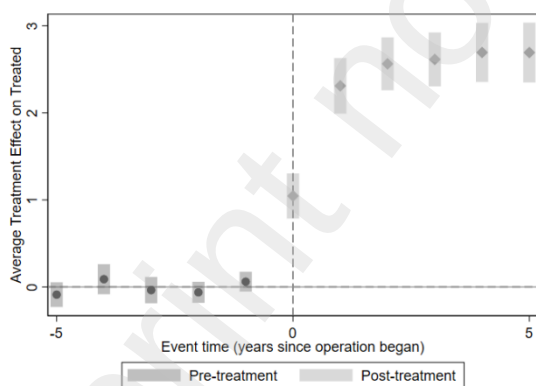
Figure s1.2. Renewable Adoption's Effect on GDP by Sector



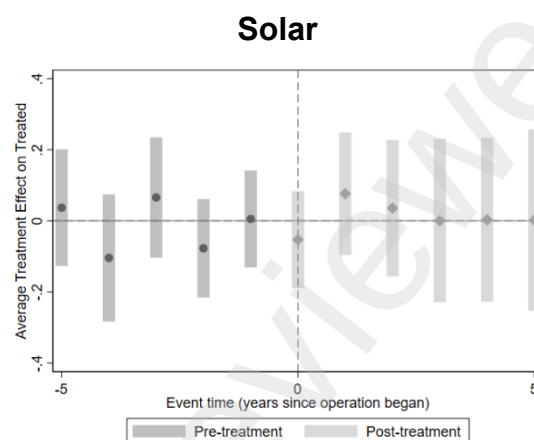
(a) Agriculture



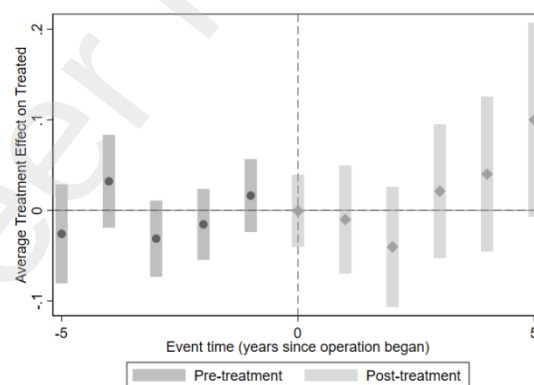
(c) Construction



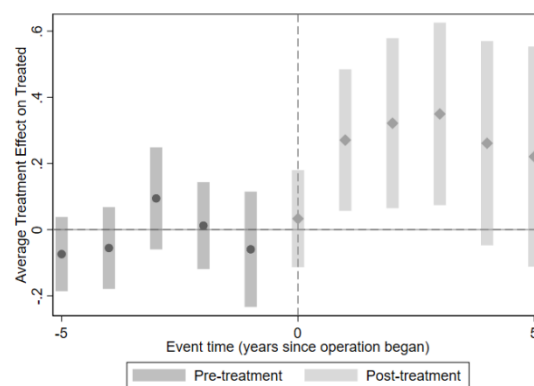
(e) Utilities



(b) Agriculture



(d) Construction



(f) Utilities



Figure S1.3. Renewable Adoption's Effect on Employment by Sector

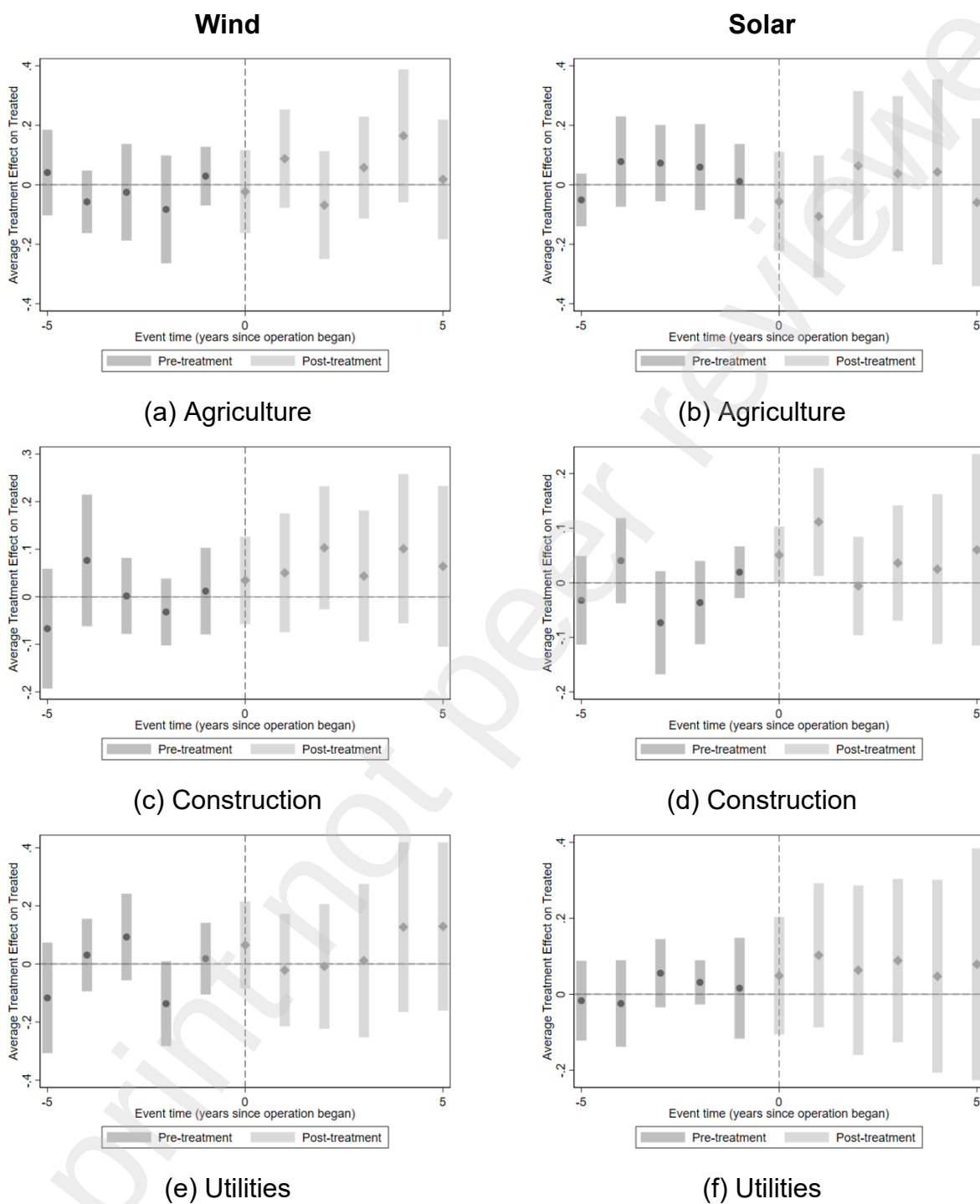


Figure S1.4. Renewable Adoption's Effect on Wages by Sector

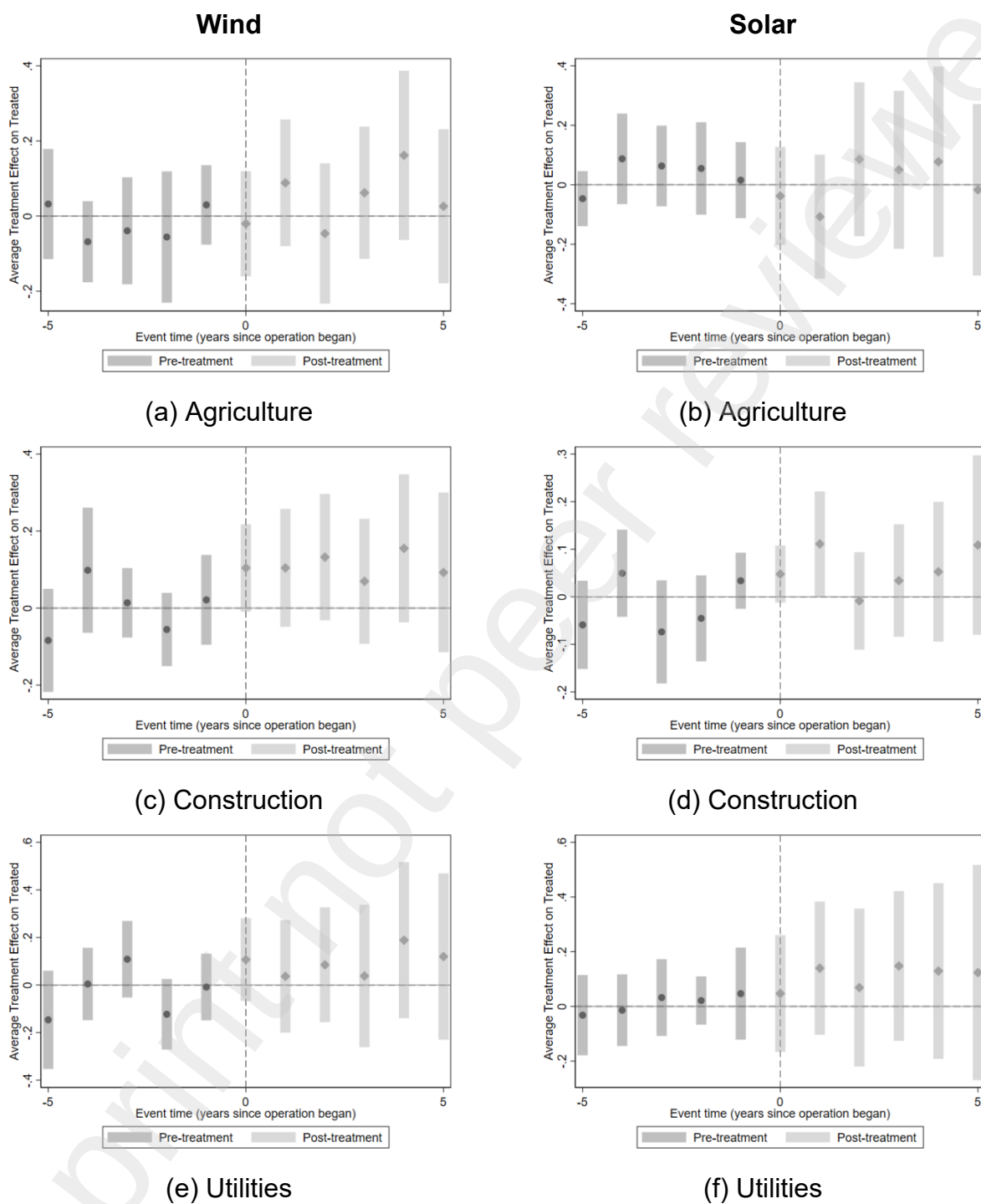


Figure S1.5. Renewable Adoption's Effect on GDP by Sector with Covariates

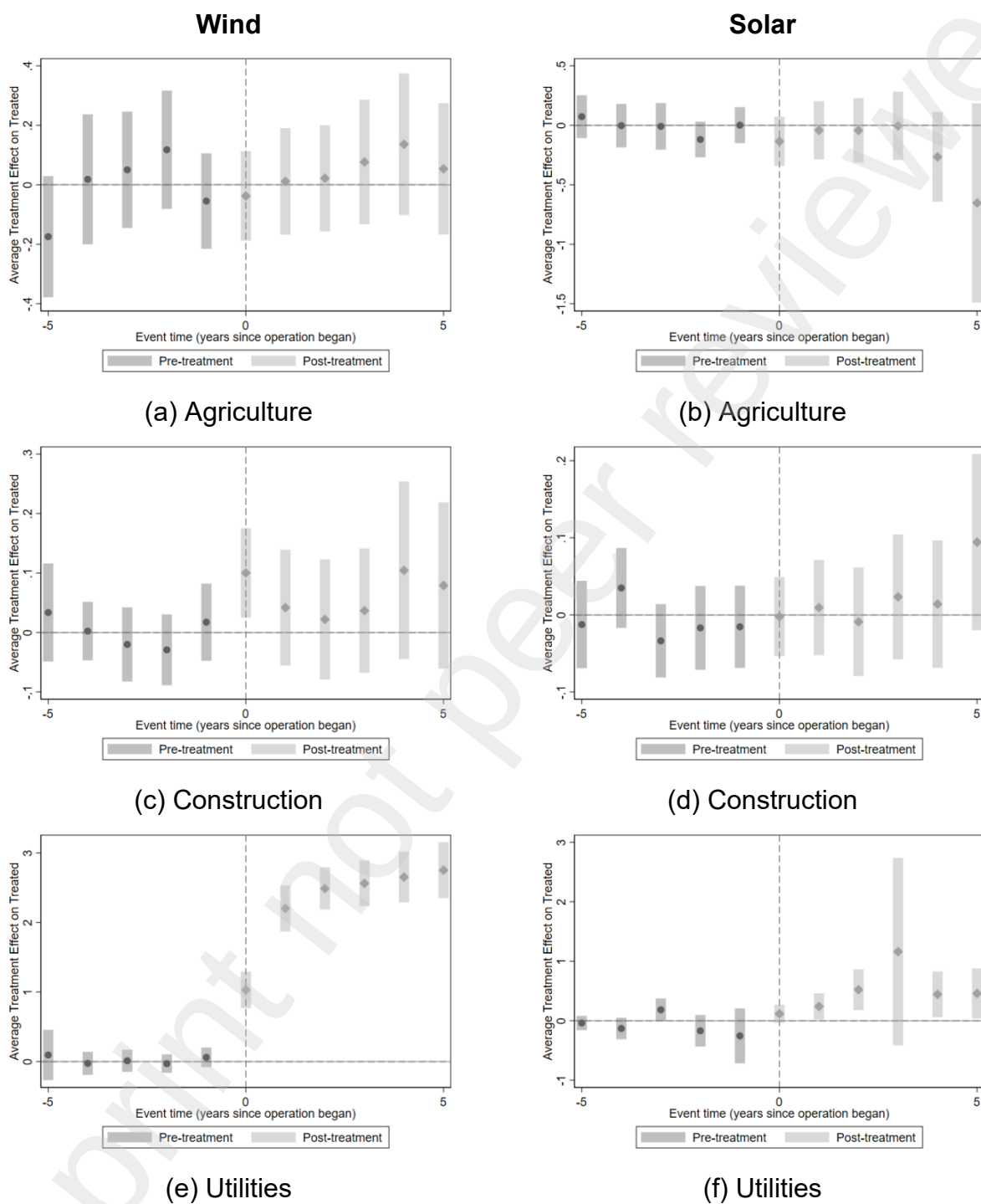


Figure S1.6. Renewable Adoption's Effect on Employment by Sector with Covariates

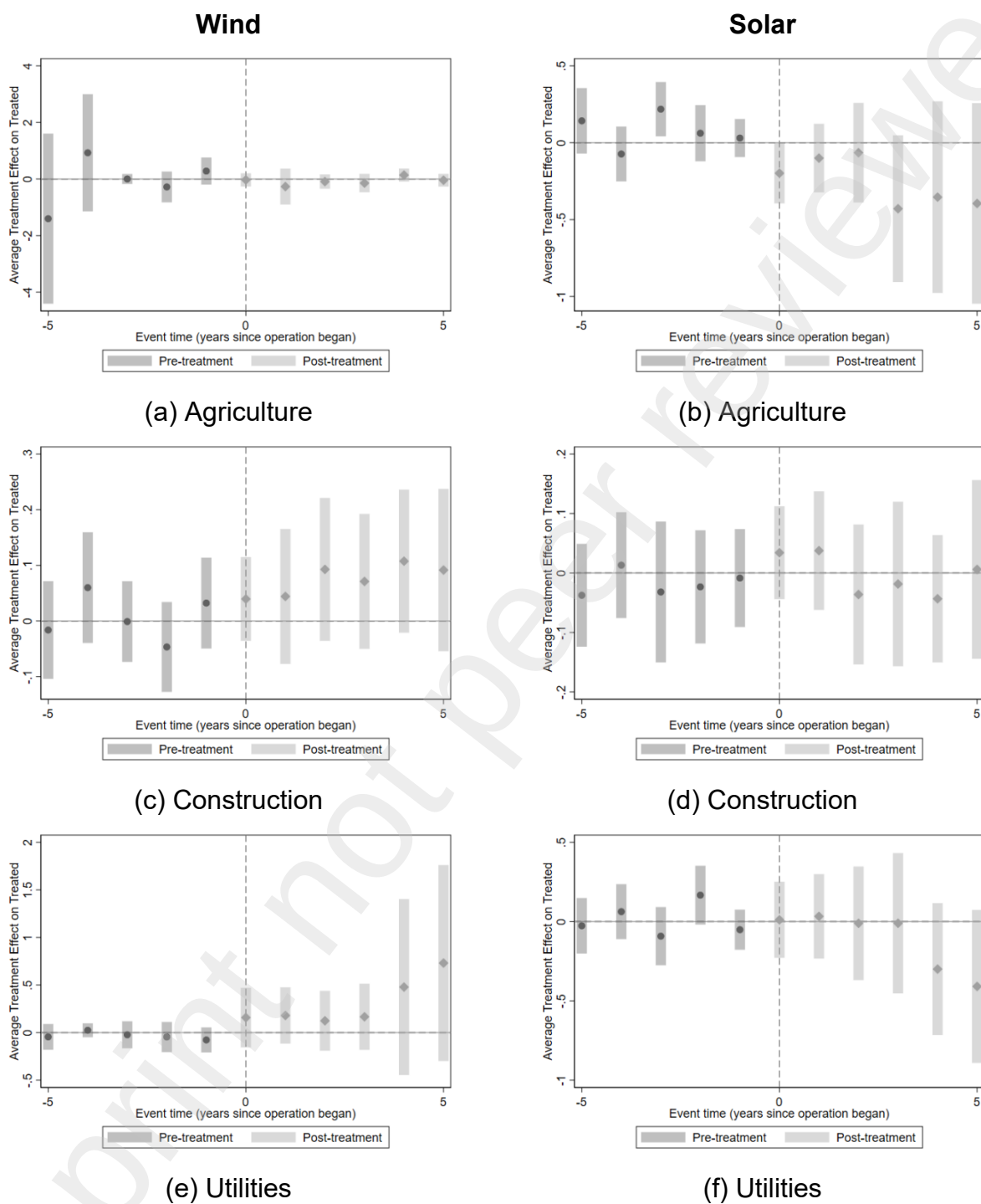
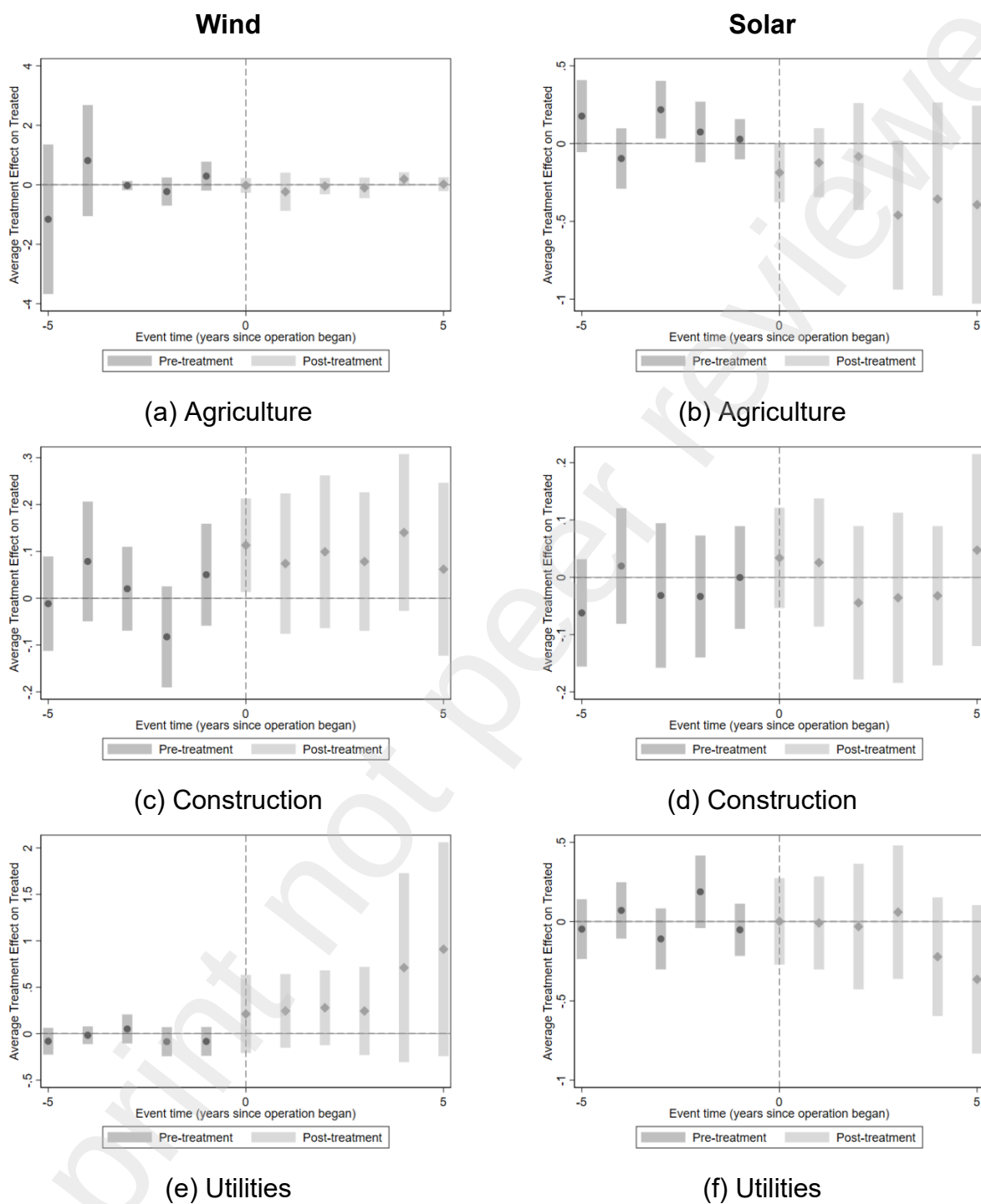


Figure S1.7. Renewable Adoption's Effect on Wages by Sector with Covariates



Online Supplemental Appendix S2. One Year Lag

Figure S2.1. Effect of Renewable Adoption

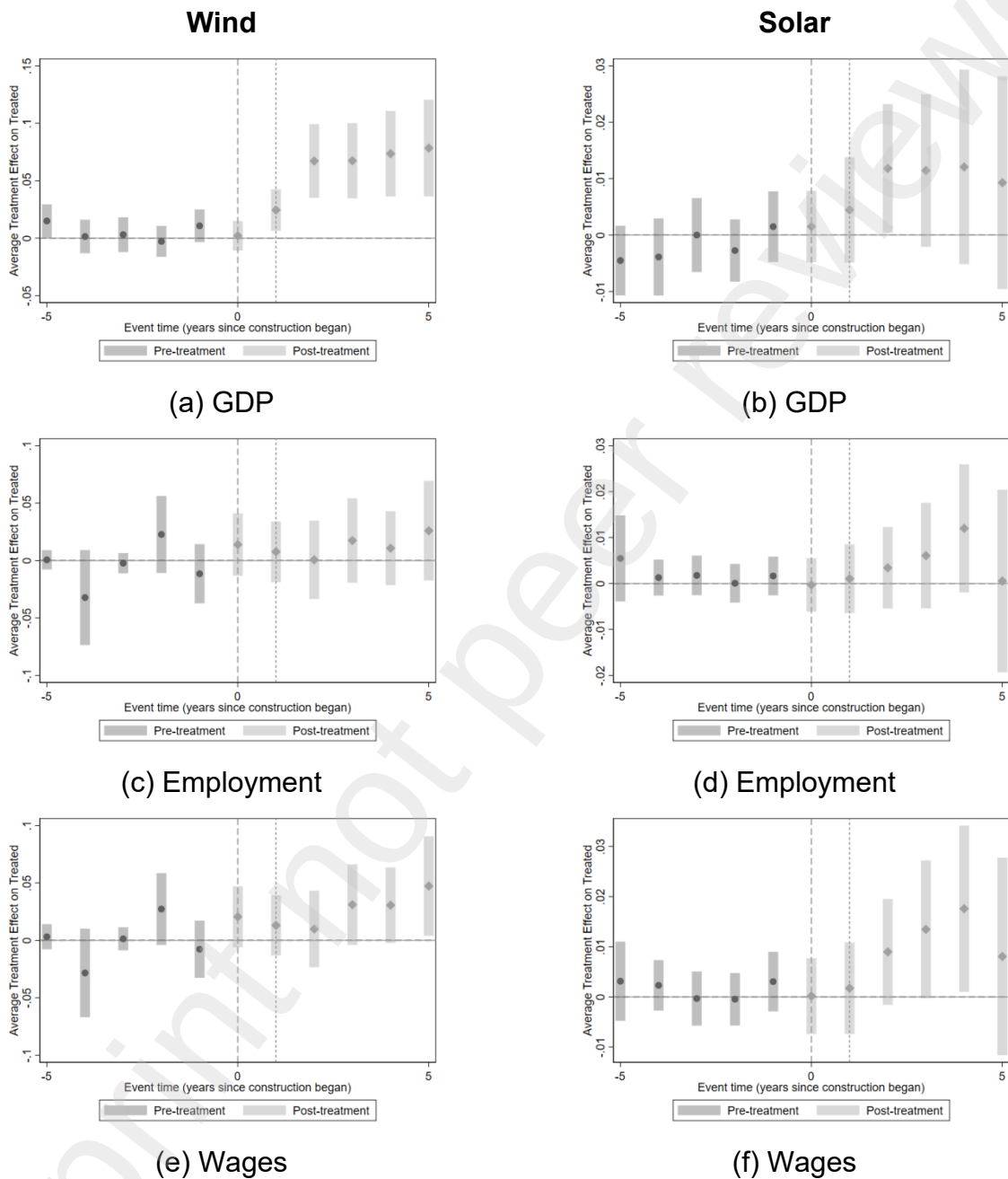


Figure S2.2. Renewable Adoption's Effect on GDP by Sector

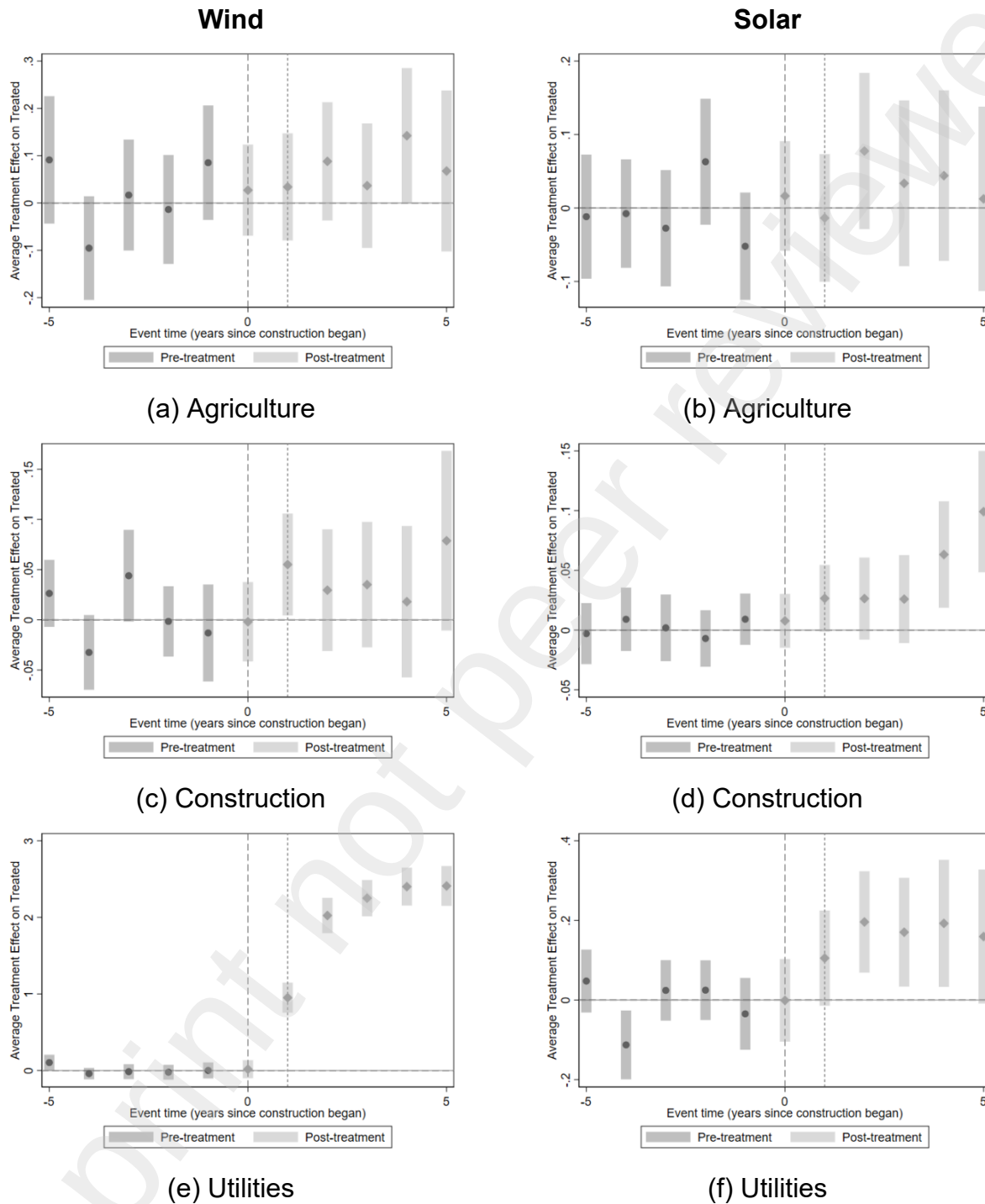


Figure S2.3. Renewable Adoption's Effect on Employment by Sector

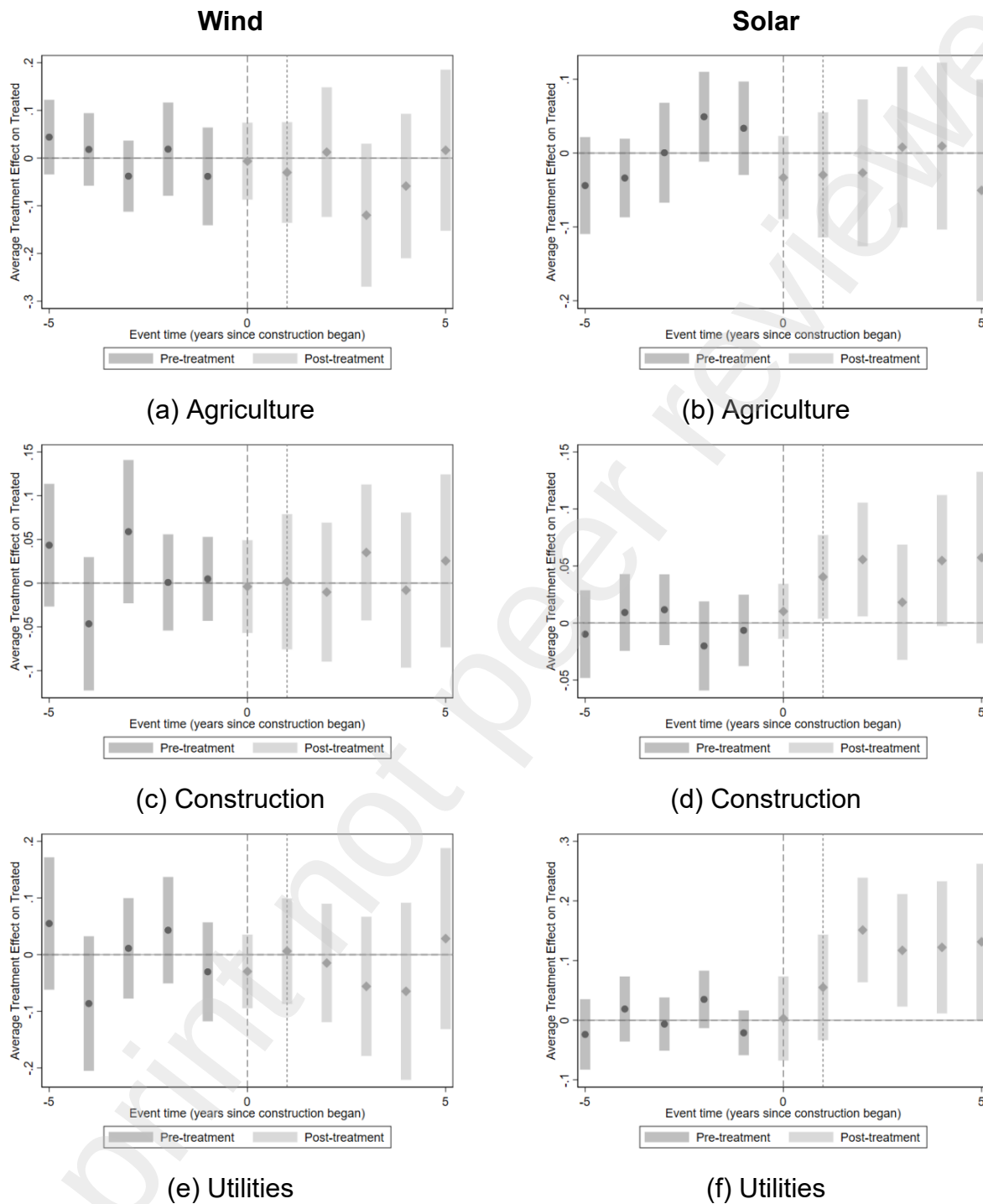


Figure S2.4. Renewable Adoption's Effect on Wages by Sector

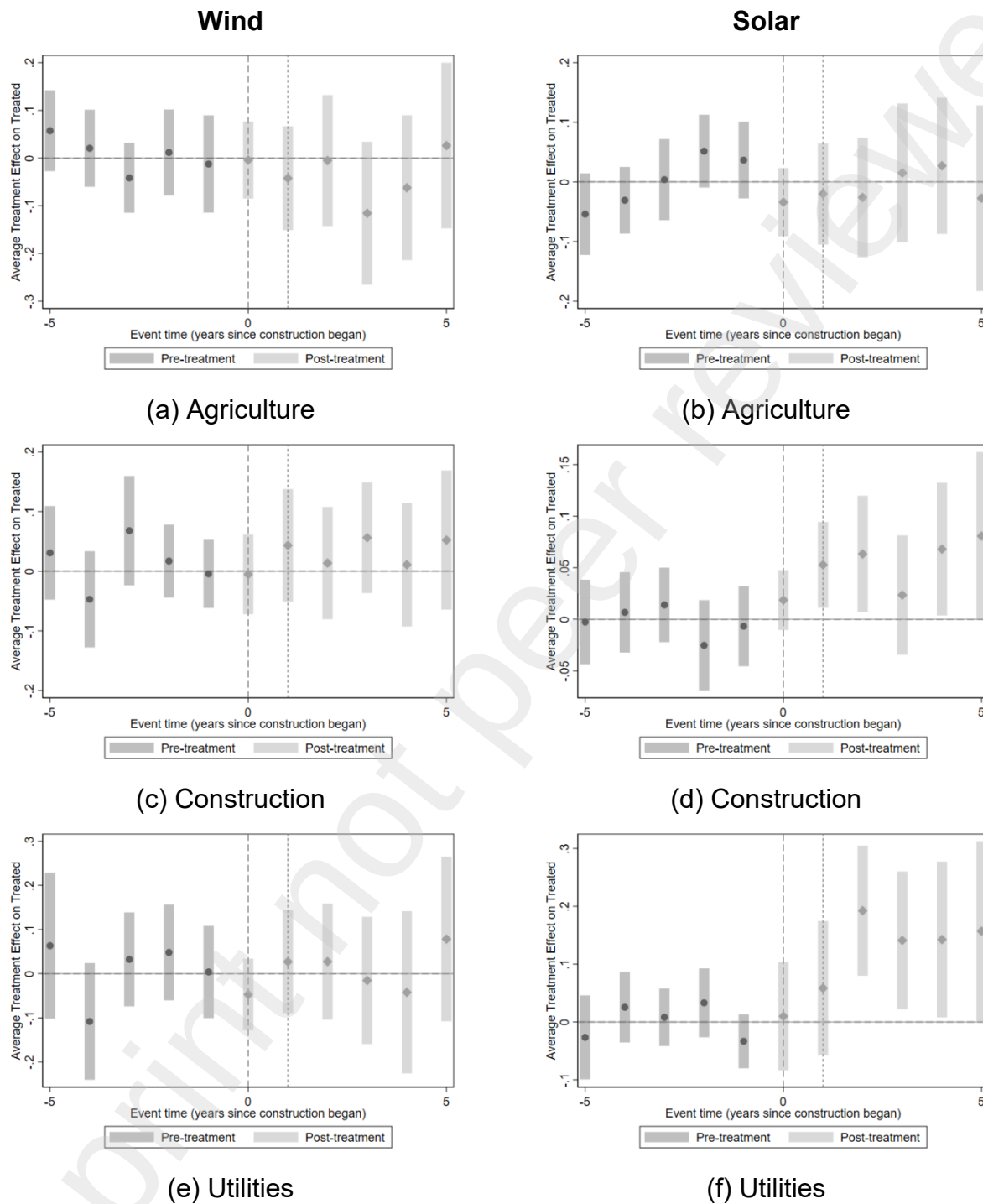


Figure S2.5. Renewable Adoption's Effect on GDP by Sector for Rural Ag. Counties

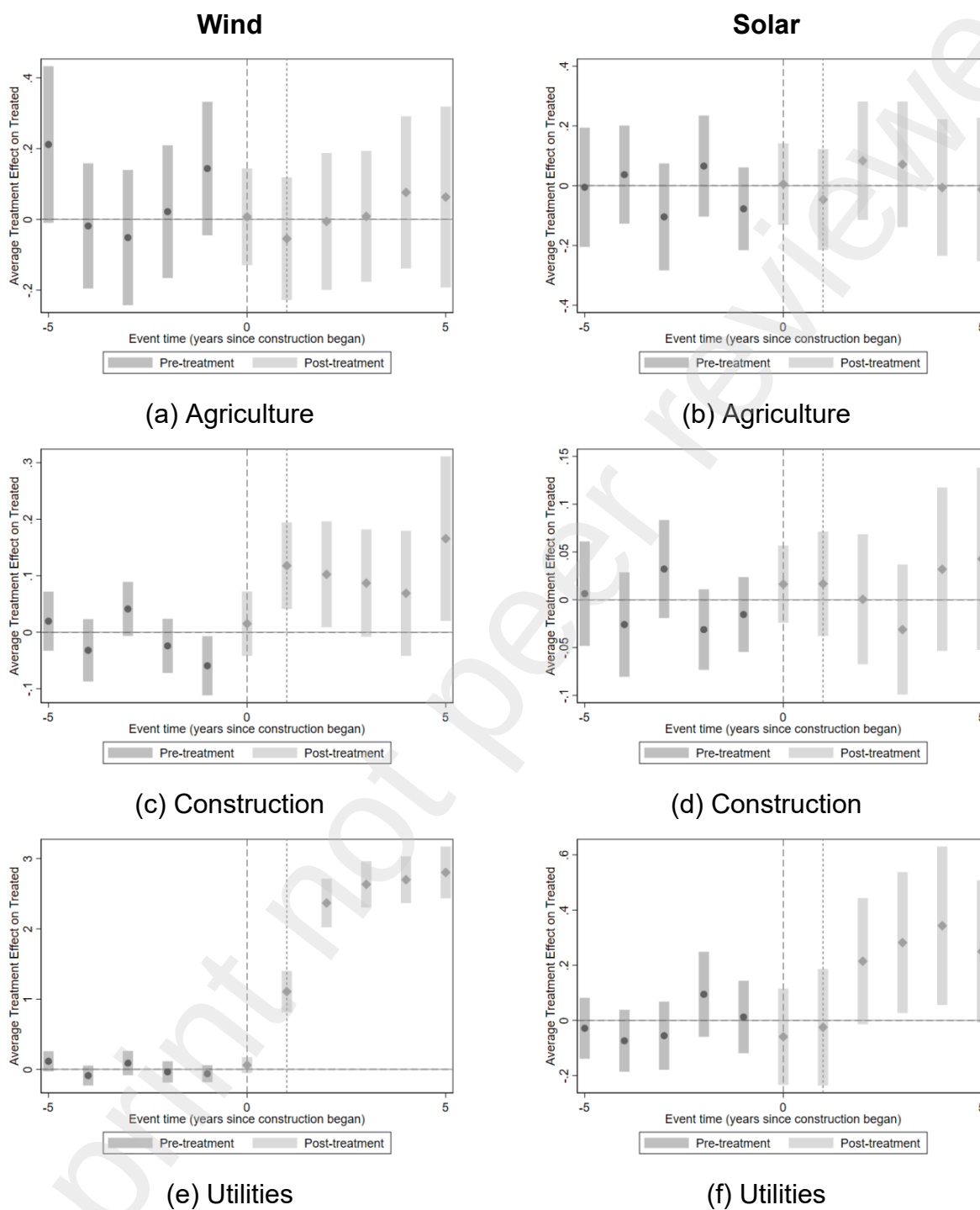


Figure S2.6. Renewable Adoption's Effect on Employment by Sector for Rural Ag. Counties

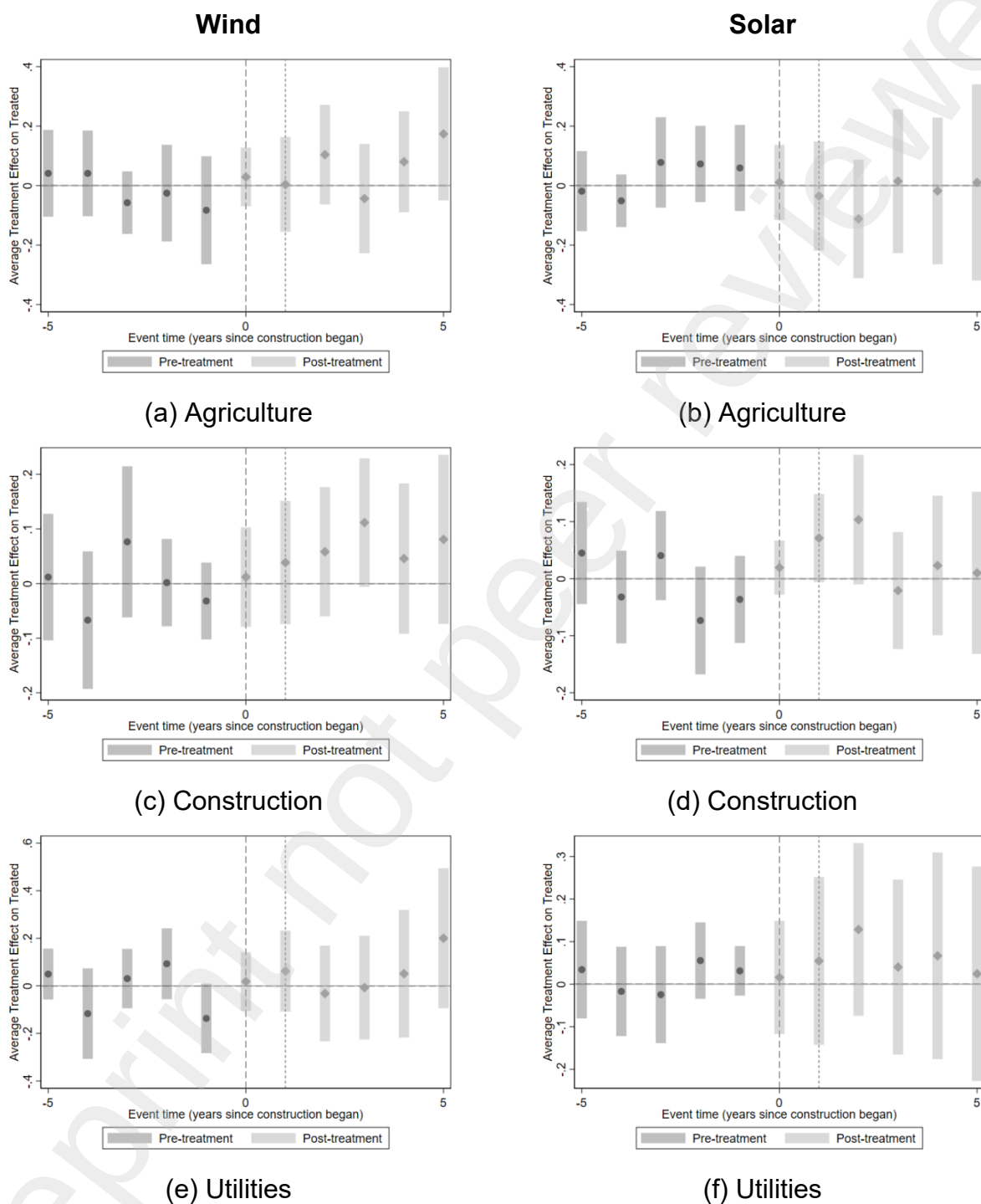
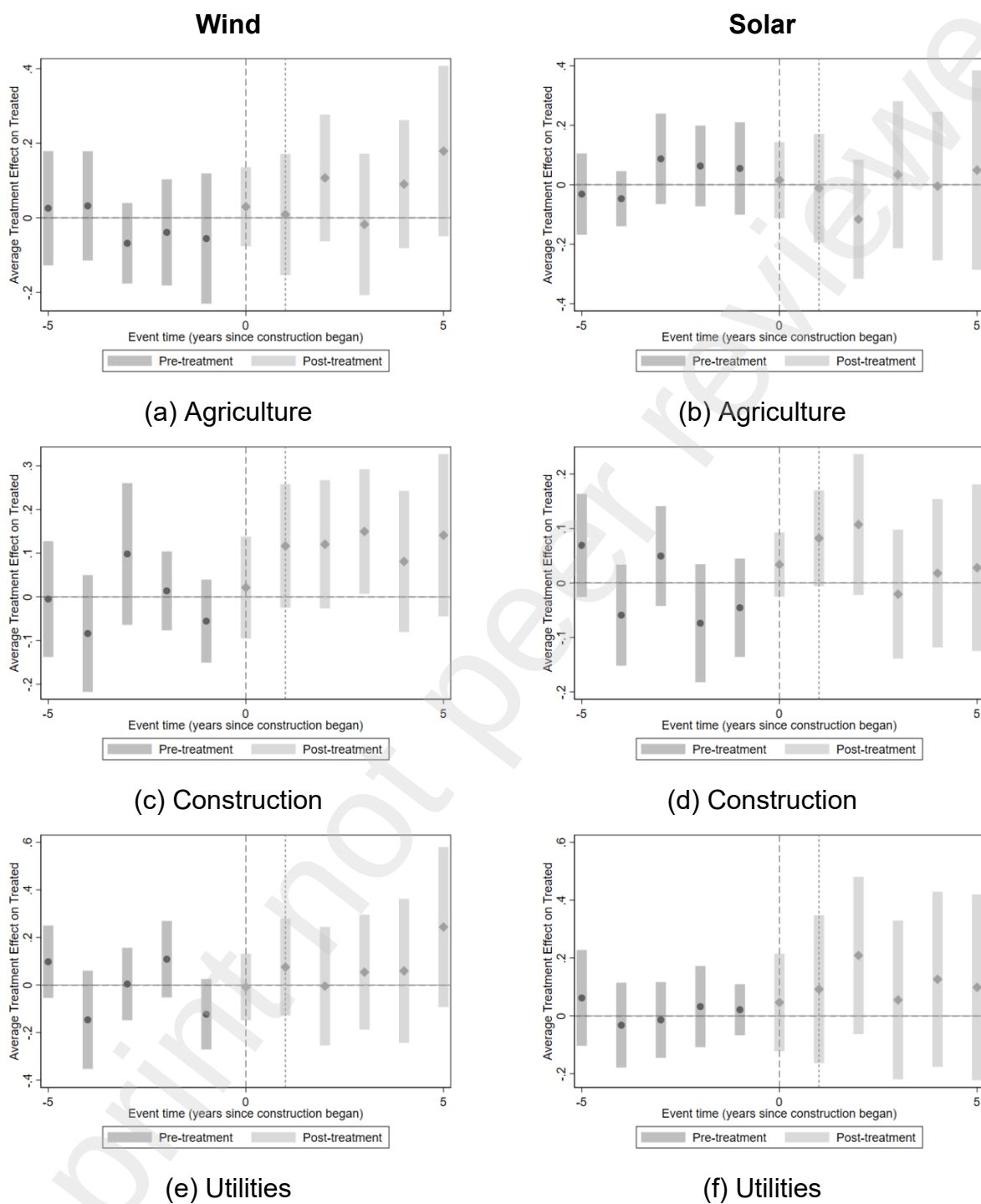


Figure S2.7. Renewable Adoption's Effect on Wages by Sector for Rural Ag. Counties



Online Supplemental Appendix S2. Two Year Lag

Figure S2.8. Effect of Renewable Adoption

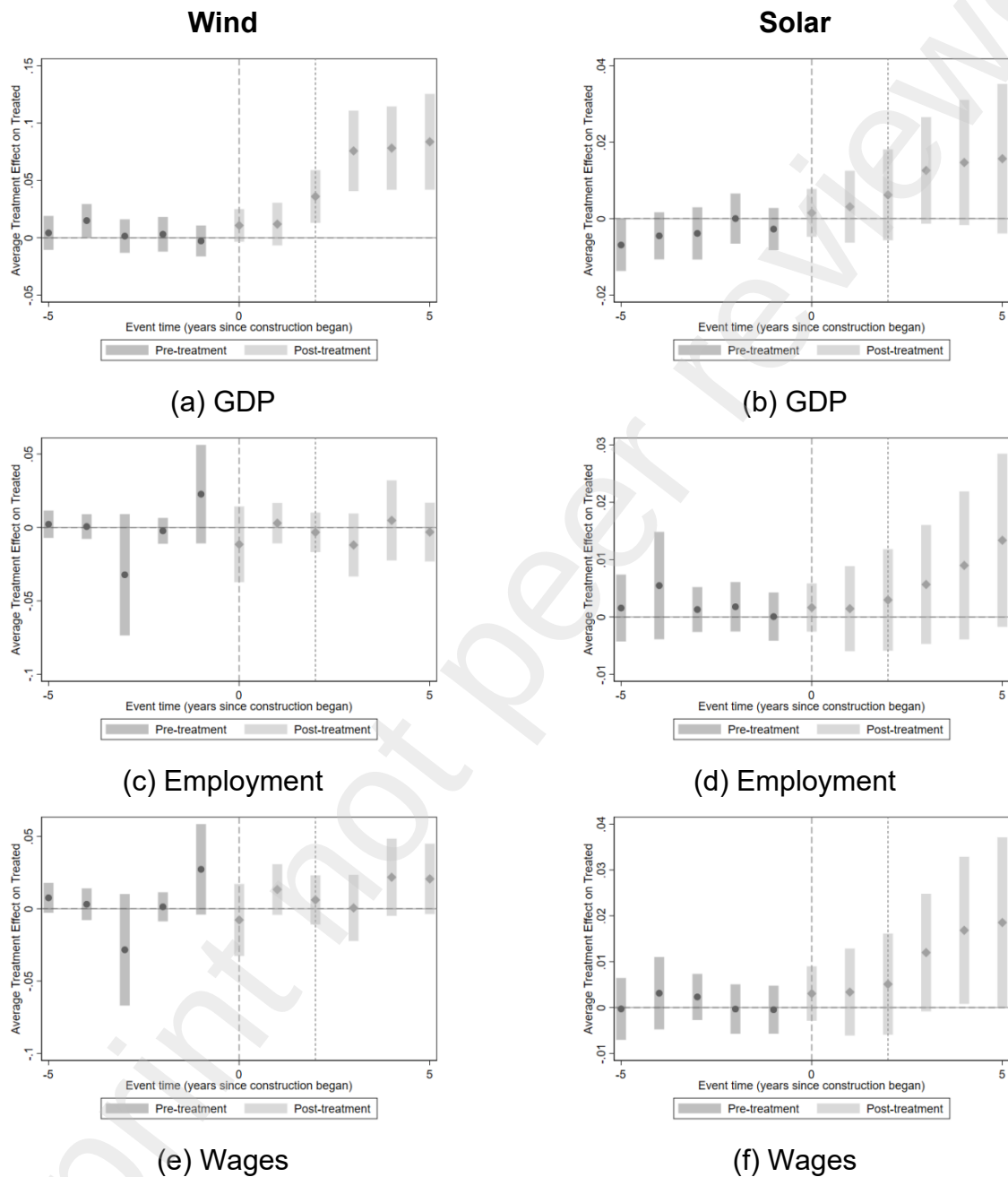


Figure S2.9. Renewable Adoption's Effect on GDP by Sector

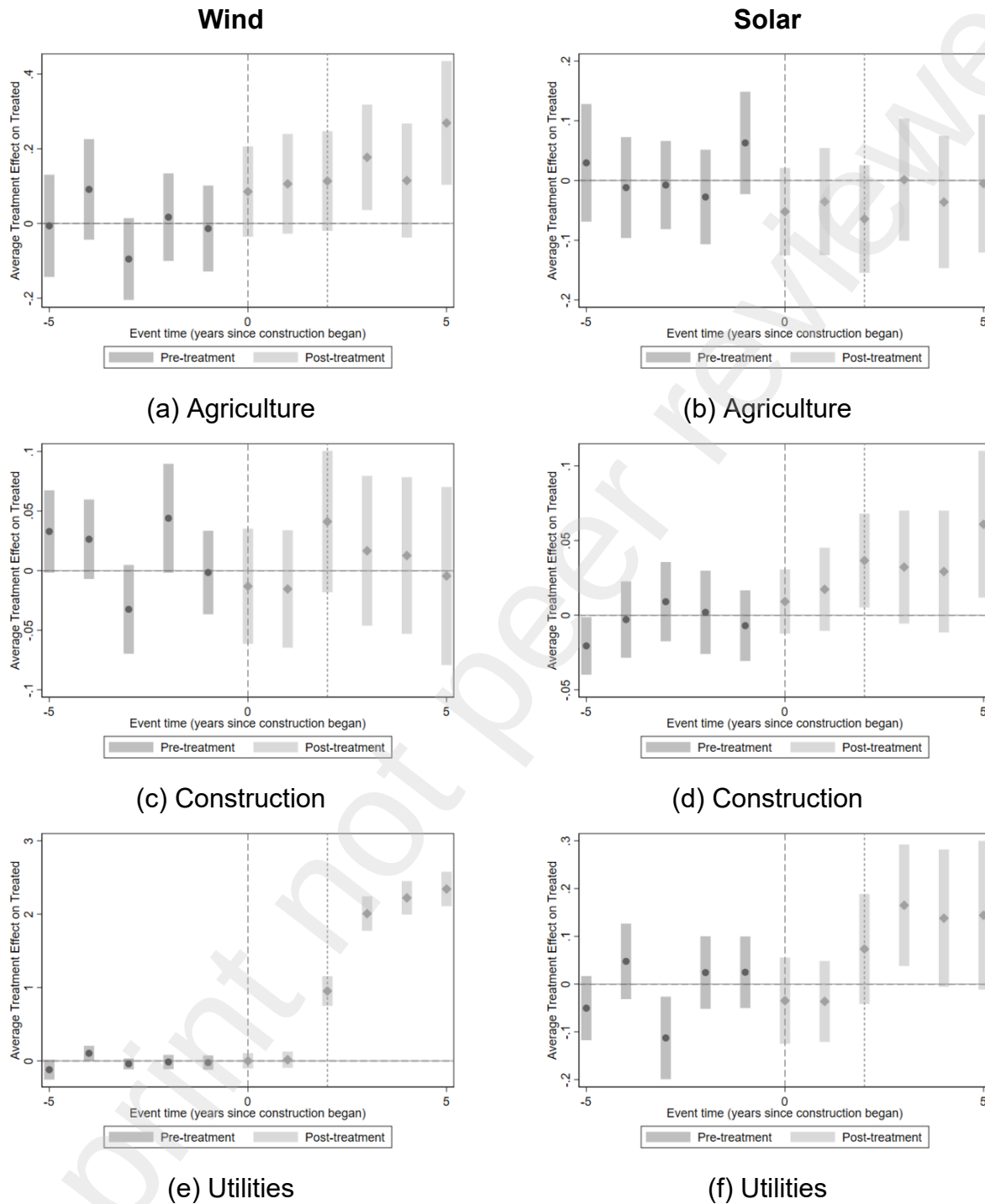


Figure S2.10. Renewable Adoption's Effect on Employment by Sector

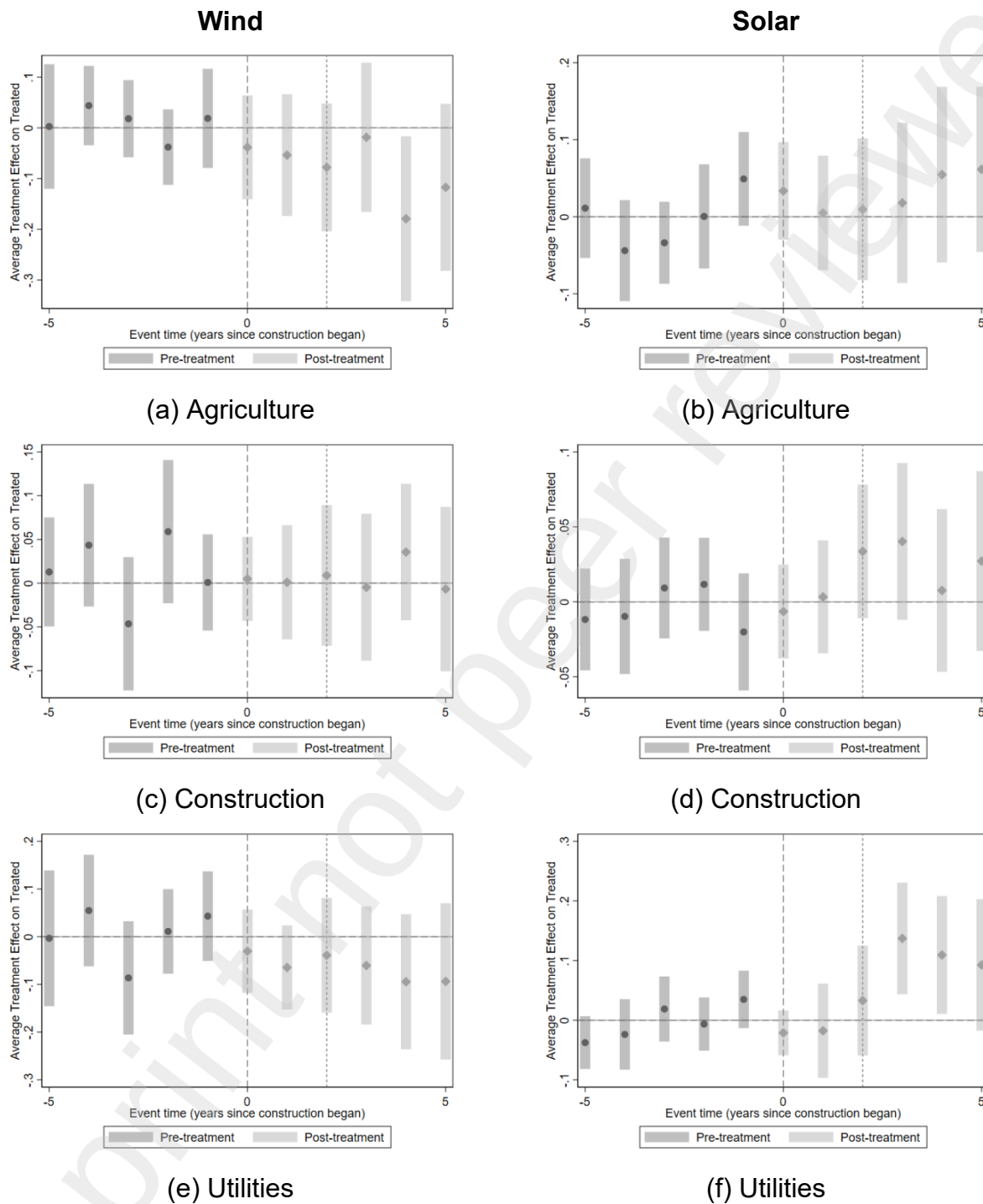


Figure S2.11. Renewable Adoption's Effect on Wages by Sector

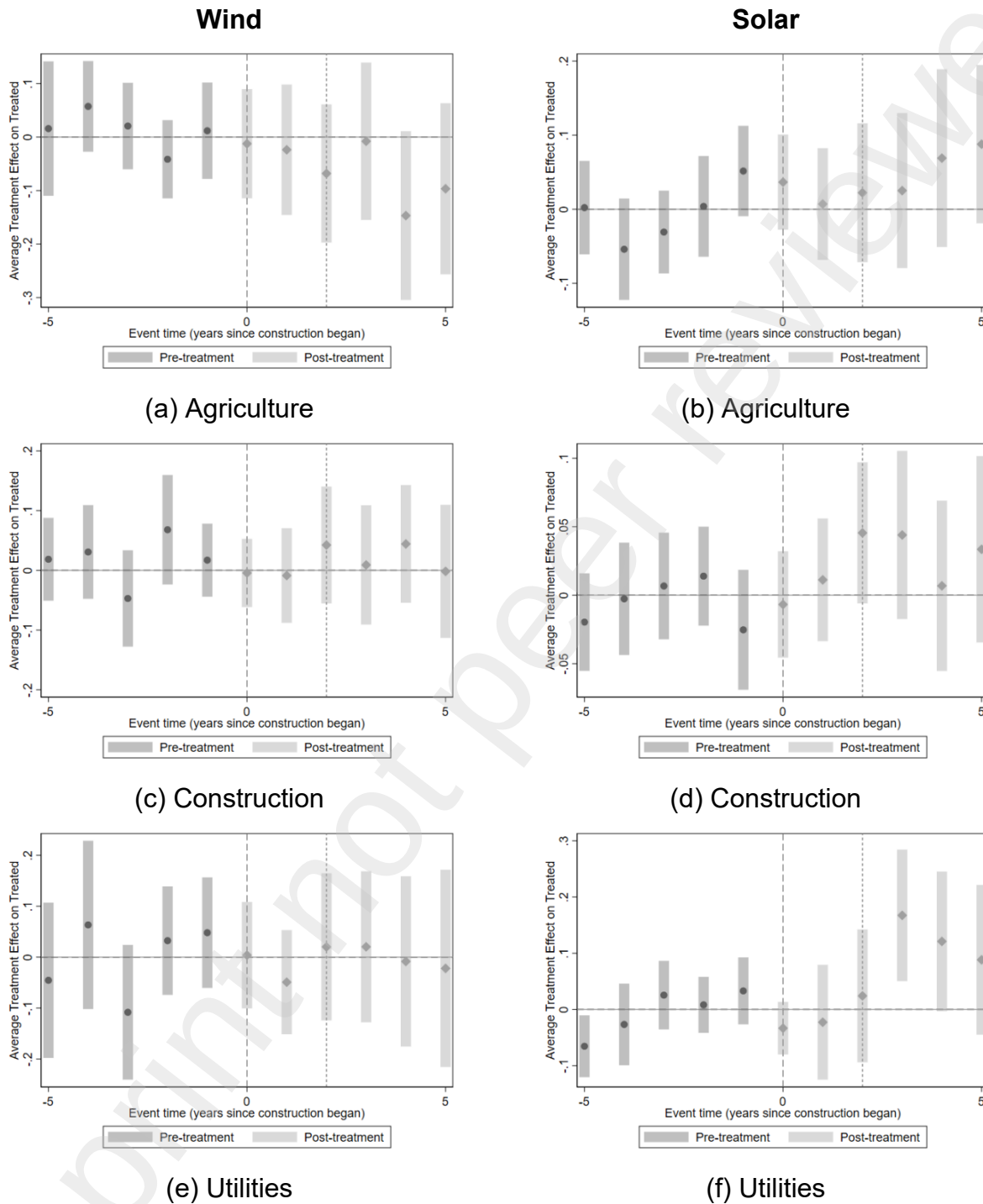


Figure S2.12. Renewable Adoption's Effect on GDP by Sector for Rural Ag. Counties

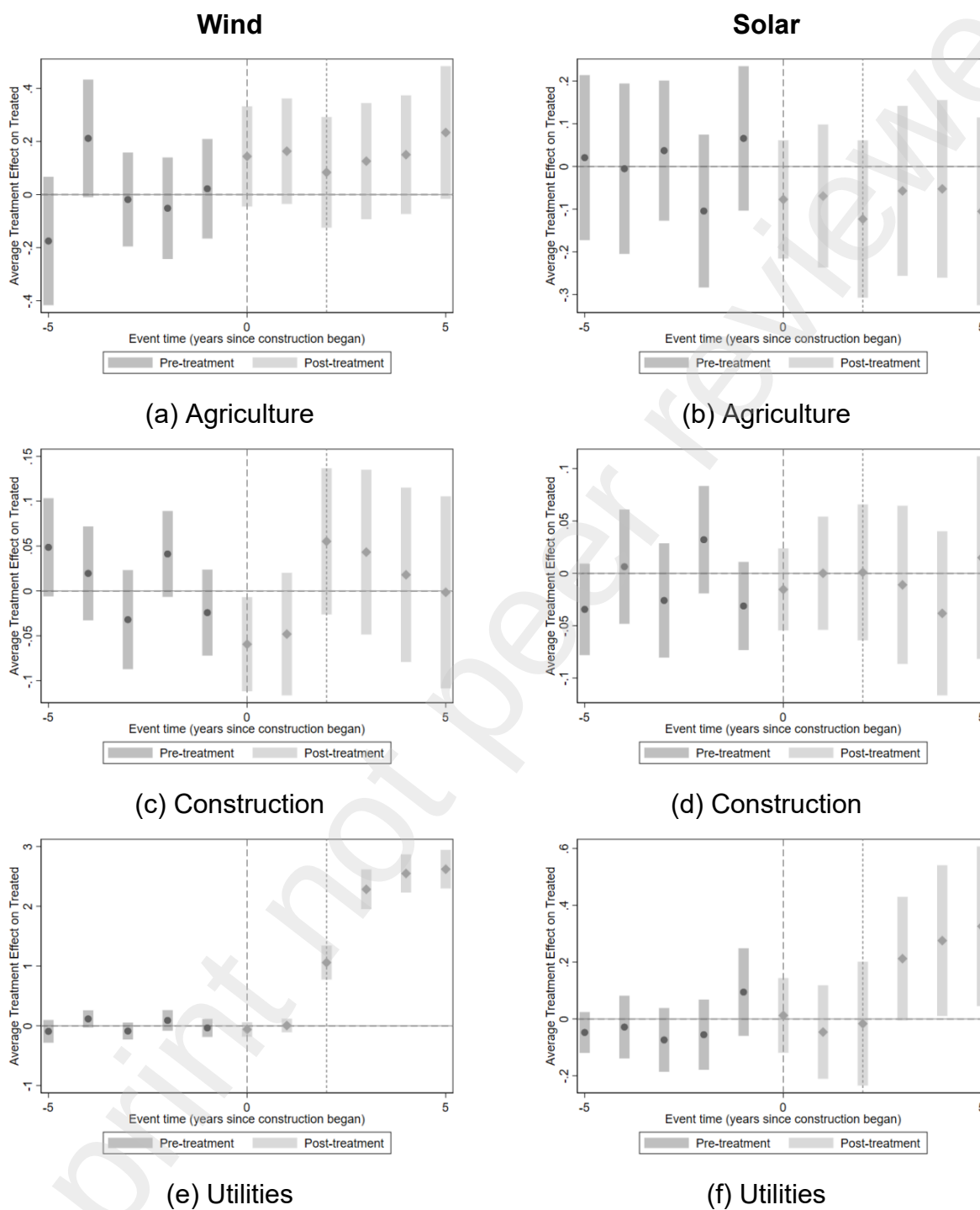


Figure S2.13. Renewable Adoption's Effect on Employment by Sector for Rural Ag. Counties

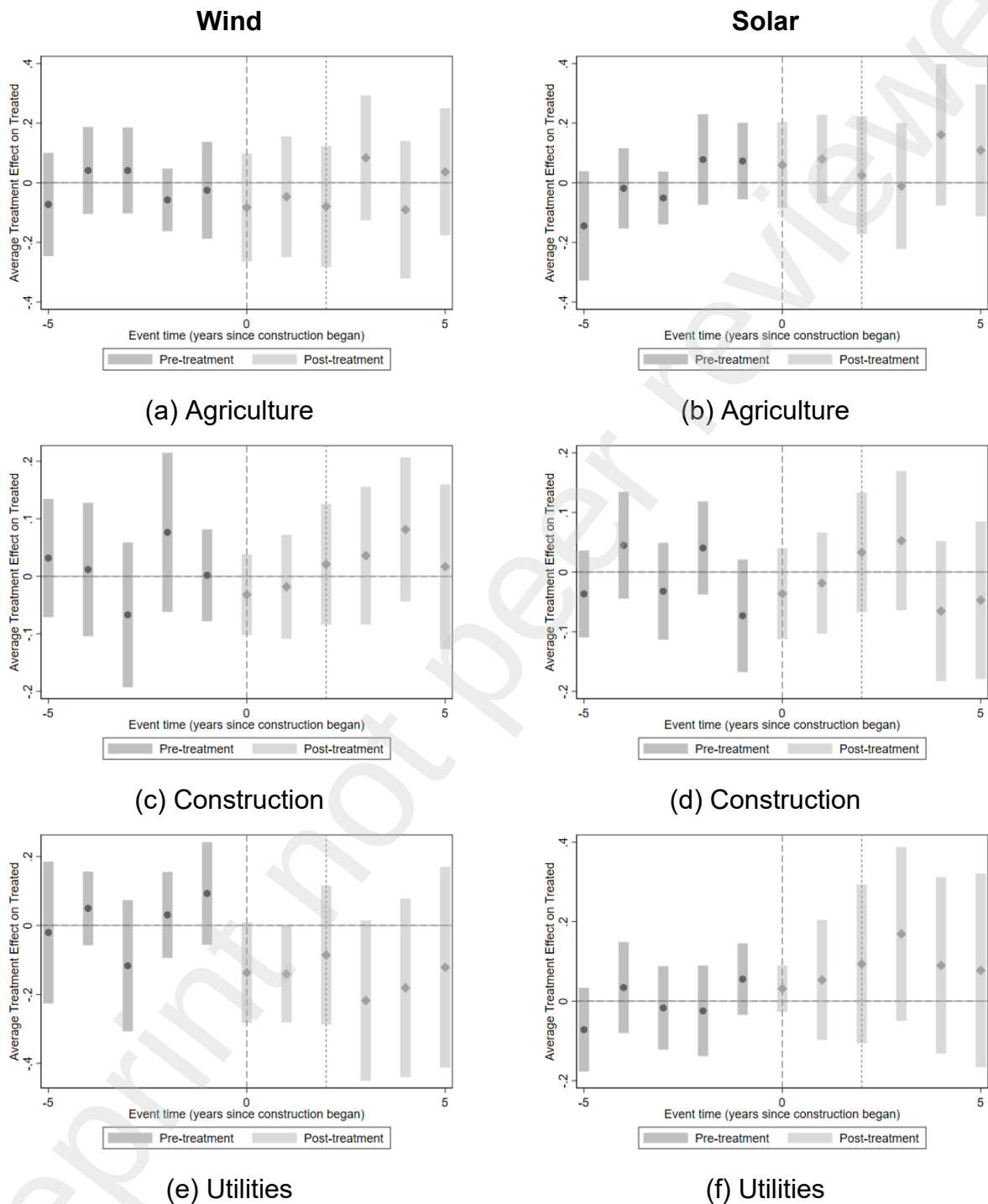
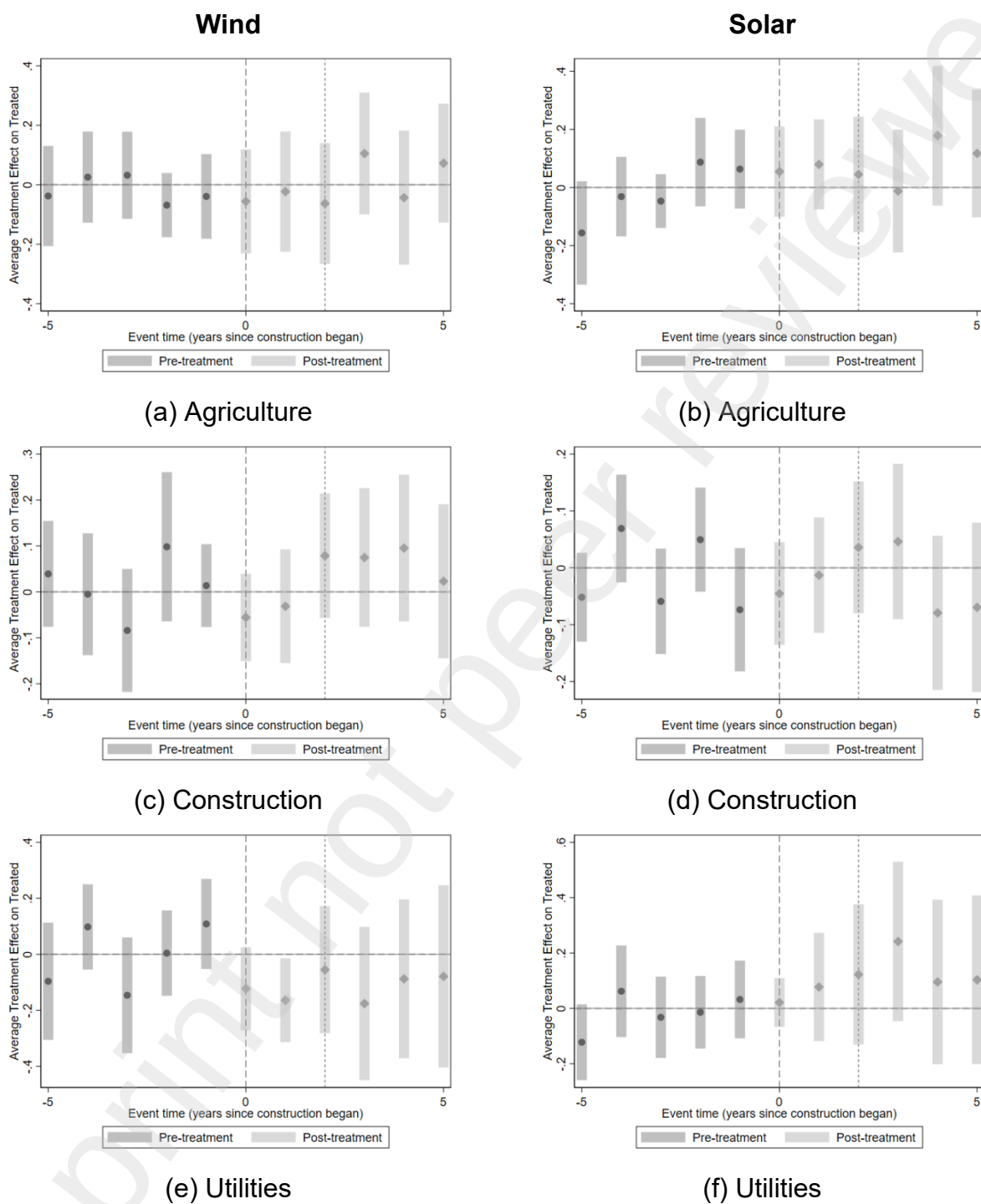


Figure S2.14. Renewable Adoption's Effect on Wages by Sector for Rural Ag. Counties



Online Supplemental Appendix S3. Main Model Results with Covariates

Figure S3.1. Effect of Renewable Adoption with Covariates

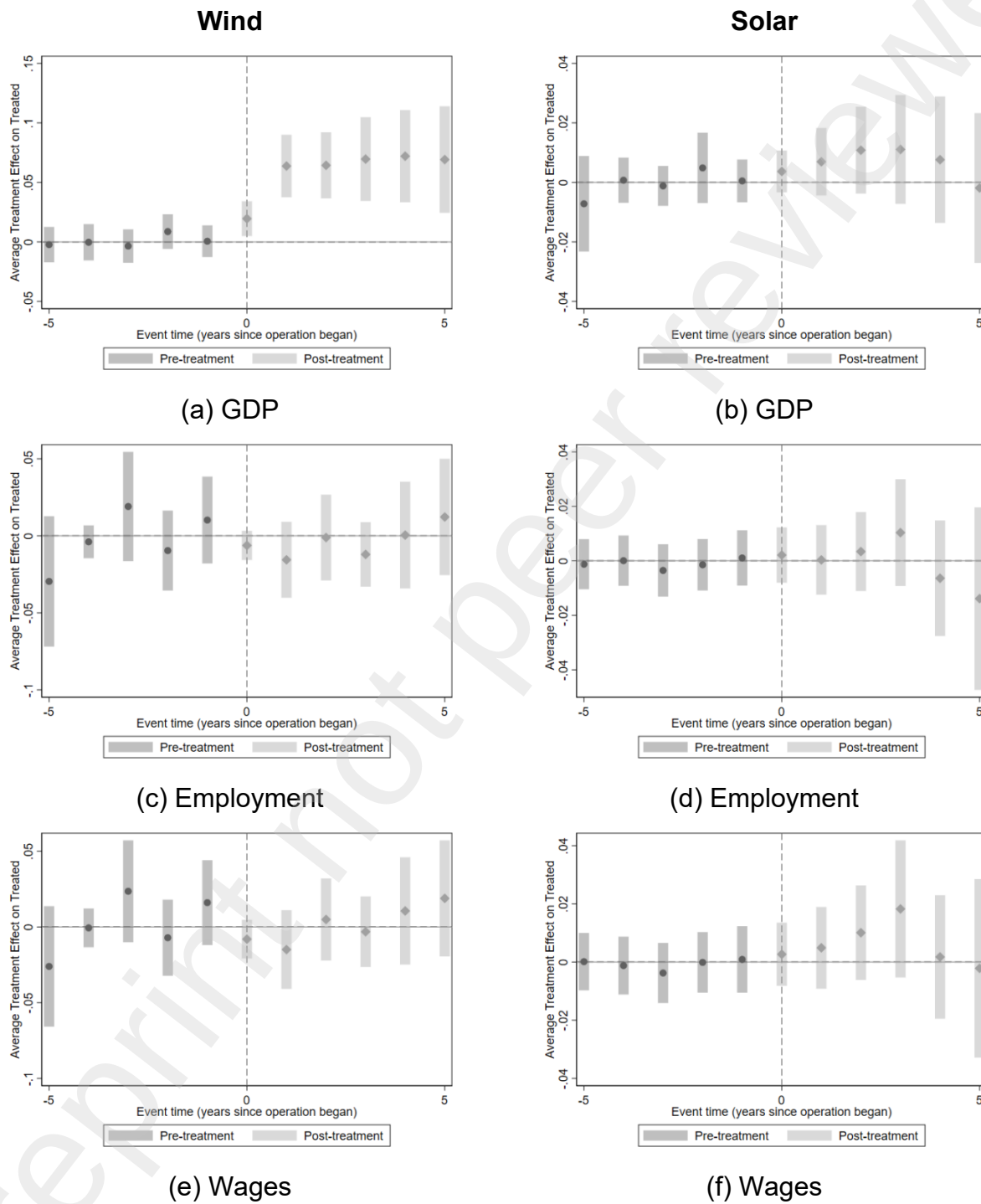


Figure S3.2. Renewable Adoption's Effect on GDP by Sector

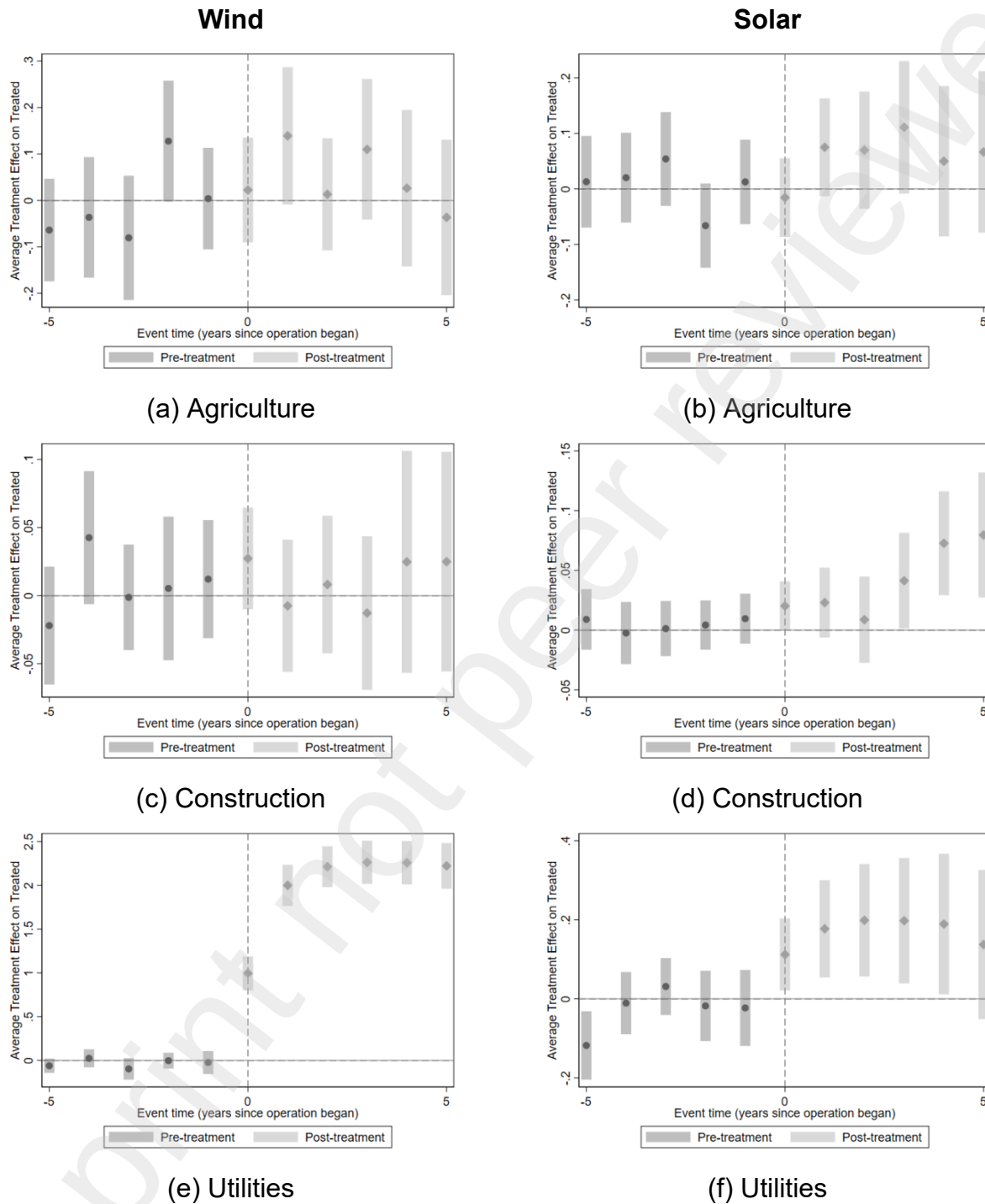


Figure S3.3. Renewable Adoption's Effect on Employment by Sector

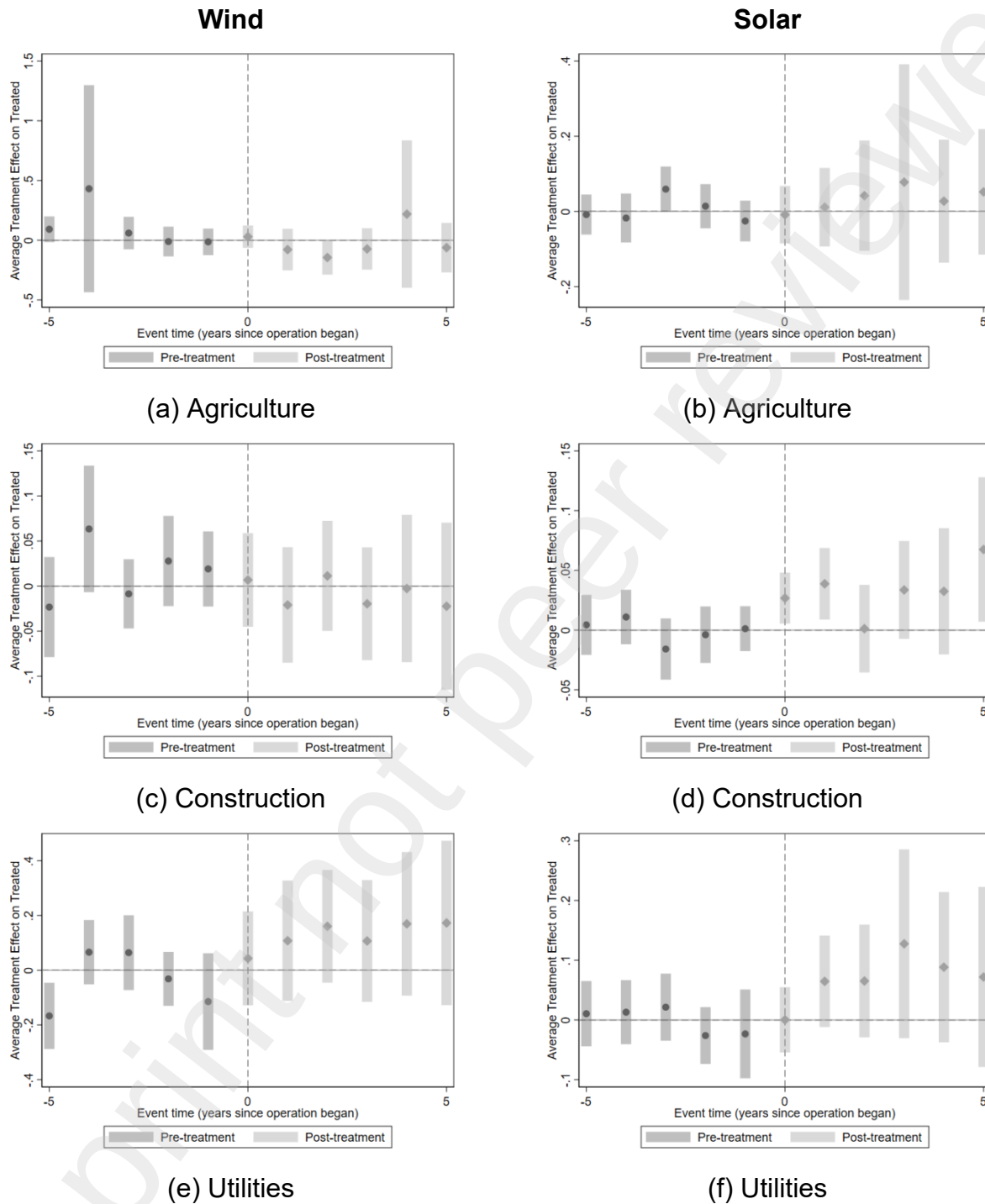


Figure S3.4. Renewable Adoption's Effect on Wages by Sector

