The Effects of Hydroelectric Projects on Local Communities: The Case of Chile

Abstract

Policymakers often see hydroelectric projects as a way to boost local economies, principally through job creation and investment inflow. This paper estimates the local effects of hydroelectric projects using Chilean data spanning 27 years. It employs a weighted two-way fixed effect difference-in-differences estimator that accounts for selection into treatment and heterogeneous treatment effects over time. In particular, this study focuses on salary and employment effects, glimpsing at housing and health effects. The results show no significant employment effects and the positive local salary effects are short-lived, limited to the second and third years after the project's construction starts. During these years, the projects increased local salaries in the construction industry by 29%, with positive spillover effects on the manufacturing and hospitality industries. Further, across all industries local salaries increased by 8%, concentrated in relatively poor and non-Indigenous counties. The short-term nature of the effects highlights the necessity of understanding the local effects of energy projects, especially as we are increasingly transitioning to renewable energy. Policymakers could use these short-lived economic benefits as a foundation for a more comprehensive development strategy that involves other industries and considers the needs of local communities.

Keywords: Hydroelectricity, Local labor markets, Two-way fixed effects, Difference-in-differences.

JEL Codes: Q4, Q2, J2, J3, C2

1 Introduction

The ongoing renewable energy transition experienced another year of record growth in 2021, with hydropower (hydro) leading the worldwide renewable energy generation (REN21, 2022). On the one hand, policymakers frequently view hydro projects as dual drivers of energy security and local economic stimulation, fostering local job creation and investment (Koch, 2002; Ministry of Energy, 2017).[1] This view has led to a surge in hydro projects worldwide since 2000, exemplified by Chile's threefold increase in its number of projects. On the other hand, the social sentiment towards hydro plants in Chile has deteriorated, resulting in conflicts and protests against the government and project developers (Ministry of Energy, 2011; 2015; Susskind et al., 2014). The communities that are intended to benefit from the hydroelectric projects, as advocated by policymakers, are showing resistance against them as they claim lack of local benefits. This resistance may be reinforced by the limited empirical evidence regarding these projects' short- and long-term effects on surrounding communities, despite their potential environmental benefits on a global scale and the broader positive economic implications in the country.

This paper aims to advance the understanding of the effects of hydro projects on local communities, with a specific focus on the Chilean context from 1990 to 2017.[2] In light of the countervailing perspectives from policymakers and project developers on one side and local communities on the other, the main goal is to empirically identify the effects of hydro projects on local salaries and employment at the county level.[3] Furthermore, this paper accounts for heterogeneous effects over time, adjusted by project size, and conducts specific analyses for counties with different demographic and socioeconomic compositions. In particular, the paper studies the impacts of these projects on counties with higher shares of Indigenous population, which may experience disproportionate adverse effects (Kelly, 2018).

Hydro facilities are often located in communities with specific characteristics that attract projects but are also related to outcome variables, such as salaries or housing prices. Following Abadie (2005), this paper addresses this selection problem by using pre-treatment variables deemed predictive of treatment to establish county-level weights representing the likelihood of undergoing treatment (i.e., hosting a hydro project). Employing these weights yields comparable control and treated counties based on observable characteristics. Subsequently, the weights are used in the primary specification, which relies on a newly developed two-way fixed effects (TWFE) difference-in-differences estimator (de Chaisemartin and D'Haultfoeuille, 2022). The estimator's main advantages for this study are that it allows heterogeneous treatment effects over time and a continuous treatment variable. The analysis considers 11 single-project counties ranging from 12 MW of capacity to 359 MW.

The results show a short-term increase in salary during the construction phase but no employment gain. The positive salary effect is industry-specific and concentrated in relatively poor and non-Indigenous counties. For example, considering an average size plant of 79 MW, salaries in the construction industry increase by

[1] For example, among the many benefits of hydropower, the U.S. Department of Energy lists on its website (www.energy.gov) that "hydropower creates jobs in rural locations and boosts local economies."

[2] The main data is collected roughly every second year so, throughout the paper, a period represents about two years.

[3] In Chile, counties represent the smallest administrative subdivisions.

29% between the second and third year after construction of the plant starts; however, this effect disappears afterward. The hospitality and manufacturing industries show a similar salary pattern, experiencing a 22% and 11% increase between the second and third years after construction starts and no effect thereafter. Across industries, the average local salary effect is 8% between the second and third year of construction, and no significant effects after that. These results suggest that local salary benefits are transitory, which is particularly important in the context of potentially longer-lasting local environmental costs.

Expanding upon two influential studies regarding hydro plants and local communities in Brazil (Faria et al., 2017; de Alburquerque et al., 2019), this paper's contribution is threefold. Firstly, it employs novel data specific to the Chilean context, incorporating a comprehensive set of variables influencing project placement. This dataset serves to mitigate the issue of projects self-selecting into particular county types. Secondly, in light of the existing literature, this is the first study on renewable energy projects that transitions from a dichotomic treatment indicator to a continuous treatment framework based on the installed capacity in MW, adjusted by the county's population size. This departure allows for the inclusion of relatively smaller projects in counties with low population density. Thirdly, this paper is the first step in bridging the qualitative evidence of hydro projects effects on Indigenous communities (Susskind et al., 2014; Kelly, 2018; Karanasios and Parker, 2018; Hoicka et al., 2021) towards a more quantitative approach. Although the nature of the available data limits the capacity to observe individual Indigenous communities directly, the paper employs the county's proportion of the Indigenous population as a proxy to analyze the effects of the hydro projects in this community.

This paper provides new empirical insights into the ongoing debate surrounding financial incentives for infrastructure and energy projects provided by policymakers. Drawing from the outcome variables analyzed, this study suggests that an exclusive reliance on hydro development may not be sufficient to boost local economies in the long run. However, the transitory benefits observed in this study suggest that policymakers could use this short-lived economic boost as a foundation for a more comprehensive development strategy that involves other industries, such as forestry and tourism. Furthermore, project developers and policymakers aiming to gain local support on these projects may rely on hydroelectricity's global environmental and economic benefits (e.g., lower electricity prices and pollution). The transfer of a portion of these global benefits to local communities for the enduring utilization of their surroundings might enhance the local perception of such projects. Increasing local benefits may facilitate the development of currently disputed and controversial projects.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 provides background information about Chile and the geographic distribution of the hydroelectric projects. Section 4 provides a detailed description of the empirical identification strategy, including the data sources and the estimator used in the analysis. Section 5 presents the main results, and Section 6 concludes.

2 Literature Review

Extensive literature studies the local labor market effects of new establishments, businesses, or social events on their communities (Michaels, 2010; Aragon and Rud, 2013; Adams, 2016). For instance, Humphreys and Marchand (2013) find that casino openings in Canada positively affect employment and earnings in the local areas. However, the authors caution that these are short-term effects, concentrated within the gambling and hospitality industries only. Similarly, Adams (2016) studied the effects of opening a motor vehicle assembly plant in the United States. The author, using propensity score matching, finds a positive effect on local employment. However, he finds that this effect is lower than predicted by ex-ante input-output models used by state development agencies to support these projects.

Regarding natural resources, the literature generally finds that resource extraction increases employment and income. Using a quasi-experimental approach Marchand (2012) shows that local labor markets with energy resources in Western Canada have greater employment and earnings growth compared to labor markets with no energy resources. Along the same line, but using a differences-in-differences approach, Aragon and Rud (2013) show that a large gold mine project in Peru positively affected real income in the local economy. Nevertheless, the evidence is rather mixed regarding inequality and other socioeconomic variables (Michaels, 2010; Marchand, 2015).

In the particular case of hydro projects, policymakers often view them as a way to boost local economies in the long run (Ministry of Energy, 2017). However, there is limited empirical evidence to support such claims. In particular, the debate of whether the local economic benefits of hydroelectric plants outweigh their social and environmental costs is wide open (Fearnside, 2001; Ansar et al., 2014). This is where this paper contributes, by empirically analyzing the local economic effects of hydro plants.

In two related papers, Faria et al. (2017) and de Alburquerque et al. (2019) study the effects of hydro plants in the Brazilian context. Faria et al. (2017) employ a TWFE difference-in-differences model to identify the causal effects of a binary treatment, using not-yet-treated counties as a control group. The authors find no evidence of increased average income or any long-term effects on other social indicators, such as life expectancy, educational level, access to electricity and piped water, HIV cases, and teenage pregnancy levels. While the authors mitigate the self-selection problem of projects and locations, they warn that, in general, there may be unobserved differences between control and treated counties, such as electricity infrastructure (e.g., electricity transmission lines), that could play an essential role in the location decision of the plants. Considering this information, this paper includes electricity transmission lines, electricity generation installed capacity, and electricity substations in the analysis.

De Alburquerque et al. (2019) also studied the Brazilian context. For their identification strategy, the authors rely on a difference-in-differences approach and Propensity Score Matching based on observable characteristics such as municipality-installed power, population, and region dummies. The authors find a positive effect on salaries and employment, while no effect on health (except birth rate) and environmental indicators (i.e., deforestation). Their study focuses on plants with more than 100 MW of capacity, excluding the potential impact of small-scale projects. In Chile, around 90% of the currently operating hydro projects are less than 100 MW of capacity. That is why including relatively small-scale projects in the analysis is crucial.

This paper extends the analysis of the above studies in several ways: first, it studies the effects of hydroelectric plants in the Chilean context. While Chile and Brazil approve projects mainly based on their feasibility, Chile has a different regulatory framework that allows private firms to decide the location of the plants exclusively based on project profitability.[4] This different regulatory framework means that in contrast to Brazil, the Chilean regulatory process to approve a project is relatively short, which reduces the possibility of anticipatory effects that may bias the estimators. For instance, if a big project is expected to be approved and starts building in the coming months or years, the behavior of other businesses may be affected (e.g., expand or contract their operations as an anticipated response to the project). These features facilitate the identification of the factors that determine the locations of the projects.

Second, this paper implements a continuous treatment indicator normalized by the county's population. Intuitively, bigger plants (i.e., higher generation capacity in MW relative to the county's population) have different requirements, such as more specialized labor and special land conditions, which may influence the magnitude and sign of the effects on the local population. So, a continuous treatment identifies heterogeneous effects depending on the plant size. Based on the existing literature, this is the first study that departs from the binary treatment indicator and analyzes the effects of hydroelectric plants based on their population-adjusted capacity.

Third, as new evidence has raised questions about the robustness of TWFE difference-in-differences estimators when facing heterogeneous treatment effects over time (de Chaisemartin and D'Haultfoeuille, 2020; Goodman-Bacon, 2021). This paper relies on a newly developed estimator that allows heterogeneous treatment effects across time and treated counties (de Chaisemartin and D'Haultfoeuille, 2022). As mentioned

[4] On the one hand, in Chile, private firms submit independent applications for project approvals, and, as private businesses, they are primarily profit-motivated projects. Additionally, water rights and most of the land in Chile are privately owned. On the other hand, the Brazilian government generally decides the location of projects and auctions out the projects to the private sector through competitive auctions. In this case, the main motivation is not based on profits but on other features such as increasing electrification or boosting local economies (Lipscomb et al., 2013). The profit-driven nature of hydro projects in the Chilean case facilitates the identification of the factors that determine the location of these projects.

earlier, the construction stage of a hydroelectric plant requires not only different types of workers but also a more significant number of workers compared to the operation stage of the plants (see Pacific Hydro, 2012 and Faria et. al, 2017 for examples of number of job created and investment during the construction phase). Therefore, the effects of a hydroelectric plant may fluctuate over time, leading to potential bias in the TWFE difference-in-differences models if not properly addressed.

Hydro plants stand out from other types of businesses because they generate additional externalities and effects, such as involuntary displacement, environmental impacts, and housing market distortions (Rosenberg et al., 1995; Trussart et al., 2002; Manyari and de Carvalho, 2007; Bohlen and Lewis, 2009). This paper glimpses into the latter two areas by assessing the effects on the probability of visiting a healthcare provider due to illness or accident and an indicator of owning versus renting a property.[5]

Finally, relatively new evidence highlights the importance of public perception in successfully developing renewable energy technologies, including hydroelectricity (Mayeda and Boyd, 2020). Particular attention has been given to the effects of energy projects on local Indigenous communities (Susskind et al., 2014; Kelly, 2018) and the different ways of engaging with Indigenous communities in the development of renewable energy projects (Karanasios and Parker, 2018; Hoicka et al., 2021). Indigenous communities may experience disproportionate adverse effects, for example when asked to relocate or their sacred lands are damaged, influencing negatively their culture (Kelly, 2018). This paper is a first step to bridging the gap between qualitative case-specific analysis of hydroelectric projects' effects on Indigenous communities and a quantitative approach to estimating these effects.

3 Chilean Background

This section includes relevant information about Chile and the geographic distribution of hydroelectric projects. The objective is to provide a broad view of the Chilean context and information on how the government revised and approved the projects during the study period.

According to the Library of the National Congress,[6] Chile is divided into 346 counties, which represent the smallest administrative subdivision. Based on the 2017 Census, the county's geographic area and population vary greatly, ranging from 6.5 km^2 to $48,974$ km^2 and from 311 inhabitants to $617,914$ (excluding the Antarctic county). The average county size is 300 km^2, and the average population is $50,939$ per county. INE (2018) reported that in 1992, 16.5% of the population lived in rural areas and that by 2017 that percentage decreased to 12.2%.

[5]Refer to Lerer and Scudder (1999) and Smith et al. (2013) for evidence of environmental effects on human health, and Moretti (2011) and Kline and Moretti (2014) for the theory behind labor demand shocks and housing demand.

[6]The information of the Library of the National Congress (Biblioteca del Congreso Nacional de Chile) is publicly available on their website: www.bcn.cl.

In Chile, provincial and local jurisdictions exist, but the national government has the supreme legislative authority. For example, the same minimum wage and labor legislation apply to all counties, and local jurisdictions cannot modify this. In terms of identification strategy, this centralized authority configuration is convenient because all projects face the same regulations and legal conditions for approval. Additionally, Chile is one of the few countries worldwide with privatized water resources. In 1981, the national government started distributing free water rights to the private sector (in cubic liters per second). However, between January and March of 1990, the vast majority of these property rights were allocated (about 74% of all property rights). These property rights were mainly allocated to the private electricity company ENDESA (now named ENEL), which led to an oligopoly water market.

Faria et al. (2017) comment on the importance of electricity infrastructure in the location decisions of hydro projects. In Chile, during the study period, the electricity market was divided into four main independent sub-markets: Central Interconnected System (SIC), Grand North Interconnected System (SING), Aysen System (SEA), and Magallanes System (SEM).[7] Electricity generators face three different, independent markets: regulated consumers, unregulated consumers, and spot market. The regulator sets nodal prices for regulated consumers (consumers below 5 MWh) twice a year aiming to reflect the marginal cost of generation, transmission, and distribution of electricity. If this regulated price truly captures the marginal cost of generation, then it does not affect the profitability of the project. For consumers above 5 MWh the price is unregulated and the firms can negotiate long-term contracts directly with the consumers. The Chilean regulator assumes that consumers above 5 MWh have bargaining power to negotiate with generators. In the spot market, firms interact with each other to sell and buy electricity to cover their long-term contracts and other necessities. In this market, the independent system operator (ISO) uses a cost-based dispatch to clear demand and supply.[8] The profitability (therefore the location of the projects) may be affected if generators sell most of their output to unregulated consumers or the spot market firm can exercise market power; however, the final sample of projects analyzed in this paper sells most of their output to regulated consumers.

Private companies own the generation, transmission, and distribution of electricity and the government acts as a regulator and, in some cases, as a subsidiary for companies that need financial help. The electricity infrastructure (e.g., transmission lines and electricity substations) directly affect the profitability of the hydroelectric projects because the firm must cover the cost to transport its electricity generated to the

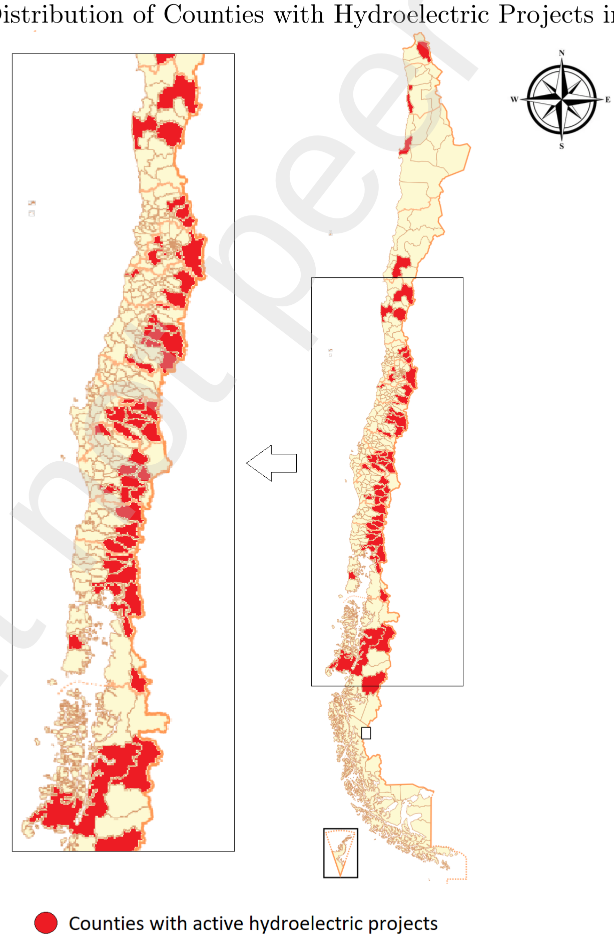
[7]In 2017, SIC and SING merged to form the National Electricity System (SEN), but this likely does not affect the analysis because 2017 is the last year of the study period.

[8]In Chile, power plants submit the marginal costs of their generation units to the ISO. Based on this information, the ISO ranks power plants from those with lower marginal costs to those with higher marginal costs and determines the generators required to balance demand and supply. The resulting spot market price is equal to the marginal cost of the most expensive unit of generation in use, which is published hourly at the node level (the most spatially disaggregated price points).

nearest transmission line. This transmission line receives electricity from all surrounding generators, so it is important to know the total capacity already installed in the area.

According to the Chilean National Energy Commission, 185 private hydroelectric projects were operating in 2022, providing about 7,254 MW of capacity. This represents slightly less than 30% of the country's total generation capacity. As of 2022, there are 67 medium-to-large projects with sizes ranging from 10 MW to slightly less than 700 MW. Likewise, there are 118 small hydro projects of less than 10 MW. Approximately 51% of these plants are located in traditional Indigenous territory, creating disagreements between Indigenous communities and hydro proponents (Susskind et al., 2014; Kelly, 2018). Figure 1 shows the distribution of the counties with hydroelectric projects. The 61 counties with projects currently operating are highlighted in red. Aside from the three counties in the north, all hydroelectric projects are concentrated in the middle portion of the county, which helps with identifying comparable counties without projects.

Figure 1: Distribution of Counties with Hydroelectric Projects in Chile



In Chile, private companies independently propose hydroelectric projects. Projects larger than 3 MW are required to submit an environmental evaluation with a detailed description of the three main stages of the project: construction, operation, and closure (see, for example, SEA, 2021).[9] The project's developers chooses the location and all technical specifications, which the government evaluates. In addition, the government requires an Indigenous consultation per project; however, a project cannot be rejected solely based on a negative response to the consultation. The limited role of the Indigenous consultation has led to considerable public opposition and local conflicts. For example, the Río Picoiquén project became operational despite the opposition of the local Mapuche communities (Susskind et al., 2014). After this project was built, there was a subsequent increase in conflicts in the area.[10]

To provide a sense of the magnitudes of the projects included in this study, take the case of Machalí. This county, started constructing a 111 MW hydro project in 2006. Machalí's population in that year was 32,583 inhabitants, and the county covers an area of 2,865 km^2. According to Pacific Hydro (2012), the hydroelectric plant "Chacayes" employed 2,652 full-time workers at its construction peak, and the construction investment was approximately US$450 million. While the company claims to provide training for local workers, it does not provide information regarding the origin of the workers hired during the construction stage (local or from outside the county).[11] This project meant a sudden labor demand of about 8.1% of the county population. Pacific Hydro argues that the construction of the hydroelectric plant helped more than 2,000 people directly and approximately 3,000 people indirectly, "contributing to the regional, local, and national development" (Pacific Hydro, 2012).[12] This study aims to examine these claims empirically.

4 Empirical Methodology

This section starts by describing the data sources used in this study. Second, it presents a detailed description of the treated counties (i.e., counties with hydro projects starting the construction phase during the study period) and summary statistics comparing the treated and control groups before the treatment occurs. The purpose of this section is to explain the main methodological challenges, starting from understanding how well-suited are the control counties to be a good comparison group for treated counties. It is shown that control and treated counties are different in various dimensions, which needs to be addressed before they can be comparable. Once this difference is addressed, the section discusses the primary identification strategy.

[9] In some specific cases for proposed plants located in sensitive environmental areas, the government may require an environmental impact assessment for less than 3 MW projects.

[10] Indigenous communities represent a large portion of the conflicts related to hydro projects. Mapuches are the largest indigenous community in Chile, with about 10% of the total population, followed by Aymara and Diaguita, with 1% and 0.5%, respectively (INE, 2018).

[11] According to IHA (2021), building medium and small-size hydroelectric projects do not require on-site housing unless they are located in highly isolated rural areas. In Chile, there is limited information regarding camp sites to host employees during the construction of the projects, especially for projects that are more geographically isolated. However, all the projects analyzed in this paper are close to towns, which decreases the probability of needing on-site housing.

[12] The quote "contributing to the regional, local, and national development" was translated from the Spanish "... contribuyendo así al desarrollo regional, local y nacional."

4.1 Data

The data is combined from five different sources. The primary dataset used is CASEN (Encuesta de Caracterización Socioeconomica Nacional), which is publicly available from the Ministry of Social Development of Chile. These are repeated cross-sectional surveys implemented approximately every two years from 1990 to 2017, which means that a period in the analysis represents two to three years.[13] CASEN is an individual-level survey representative of the national population that aims to characterize the socioeconomic conditions of Chilean households. The survey is administered through in-person interviews with household heads (or another adult) in randomly selected households in the country. CASEN contains measures of household size, education, gender, age, marital status, income other than salary, detailed health description, and household appliances, among others. All the outcome variables in this study (i.e., salary, employment, housing, and health) are based on CASEN data. In addition to CASEN, four other data sources provide information on the main factors that determine the location of the projects in the Chilean context: Indigenous political representation and conflicts, river water resources, and electricity infrastructure.

In Chile, Indigenous communities are often openly against the development of hydroelectric projects. To account for this opposition, this paper uses information regarding Indigenous communities from the Mapuche Data Project (MDP). The MDP is a dataset that provides detailed county-level information about Indigenous land ownership, political representation (elected and running representatives), and conflict information. A conflict is generally defined as an alteration of the public order that needs the intervention of law enforcement.[14]

Intuitively, the amount of water flowing in the rivers is another factor that determines the viability of a hydroelectric project. Therefore, county-level water data is obtained from the Center for Climate and Resilience Research (CR2). The CR2 has collected water flow from rivers (in cubic meters per second) at 788 stations along the country from 1930 to 2016. The daily observations are per river, but for this paper the observations are aggregated into a yearly county-level measure of river water flows.

Finally, information regarding electrical infrastructure is included (i.e., transmission lines and substations) with spatial data from the Chilean Ministry of Energy. The data is aggregated at the county-level per year. The analysis also includes the km of lines and the number of substations adjusted by the county's population and geographic area. Furthermore, the county's electricity generation capacity installed is obtained from the National Energy Commission (CNE). The CNE provides detailed information about the type of generation facility (e.g., solar, wind, and natural gas), location, capacity, ownership, and year of operation. It is

[13]The relevant surveys for this study were carried out in 1990, 1992, 1994, 1996, 1998, 2000, 2003, 2006, 2009, 2011, 2013, 2015, and 2017.

[14]In this analysis, all types of conflicts are included but the results are robust to restricting the conflicts to energy-related projects.

important to control for nearby generation facilities primarily because of possible electricity transmission congestion.

4.2 County Groups Description

During the period of study, 32 counties initiated the construction of hydro projects. Due to data limitations (e.g., not enough pre- and post-treatment periods), 11 counties with single projects are considered. Table 1 briefly describes the treated counties considered in the analysis. Of the 11 treated counties, Melipeuco has the lowest total population, while Los Andes is the most populated. There is a significant variation in the rural population, ranging from counties that are almost entirely urban, like Mejillones, to other counties with around 70% rural population, like Puerto Octay and Colbún. Likewise, the Indigenous population share is low in most treated counties, and only three counties are above the national average of 13%. Regarding geographic area, San Esteban is the smallest, and Coyhaique is the largest. The largest plant in the sample is in San Fernando, with 359 MW capacity, while the smallest is in San José de Maipo, with 12 MW. Two plants started construction in 2000, four in 2006, four in 2009, and one in 2011. As mentioned earlier, the construction stage involves most of the investment inflow and is expected to create the most jobs. Therefore, the start of the construction stage is set as the initial treatment period. In the sample, the construction stage lasts between 2 and 6 years, depending on the project size.[15]

Table 1: Description of Treated Counties

County	Population	Rural Population	Indigenous Population	Area (KM^2)	Plant Capacity	Construction Year
Melipeuco	5,781	61%	48%	1,107	11.7	2006
Puerto Octay	9,517	68%	9.6%	1,795	22.9	2011
Mejillones	7,834	1.3%	1.2%	3,803	177.5	2009
Chonchi	12,941	66%	21%	1,362	13	2009
San José de Maipo	12,606	30%	4.6%	4,994	12	2009
San Esteban	13,560	54%	1.0%	681	25.7	2000
Colbún	17,686	71%	0.7%	2,899	48.5	2006
Machalí	28,427	6.9%	0.5%	2,597	124	2006
Coyhaique	44,017	12%	10%	7,290	14	2000
San Fernando	64,524	21%	1.6%	2,441	359	2009
Los Andes	56,627	6.6%	1.6%	1,248	61	2006

Notes: Plant capacity is expressed in MW. Averages are estimated using pre-treatment periods.

The primary specification includes 11 treated counties and 175 control counties. Some counties were excluded from the primary analysis if they had previous operating hydroelectric projects, which means that treated counties are compared with never-treated counties. This is relaxed in the robustness check of Subsection 5.3.

[15]The duration of the construction stage is approximated and based on a informal documents.

Table 2 shows the summary statistics of the four output variables of this paper. The full comparison, including other relevant variables, can be found in Table 3 of Appendix 2. Note that the tables compare treated and control counties during the pre-treatment periods.[16] The only variables that are similar between control and treated counties are the probabilities of visiting a doctor and of being employed. The average salary and the probability to rent versus own are considerably different between groups.

Table 2: Summary Statistics, Treated vs. Control Group

Variable	Group	Mean	Standard Deviation	Minimum	Maximum
Average Salary	Treated	283	424	0	7,177
	Control	205	340	0	7,465
Probability to Visit a Doctor	Treated	0.09	0.28	0	1
	Control	0.09	0.29	0	1
Probability to Rent versus Own	Treated	0.21	0.41	0	1
	Control	0.13	0.34	0	1
Probability of Being Employed	Treated	0.36	0.48	0	1
	Control	0.33	0.47	0	1

Notes: The averages presented are considered before 2000, when the first project started to be constructed. Probability of being employed include the whole population. Salaries are expressed in CAD per month.
A test for differences between control and treated means can be found in Appendix 3.

According to Table 2 (and Table 3 in Appendix 2), hydro projects tend to be located in areas with higher salaries, greater electricity infrastructure, and fewer water resources. Additionally, projects are self-selected into relatively peaceful counties with higher Indigenous representation. These differences demonstrate that there are some observable discrepancies across the treatment and control counties. Consequently, the empirical methodology must control for these differences.

4.3 Identification Strategy

This subsection provides a brief description of the identification strategy of the study. Refer to Appendix 3 for a more detailed characterization of the identification approach. As mentioned earlier, this study aims to analyze the effects of hydro plants on salaries, employment, and glimpsing at the housing market and health effects. While the treatment is at the county level (i.e., once a county hosts a project, all individuals in that county become treated), individual-level measures are observed; therefore, the estimations are at the individual level.

The salary variable is defined as the logarithm of inflation-adjusted salaries to reduce the influence of outliers. The employment variable is defined by a binary indicator that equals one if the person is

[16] As shown in Table 1, the starting date of the construction stage (i.e., the treatment) differs depending on the treated county. This means that pre-treatment periods will depend on what county is considered. For example, 2003 is considered pre-treatment for a county treated in 2006, but post-treatment for a county treated in 2000. The earliest year a county becomes treated is 2000, so the summary statistics in Tables 2 and 3 are averages from 1990 to 1998.

working and zero otherwise, including individuals aged between 15 and 65 years old. The housing variable is represented by a binary indicator that equals one for households that rent and zero for households that own the property.[17] Finally, the health variable is a binary indicator that equals one if the person has visited a health care provider due to illness or accident in the last three months and zero otherwise.

To mitigate the problem of selection into treatment, Abadie (2005) proposed the weighted difference-in-differences estimator to find control groups with similar pre-treatment characteristics to treated groups, such that both groups have a similar probability of being treated based on these observable factors. To determine what factors are relevant to estimate the weights, a balance test is employed.[18] Different factors are included, like electricity infrastructure, Indigenous political representation, river water distribution, among others.[19] The main takeaway of the balance test results is that electricity infrastructure and Indigenous presence are critical factors determining the location of the projects.

To obtain the average treatment effect on the treated, the primary specification relies on a TWFE difference-in-differences estimator. However, as de Chaisemartin and D'Haultfoeuille (2020) and Goodman-Bacon (2021) point out, the standard TWFE difference-in-differences estimator is not robust when treatment is not constant over time. In this case, there are strong arguments to believe that the effects of hydro projects are heterogeneous over time, particularly comparing the construction and post-construction periods. Therefore, a new version of this estimator proposed by de Chaisemartin and D'Haultfoeuille (2022) is used. This estimator is a generalization of the event-study approach that allows for continuous treatment and heterogeneous treatment effects over time and across treated units.

Equation (1) shows the adaptation of de Chaisemartin and D'Haultfoeuille's model to this study:

$$Y_{ict} = \alpha + \sum_{t=-q}^{F_c-1} \kappa_t D_{ct} + \sum_{t=F_c}^{T} \gamma_t D_{ct} + \lambda_t + \mu_c + X_{ict} + \epsilon_{ict}, \quad (1)$$

where Y_{ict} is one of the four outcome variables and $t = F_c$ is the period when treatment starts. α represents the intercept, κ_t is the coefficient of the placebo estimators for each pre-treatment period from $t = -q$ to $t = F_c - 1$. The κ_t coefficients test for the parallel trend assumption of a difference-in-differences design. γ_t is the coefficient of the treatment effects for each $t \geq F_c$. Treatment D_{ct} is defined as above. λ_t and μ_c are time and county fixed effects, respectively. X_{ict} is a vector of control variables.[20] The error term, ϵ_{ict}, is clustered at the county level.

[17] Renting and owning a property accounts for, on average, 93% of total types of ownership, which is relatively stable over time. While it cannot be ruled out that composition changes over time in treated and control counties, it is assumed that the proportion of other types of ownership is sufficiently small not to impact the results significantly.

[18] In essence, the balance test analyzes if the means reported in Tables 2 and 3. are statistically different from each other.

[19] Refer to Appendix 4 for a complete list of the variables included in the balance test.

[20] The controls for salary are age, gender, education, and the number of members in the household. For the probability of being employed, the controls are age, gender, and education. For the probability of renting versus owning a house, the controls are the household salary, education, and age. Finally, for the probability of visiting a doctor, household salary, age, and gender are included as control variables.

The interpretation of the γ coefficients in equation (1) depends on the average treatment estimator of each post-treatment period, and it is calculated following:

$$ATET_t = \gamma_t \left(\frac{MW\,cap \cdot 1,000}{population} \right) \left(\frac{1}{\overline{MW\,added_t}} \right), \tag{2}$$

where $ATET_t$ is the average treatment effect on the treated at period t per MW, normalized by $1,000$ inhabitants. γ_t is the estimator that represents the effect in period t. $MW\,cap$ and $population$ are the capacity of the hydroelectric plants in the sample and the population of the counties, respectively (in this sample, the average $MW\,cap = 79$ and the average $population = 27,000$). Additionally, $\overline{MW\,added_t}$ represents the average MW per 1,000 inhabitants built from period zero to t, which is presented in Appendix 5. Intuitively, equation (2) transforms the estimator effect, γ, into a "per MW effect", and then scales it up by the population-adjusted plant size. Note that setting $MW\,cap = 1$ yield the effects per MW per $1,000$ population.

Aside from this main specification, this paper analyzes heterogeneity effects by industry, county's income level, and share of the Indigenous population. The industry analysis includes mining, manufacturing, construction, agriculture (including the fishing industry), and hospitality and commerce because these are the most relevant industries in the treated counties.[21] The pre-treatment poverty share of counties estimated by Agostini et al. (2008) is used to group counties per income level. Finally, the CASEN survey started collecting data about Indigenous identification in 2000. This information is used to divide counties according to their share of Indigenous population.[22]

5 Results

This section presents the results from the identification strategy detailed above. The first-stage event-study results show the intensity of the treatment for every period after the treatment starts, and are presented in Appendix 5. Recall that the estimator described in equation (1) represents the average effect for each period, but it does not have a direct interpretation. This average effect depends on the number of MW built per $1,000$ inhabitants in each period. Based on the first-stage event-study results, this section presents the labor market results for the main specification and also when the sample is divided by income level, the share of Indigenous population, and by industry. Subsequently, the section focuses on the housing and health outcomes. Finally, the results are complemented by two robustness analyses. First, counties with existing hydro projects are included as part of the control group and, second, neighboring counties are excluded from

[21] The most important industries in Chile are mining, entrepreneurial and financial services, manufacturing, construction, agriculture (including fishing and forestry), and hospitality and commerce (Banco Central de Chile, 2020).

[22] As the Indigenous identification variable started in 2000, two counties treated that year are excluded from the analysis.

the control group.

5.1 Labor Outcomes

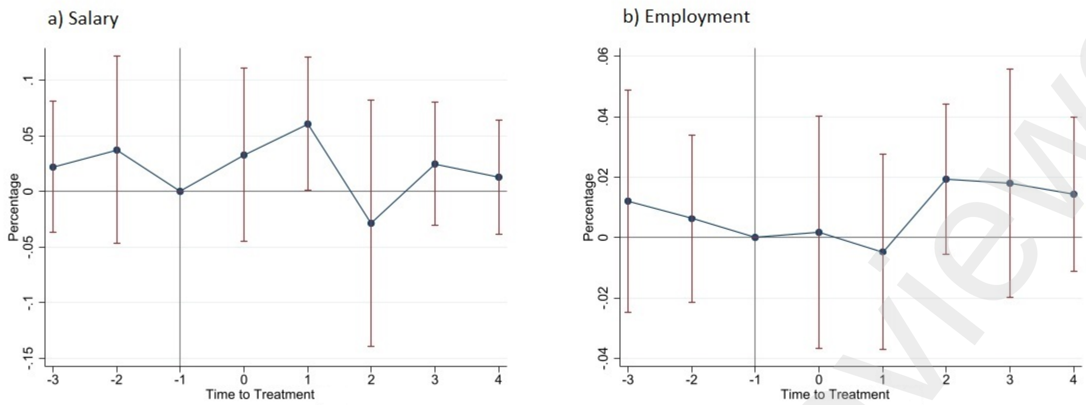
Figure 2 shows the average effects of hydroelectric projects on salaries and employment across all industries. In this and the following figures, the 95% confidence intervals are represented by the vertical red lines. Period zero, on the x-axis, represents the year construction started in each treated county. On the left-hand side of zero, the placebo estimators show the average effect before construction started. Panel a) shows that before treatment started, the logarithm of salary was not statistically different between control and treated counties, which validates the parallel trend assumption. The results show that the hydro project is responsible for increasing salary during the two and three years after the construction begins (recall that a period represents two to three years). In period one, the average effect is a 0.028% salary increase per MW built. As the average plant capacity in the sample is 79 MW, the average effect is about 8%, which is below the 12.5% found by de Alburquerque et al. (2019).[23]

Panel b) shows that the parallel trend assumption is no violated; however, hydroelectric projects have no significant effects on employment during construction or operation stages. This result raises questions about who is employed in these projects. In the example of Machalí, Pacific Hydro claims to have employed 2,652 full-time workers during the peak of the construction stage. This is an important labor demand shock for a small county, but the results show no significant effect.[24] It may be the case that a similar number of jobs were destroyed, so the net effect is insignificant. Another explanation is that migrants take the jobs and commute from their neighboring counties. If this is the case, these workers will declare their residencies in their home neighbor county, and no effects will be observed on employment in the treated county. Section 5.3 further investigates this possibility.

[23] Note that de Alburquerque et al. (2019) analyze plants starting at 100 MW of capacity. Therefore, for a 111 MW capacity, like in the Machalí example, the results would indicate a 11.3% salary increase, which is closer to what the authors find. The calculation of the average treatment effect of a 111 MW plant is given by $ATET = 0.055 \left(\frac{111 \cdot 1{,}000}{27{,}000}\right)\left(\frac{1}{2}\right) \approx 11.3\%$.

[24] The effects shown in Figure 2 are averages across all treated units. It may be the case that the in the specific case of Machalí, the employment results are significant during the construction stage; however, the analysis cannot isolate the specific effects of one project.

Figure 2: Labor Outcomes Results

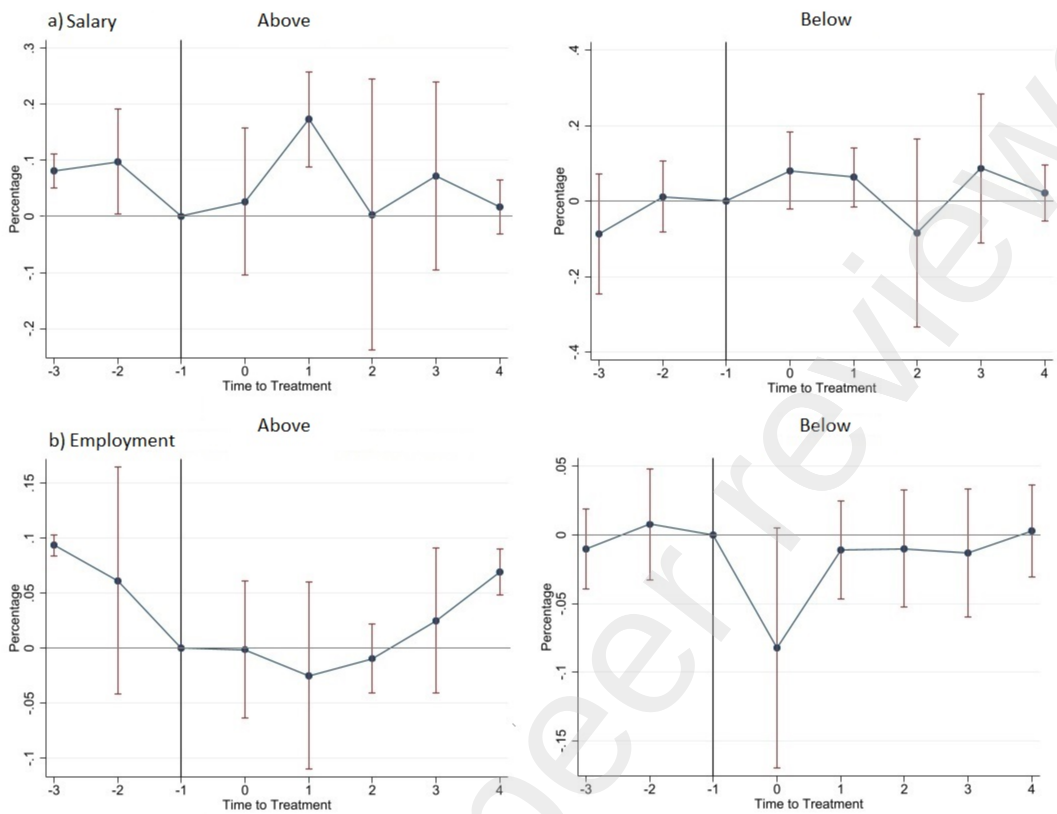


Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

The results across industries show a weak positive effect on salaries during the first period after the construction stage starts (i.e., two or three years after the construction starts) and no significant effect on employment. Next, the analysis divides the samples by income levels, share of Indigenous population, and industries.

If the government uses hydroelectric projects to boost local economies, it may be that the effects are concentrated in relatively poorer counties. Figure 3 shows the labor outcome results, separated by counties below the poverty average (i.e., relatively rich counties, on the right) and above it (i.e., relatively poor counties, on the left). The salary effects in panel a) seem to be concentrated in relatively poor counties; however, the placebo estimators indicate that the parallel assumption is not satisfied for counties below the poverty average. This violation of the parallel assumption may be driven by the low number of treated counties in this specification (i.e., three treated counties). Nevertheless, in the case of relatively rich counties, the figure shows no significant effect on salaries and employment, which suggests that the effects observed in panel a) of Figure 2 may be driven by relatively poor counties.

Figure 3: Labor Outcomes, by Income Level



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

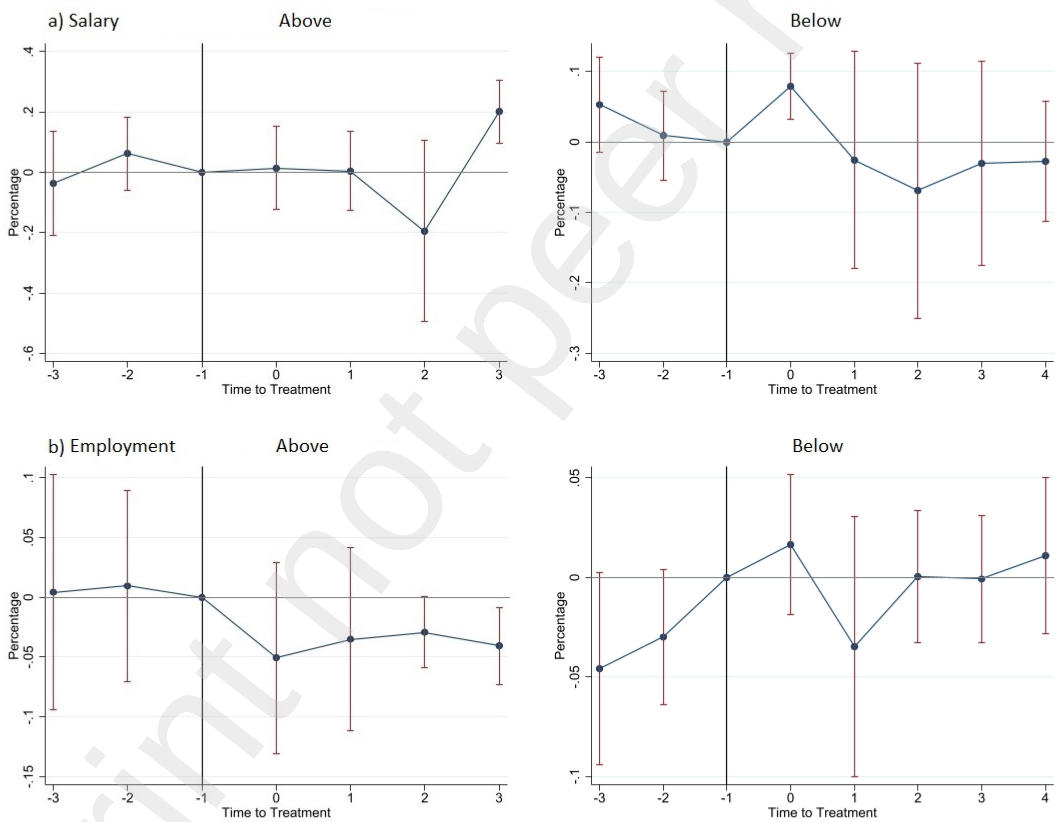
As highlighted by Susskind et al. (2014) and Kelly (2018), Indigenous people may experience disproportionate adverse effects by the development of hydroelectric projects. Figure 4 shows the results of the labor outcome variables for counties with an Indigenous population share above the national average (on the left) and counties with an Indigenous population share below the national average (on the right).

The placebo estimators for both sub-samples satisfy the parallel trend assumption.[25] Panel a) shows that, for relatively Indigenous counties salary increases in period three after the construction stage began, but for relatively non-Indigenous counties the salary increase happens in the period when construction starts. Additionally, panel b) shows that on relatively Indigenous counties employment decreases in period 3, which may be explained if workers hired during the construction stage lose their jobs after construction is finished. This would be consistent with channel two discussed in Appendix 1 (switch between jobs). If workers switch between jobs, no changes should be observed in employment during the construction stage. However, once the construction of the plant is finished, those workers become unemployed, so the probability of being employed decreases. There is no significant employment effects for relatively non-Indigenous counties.

[25]The event-study graphs for relatively more Indigenous counties present only three lags because the three projects analyzed only have three post-period data.

The three treated counties that are above the national Indigenous population average are the smallest in the sample, with less than $10,000$ inhabitants. Chonchi, one of the three treated counties, has in motion a "Plan for County Development" that aims to attract new businesses and residents to the county (see Soval (2018) for a detailed description of this plan). The plan started the design stage in 2005, but the construction of local infrastructure (e.g., roads and new neighborhoods) started in 2015. Using CASEN data, the inflation-adjusted county average salary increased by 47.2% from 2013 to 2017. This means that the results in the third period after construction starts may be affected by this external shock. Moreover, this county development plan may attract an excess workforce, which would help explain the decrease in employment.

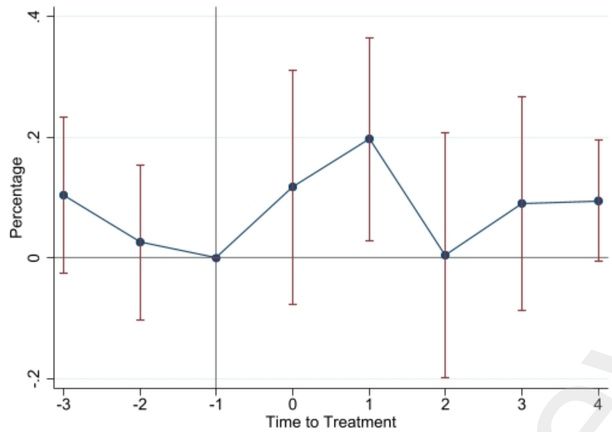
Figure 4: Labor Outcomes, by Indigenous Population



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

Figure 5 shows the effects of the hydroelectric projects on the salaries in the construction industry. The format of the figure is the same as the previous results. The placebo estimators test the parallel trend assumption for the pre-treatment periods to the left of zero. In this case, the estimators are not statistically different from zero, which indicates that the parallel trend assumption is satisfied. The graph shows that salaries increase significantly during the construction stage in period one.

Figure 5: Salary Results, Construction Industry



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

Following equation (2) and the estimator of Figure 5, the average treatment effect of a 79 MW plant on the treated counties in period one is a 29% increase in salary, or 0.37% per MW of capacity built. This large effect is only present during the construction peak and quickly disappears after 4 to 6 years (i.e., from period two). In the 111 MW plant example of Machalí county detailed in Section 3, the results would indicate that the average salary increased by 34% in the construction industry during the peak of the construction stage.[26]

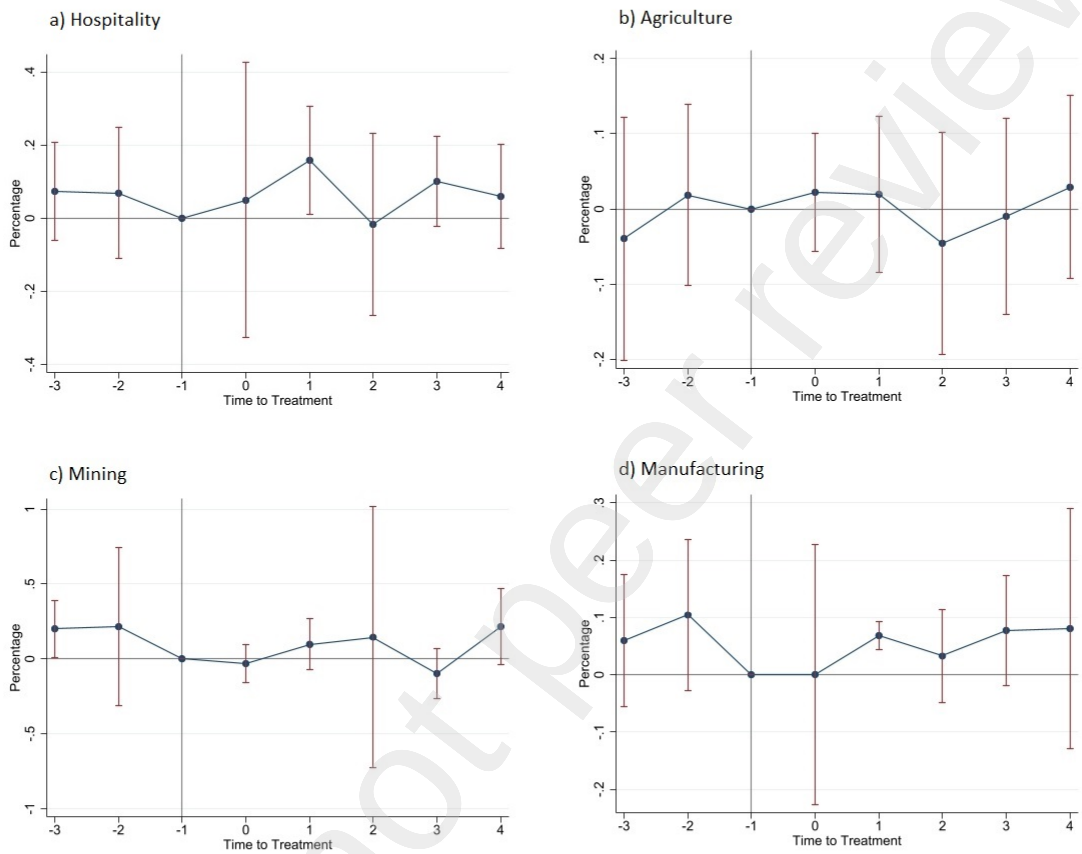
Figure 6 shows the results of possible spillover effects to the other four industries. Panel a) of Figure 6 shows that in the hospitality industry, there is a significant increase in salary in period one, but this effect disappears after that. The value of the estimate is 0.15, which corresponds to an average increase of 0.27% per MW of capacity built in the salaries of the hospitality industry (the ATET for a 79 MW plant is 21.9%). Panel b) shows the effects on agriculture, which is often cited as one of the most impacted industries by hydroelectric projects (Duflo and Pande, 2007; da Silva Soito and Freitas, 2011). This industry sees no significant effect on salaries at any period, which may be because the projects in the sample are not big enough to disrupt the agricultural labor market significantly. Additionally, ten of the eleven projects analyzed divert water from the rivers instead of relying on a dam structure, which may decrease the loss of agricultural land.

Panel c) of Figure 6 shows the effects on the mining industry. While there are no significant effects, the placebo estimator of period -3 is statistically different from zero, indicating a parallel trend assumption violation. This violation means that the results may be unreliable and must be interpreted accordingly. Finally, panel d) shows a positive effect on the manufacturing industry in period one. The estimator indicates a salary increase of 0.14% per MW built or 11.7% for a 79 MW plant. This result may be driven by the

[26] The calculation of the Machalí example es: $ATET_{Machalí} = 0.2 \left(\frac{111 \cdot 1{,}000}{32{,}583}\right) \left(\frac{1}{2}\right) \approx 34\%$.

wood (and wood-related goods) industry included in the manufacturing category (Banco Central de Chile, 2020). As large forest areas need to be removed, the wood industry may observe a positive shock in its labor market. Nevertheless, this effect is short-lived and disappears from period two onward.

Figure 6: Salary Results, Multiple Industries



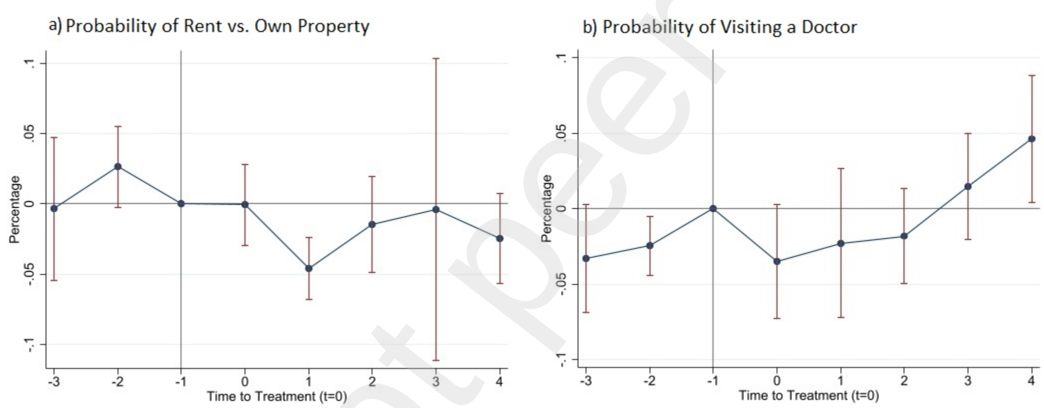
Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

The industry-level results indicate heterogeneous effects across industries. As the construction stage of hydroelectric projects is labor intensive, it was expected to observe an effect on the salaries of this industry during the peak of the construction stage, which was confirmed by Figure 5. As Figure 6 shows, there are spillover effects to the hospitality and manufacturing industries but, similar to the average effects across industries, the effects disappear after the construction finishes.

5.2 Other Outcomes

The housing results are presented in panel a) of Figure 7. The placebo estimators suggest that the parallel trend assumption is not violated. There is no statistically significant effect the year construction starts, but one period after, there is a 7.1% statistically significant decrease in the probability of renting a house versus owning a house (considering a 79 MW plant).[27] This negative effect of renting a house goes in line with the salary increase from panel a) of Figure 2 and the mechanism described in Appendix 1 if workers believe that the labor shock is permanent, a salary increase may lead to a switch from renting to owning a house. Additionally, it may be that individuals under other living arrangements (e.g., conceded with no ownership, usufruct, or irregular occupancy), which are initially excluded from the estimations in panel c), can own a house, hence, are included in the post-treatment sample. However, the proportion of individuals under other living arrangements is relatively low (about 7% on average), so this is unlikely to affect the results significantly. Finally, panel b) presents the health results; however, the placebo estimators are statistically different from zero, suggesting that the estimates may be biased. In any case, panel b) shows no significant effects on the probability of visiting a health care provider.

Figure 7: Housing and Health Outcomes

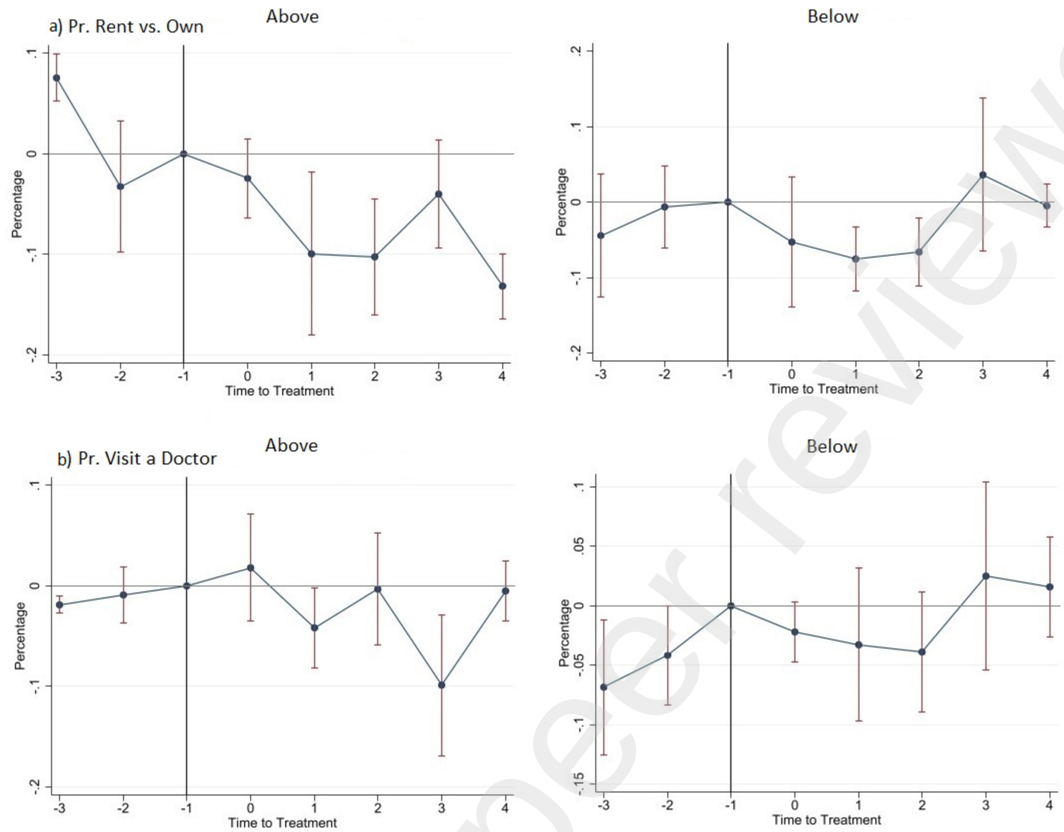


Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

Similarly with the previous subsection, the sample is divided by income levels and share of Indigenous population. Panel a) of Figure 8, indicates that the probability of renting versus owning a house decreases in relatively rich counties (i.e., counties below the average poverty) for periods one and two. The parallel trend assumption is not satisfied for relatively poor counties (i.e., above the poverty average). Furthermore, the placebo estimators in panel b) indicate that the parallel trend assumption is not satisfied for relatively rich counties either.

[27] The calculation of the housing effect in period two is: $ATET = -0.04\left(\frac{79 \cdot 1{,}000}{27{,}000}\right)\left(\frac{1}{2}\right) \approx -7.1\%$.

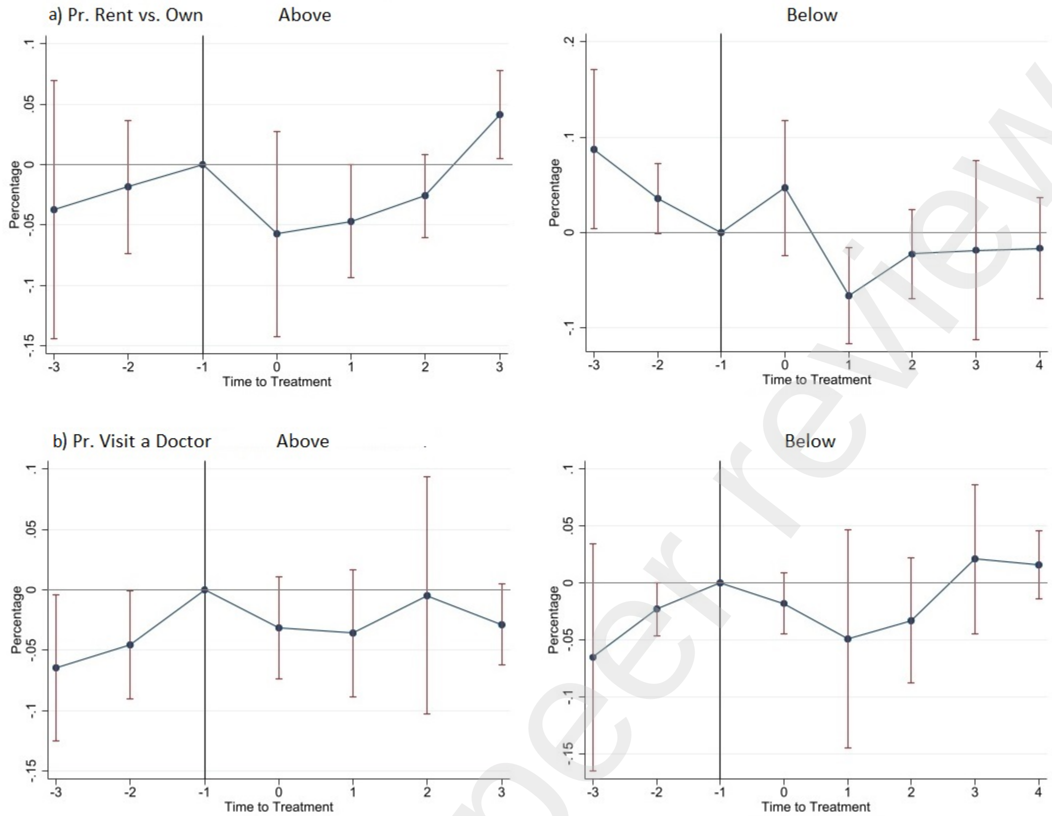
Figure 8: Housing and Health Outcomes, by Income level



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

Finally, Figure 9 shows the housing and health outcome results when the sample is divided by the share of Indigenous population in the county. The placebo estimators for the counties with an Indigenous population below the national average violate the parallel trend assumption. Therefore, the analysis is concentrated on the effects of hydro projects on counties with a higher share of Indigenous population. According to panel a), there is an increase in the probability of renting versus owning a house in period three; however, as mentioned above, this results may be influenced by the "Plan for County Development" launched by the local government in 2015. The placebo estimators in panel b) show that the parallel trend assumption is not satisfied in the health specification. Nevertheless, no significant effects are found on the probability of visiting a health care provider.

Figure 9: Housing and Health Outcomes, by Indigenous Population



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

5.3 Robustness Analysis

5.3.1 Including Previous Hydroelectric Projects

According to Figure 1, there were 61 counties with active hydroelectric projects in Chile. In the main analysis, 50 counties were excluded. This subsection analyzes the effects of hydroelectric projects, including counties with existing hydro plants as part of the control group. Counties with existing hydro projects will be referred to as early treated and the 11 counties from the main analysis as the late treated. Due to data availability,[28] from the 50 initially excluded counties, only five are considered for this analysis.

If the hydro projects have a significant effect on early treated counties, including them into the control group should biased downward the estimate of the effects on late treated counties. This is because the outcome variables of the control group (including the early treated counties) would be shifted in the same direction as the effects expected in the late treated counties.

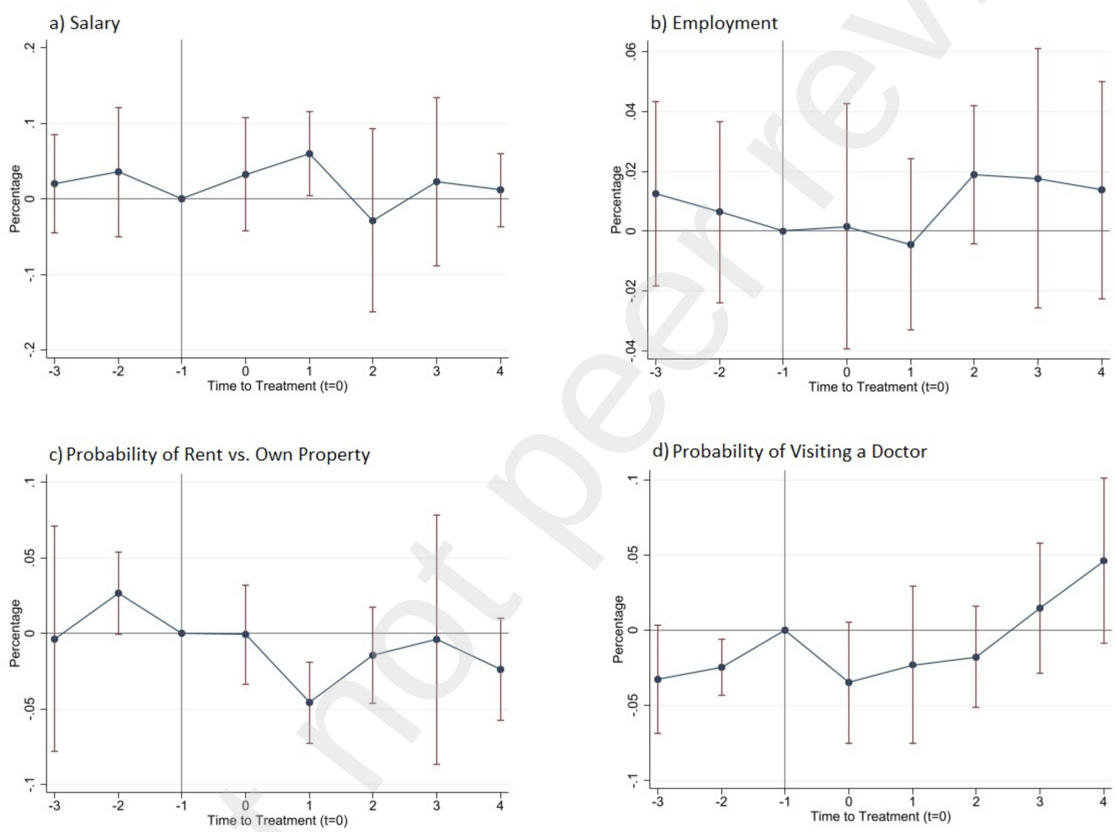
Figure 10 presents the results for the four outcome variables. The effects' intensity and direction are

[28]The main data limitation comes from CASEN. In early versions of the survey several counties were not properly represented, so cannot be used. This means that all projects in those counties must be dropped from the analysis.

similar to those in the main model. Salary increases one period after construction starts, and the probability of renting decreases during the same period. There are no significant effects on employment and health outcomes.

These results suggest that the weights estimated to control for the selection into treatment work well. This is because including counties previously treated does not significantly affect the results; therefore, counties without hydroelectric projects serve well as a control group in the Chilean case.

Figure 10: All Outcomes, Including Previous Hydro



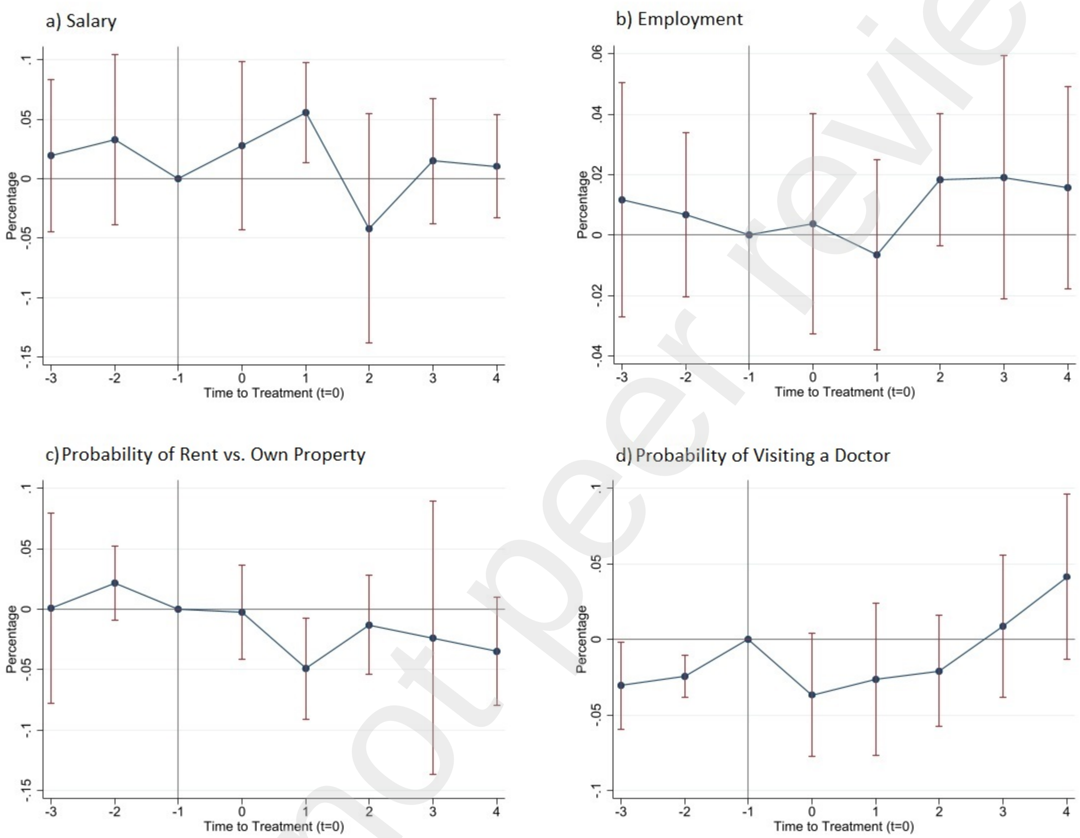
Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

5.3.2 Excluding Neighbor Counties

If workers commute from neighboring counties to the treated counties, spillover effects may bias the results downward if, for example, salaries in neighbor counties increase. As a result, this would bias down the difference between treated and control groups. This subsection limits the control group to non-neighbor counties, which drops 50 counties from the control group. The idea of excluding neighboring counties is to understand whether between-counties commuting is an issue in this study.

Figure 11 shows that when neighbor counties are excluded, the results remain similar to the main specification. Panels a) and c) show that the salary and housing effects are similar to the main model, with a slight difference in precision. Further, no significant effect is observed on employment and health. The similarity of the results, compared to the main model, suggest that between-counties commuting is unlikely to be an issue in the counties analyzed.

Figure 11: All Outcomes, Excluding Neighbor Counties



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.

6 Conclusion

This paper studies the effects of hydroelectric projects on local communities in Chile. In particular, it analyzes the effects on salaries and employment, and glimpses at the housing and health effects. The data is combined from five independent sources: the Ministry of Social Development of Chile, the Mapuche Data Project, the Center for Climate and Resilience Research, the Chilean Ministry of Energy, and the National Energy Commission. The identification of the effects relies on a weighted two-way fixed effects difference-in-differences estimator that allows for heterogeneous treatment effects over time and controls for selection into treatment. Treatment is defined as the beginning of the construction stage, given that most of the investment and labor demand is expected to happen during this phase. To the best of our knowledge, this is the first study that applies a continuous treatment indicator based on the project's capacity and the county population instead of the standard binary indicator. It is particularly important to control for the population-adjusted size of the projects in the Chilean case because plant sizes vary greatly across the country.

The results show that two and three years after the beginning of the construction stage, local salary increases by 8% and the probability of renting versus owning a property decreases by 7%. The industry-specific analysis shows a 29% increase in salaries within the construction industry during the second and third years after construction started; however, this effect disappears afterwards. Spillover effects are found in the hospitality and manufacturing industries, which show the same evolution as the construction industry. Furthermore, the positive salary effects seem to be more prominent in relatively poor and non-Indigenous counties, while the housing effects are concentrated in wealthier counties. No significant effects on employment and health are observed. These results show that the construction of a hydro project, in fact, increases salaries, but these effects are short-lived, ending with the construction phase.

As governments worldwide continue supporting hydropower development, this paper's results highlight the importance of backing up this support with empirical evidence. Similarly to Faria et al. (2017) in the Brazilian case, no evidence of long-term benefits for local communities is found in the Chilean context. The only positive effects are short-lived and during the construction stage of the projects. Therefore, policymakers seeking local support for these projects should aim for more comprehensive development strategies. This development strategy could use the hydro project short-term benefits as a stepping point and incorporate a longer-term vision for the county, including the sustainable development of other industries while respecting the local opinion. Furthermore, another possibility to gain local support relies on hydroelectricity's global environmental and economic benefits (e.g., lower electricity prices and pollution). Transferring part of the global benefits to local communities for the long-term use of their surrounding resources may help improving the local perception of these projects.

It is important to be aware of some limitations of this work. First, due to the cross-sectional nature of the data, it is not possible to study migration patterns. If projects attract temporary workforce from neighbor counties, there may be spillover effects to these neighbor counties. These spillovers would decrease the effects observed in the treated counties of the analysis. While empirical evidence suggests that relatively lower-skilled workers are less likely to migrate (Topel, 1986; Bound and Holzer, 2000), it is unrealistic to believe that migration does not happen and that the local labor market fills all jobs created. Depending on data availability, future research should consider the migration effects of these projects.

Second, this paper analyzes the effects of hydro at the county level. While the average county area and population are relatively small, future research with more granular geographic area warrants investigation. Intuitively, the effects could be more substantial in towns and villages close to the projects; however, it is anticipated that hydro projects alone will not have the long-term effects expected by policymakers and private developers. This is because of the recent tendency to build small and medium-sized projects that, by themselves, do not have the potential to significantly improve the economy in the long term. This, of course, would change if a more comprehensive development strategy accompanied the projects.

Third, this study focuses on labor effects and includes two housing and health outcomes proxies. However, the effects of hydro projects go beyond those four measures and should be considered when estimating the total net effects of these projects. Future research may include other relevant factors, such as the ecosystem effects or comparing the relative impacts of hydro with other electricity generation projects.

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Appendix 1: Theoretical Framework

This section explores the theoretical framework that defines how hydro plants affect the local communities. It starts by analyzing the mechanisms that can explain the effects on salary and employment using a modified version of the Rosen-Roback framework (Rosen, 1979; Roback, 1982) for local labor markets. This study follows the insights of Moretti (2011) and Kline and Moretti (2014) to allow for local labor market frictions. Subsequently, and considering the expected labor market effects, the possible channels that determine the effects on the housing market and health are analyzed.

Labor Outcomes

In the standard Rosen-Roback theoretical framework, workers' utility depends on nominal salary and the cost of housing and local amenities. Among other assumptions, this theoretical framework assumes that labor is perfectly mobile and that land is the only immobile factor with a fixed supply. In this setting with a perfectly efficient local labor market, any local shock to the labor demand or supply has no long-term effects on workers' welfare, and only landowners benefit. For instance, a local labor demand shock will increase nominal wages, but subsequently, the cost of housing and local amenities will increase. Therefore, workers' welfare will see no real change, and only landowners will benefit.

Two particularly restrictive assumptions of the Rosen-Roback theoretical framework are perfect mobility and the fixed land supply. Perfect (and infinite) mobility of workers leads to a perfectly elastic labor supply, while fixed land leads to a perfectly inelastic land supply. However, in reality, the local labor market presents frictions that allow labor demand-side interventions to benefit local workers (Moretti, 2011; Kline and Moretti, 2014). Therefore, the theoretical framework is based on the models described by Moretti (2011) and Kline and Moretti (2014). In this context, there is likely limited mobility, land (and housing) is not fixed, and there are multiple industries and types of workers within a county.

The construction stage of hydroelectric projects attracts a large number of workers. For instance, Faria et al. (2017) report that building a 430 MW hydroelectric plant would create around 3,000 direct full-time jobs. In the particular setting of this paper, as discussed in section 3, Pacific Hydro claims to have created 2,652 full-time jobs during the peak of the construction stage of the 111 MW plant (Pacific Hydro, 2012). To fulfill the jobs created by the hydroelectric plants, this paper considers three possible channels: migration, switch between jobs, and employment of the unemployed and inactive population.

First, close to the standard Rosen-Roback framework with perfect mobility, let us assume that migrants from other counties fill all jobs and that the number of migrants equals the number of jobs. Then, salary and the probability of being employed should increase.[29] It is expected that the average salary of the treated county will increase because construction jobs pay above the average salaries.[30] If not all migrants find a job or if they migrate with working-age family members, employment still increases as long as half of the migrants find a job. Similarly, the average salary increases if a sufficient proportion of the migrants find a construction job. Due to the cross-sectional nature of the data, migration is not observed; however, empirical evidence suggests that low-skill workers are less likely to migrate due to labor demand shocks (Topel, 1986; Bound and Holzer, 2000), which supports the limited mobility assumption of Moretti (2011) and Kline and Moretti (2014). High-skilled workers will be needed to manage special equipment and higher positions, but most construction jobs require relatively lower-skilled workers. Recall that given the size of the projects analyzed in this paper, it is likely that no on-site camps are needed and an important portion of the jobs are filled by local workers.

Second, consider the intuition of the direct and indirect effects of labor demand-shocks on employment and salaries with different industries described by Moretti (2011).[31] Suppose that the jobs are filled by employees currently working in other industries (i.e., there is a switch between jobs). The employment effects will depend on how many jobs are created in the construction industry, the number of vacant jobs in other industries, and the job destruction derived from the projects. Job destruction may occur if agricultural land is destroyed or diminishing fish resources (Duflo and Pande, 2007; da Silva Soito and Freitas, 2011); however, this is most likely to happen with large projects that require a dam construction. In this analysis, all but one project are run-the-river which do not require flooding. Assuming a low job destruction rate and at least some of the vacant jobs in other industries are fulfilled, it is expected an increase in overall employment. Regarding average salary, it is expected to increase because workers will leave their current jobs if construction jobs are better paid. Even in the case of moderate industry-specific job destruction, the average salary is expected to increase during the construction stage because these jobs pay more than agriculture and fishing jobs.

Finally, assuming that there is some involuntary unemployment, the jobs may fulfilled only by local unemployed or inactive people who become active. In this case, an increase in employment and the average salary should be observed, leading to a possible welfare improvement by this demand-side intervention as stated by Kline and Moretti (2014). People that were not working before (earning no salary) become employed in a job that pays above the average. This channel is particularly relevant for low-skilled construction jobs in these medium-to-small-size hydroelectric projects. Building medium and small-size hydroelectric projects do

[29]Due to the nature of the data, the individual probability of being employed is used as a measure of employment effects. Therefore, throughout the paper, employment effects refer to the individual probability of being employed.

[30]The best-paid industries in Chile are Finance and Insurance, Mining, Communication, and Construction, while Agriculture and Fishing are the second worst-paid industries (Fundación Sol, 2020).

[31]Moretti (2011) categorizes industries as tradable and non-tradable, but the intuition holds for this analysis.

not require on-site housing unless they are located in highly isolated rural areas (IHA, 2021), which is not the case for the selected projects in this study.

In reality, the effects will be driven by a mix of these three channels, but in general it is expected to see an increase in both, the probability of being employed and the average salary. The duration and magnitude of these effects will depend on whether workers and the private sector perceive this shock as a long-run development propeller or just as a short-lived opportunity. On the one hand, if the labor demand shock is seen as transitory, the effects will disappear (or at least decrease) after the construction is finished. On the other hand, if the labor demand shock is perceived as permanent, the effects will continue after the construction stage. Additionally, these results will be exacerbated if the infrastructure investment has positive spillover effects in other industries. These spillover effects would increase the labor demand and salaries in other industries, which, as long as the cost of living (including housing) increases in a smaller proportion, would lead to an overall improvement for workers in the county.

Housing and Health Outcomes

To study the effects of the hydro projects on the housing market the paper uses the probability to rent versus own property.[32] This variable is defined as a binary indicator equal one for households that rent and zero for households that own the property. Only household heads are considered, and other types of ownership, like conceded with no ownership (the owner lets the occupant live in the house with no charge and property rights), usufruct (limited right to occupy a property), and irregular occupancy (properties that illegally occupied) are ruled out. Regarding the health effects of hydro projects, the focus is on the individual probability to visit a healthcare provider.

The positive effects on salaries and employment, together with possible migration, will increase demand for housing in treated counties. On the one hand, higher disposable income allows induviduals to afford a better house and possibly switch from renting to owning a house. At the same time, increasing income and migration will shift the housing demand upward, putting upward pressure on house and renting prices. The effects will depend on whether the shock is permanent or transitory (Dynarsky and Sheffrin, 1985; Robst et al., 1999; Zheng et al., 2018). If the community expects the increasing economic development to be permanent, the incentives to own a house increase compared to renting. Otherwise, if the migration and the increase in income and employment are transitory, the probability of renting during the construction stage increases and no effect should be observed after that.

As pointed out in previous studies, hydroelectric plants may cause significant environmental damage,

[32] This data does not report housing prices or other relevant variables, so home ownership is the closest to get an idea of housing effects.

such as the emission of harmful gasses (Manyari and de Carvalho, 2007). These environmental effects can impact the health of people living nearby (see Fearnside, 2001; Smith et al., 2013; de Alburquerque et al., 2019). In this study, health is measured by the probability of visiting a health care provider due to illness or accidents. An increase in this probability does not necessarily have a negative connotation because there could be three main explanations: first, with a salary increase, people may be able to afford better care and, in the short run, increase their doctor visits.[33] If this is the case, an increase during the first few years after the construction starts should be observed, followed by a reduction below pre-construction levels (refer to Adda et al., 2009; Schwandt, 2018, for evidence of income effects on health).

Second, an increase in the probability of visiting a health care provider can also mean that the person is getting sick or is having accidents more often. If this happens during the construction stage only, the probability of visiting a health care provider should temporarily increase. However, if the person is getting sick more often as a result of the hydro project, the probability of visiting a health care provider should permanently increase, which would have a negative connotation. Third, if the treated counties build additional hospitals, people will have more options to visit the doctor more often. In this case, it would be expected a constant increase in the probability of visiting the doctor, which will be associated with a positive effect.

Using data on hospital additions and information on the reason why individuals visit the health care provider, the most dominant mechanism driving the results can be identified. During the study period, from 1990 to 2017, no significant hospital additions were observed in the treated counties, which weakens the third channel. Additionally, the health indicator used in this paper includes only acute illnesses and accidents, which means that channel two is more likely to explain the sign of the effects. There is no reason to believe that an increase in income (channel one) leads to an increase in short-term illnesses and accidents for people relying on the public health system. Therefore, it is considered that an increase in the probability of visiting a health care provider to be associated with adverse health effects.

[33] Chile has private and public health services, with the private services located mainly in bigger cities. In general, the cost of the private health services is too high for most of the population, resulting in 87.4% using the public healthcare system (FONASA, 2020).

Appendix 2: Treated versus Control Counties

Table 3: Full Summary Statistics, Treated vs. Control Group

Variable	Group	Mean	Standard Deviation	Minimum	Maximum
Average Population	Treated	43,000	16,531	6,424	62,132
	Control	32,749	16,237	832	71,134
Rural Population	Treated	16.5%	14.6%	0%	72%
	Control	32.4%	24.3%	0%	100%
Indigenous Population	Treated	4.3%	4.1%	0.4%	48.3%
	Control	4.4%	10.2%	0%	96.4%
Average Area	Treated	3,667	2,563	681	7,290
	Control	1,806	5,085	51	49,924
Average Salary	Treated	283	424	0	7,177
	Control	205	340	0	7,465
Average Education	Treated	9.2	4.2	0	21
	Control	7.9	4.2	0	21
Average Conflicts	Treated	0	0	0	0
	Control	0.35	2.6	0	36
Mean Water	Treated	38.3	18.7	0.05	94.6
	Control	39.8	80.8	0.01	552.9
Ind. Running Politicians	Treated	0.37	0.85	0	3
	Control	0.23	0.75	0	8
Ind. Elected Politicians	Treated	0.18	0.52	0	2
	Control	0.03	0.21	0	3
Average Age	Treated	28.8	18.75	0	99
	Control	29.2	20.8	0	102
Transmission Line	Treated	32.5	34.8	0	99.5
	Control	13.8	35.2	0	556.3
Trans. Line per 1,000 Pop.	Treated	0.9	1.6	0	10.3
	Control	0.8	3.8	0	185
Elec. Substations per 1,000 Pop.	Treated	0.1	0.13	0	0.78
	Control	0.03	0.07	0	1.7
Capacity per 1,000 Pop.	Treated	4.4	12.6	0	70.6
	Control	0.7	6.5	0	141.8
Probability to Visit a Doctor	Treated	0.09	0.28	0	1
	Control	0.09	0.29	0	1
Probability to Rent versus Own	Treated	0.21	0.41	0	1
	Control	0.13	0.34	0	1
Probability of Being Employed	Treated	0.36	0.48	0	1
	Control	0.33	0.47	0	1

Notes: Area in KM^2. Salary in CAD per month. Education in years. Conflicts per year.
Mean water is the annual average of m^3/second. Transmission line represented in KM.

Appendix 3: Identification Strategy

This study aims to analyze the effects of hydro plants on salaries, employment, and glimpsing at the housing market and health effects. While the treatment is at the county level (i.e., once a county hosts a project, all individuals in that county become treated), individual-level measures are observed; therefore, the estimations are at the individual level.

The salary variable is defined as the logarithm of inflation-adjusted salaries to reduce the influence of outliers. This definition means that the analysis is restricted to employed individuals with observed positive salaries. The employment variable is defined by a binary indicator that equals one if the person is working and zero otherwise. This specification includes only people aged between 15 and 65 years old. The housing variable is represented by a binary indicator that equals one for households that rent and zero for households that own the property.[34] The analysis only considers household heads and rules out other types of ownership, like conceded with no ownership (the owner lets the occupant live in the house with no charge and property rights), usufruct (limited right to occupy a property), irregular occupancy (properties that illegally occupied), among others.[35] Finally, the health variable is a binary indicator that equals one if the person has visited a health care provider due to illness or accident in the last three months and zero otherwise. All county's population is included in this specification.

As mentioned earlier, the construction stage involves most of the investment inflow and is expected to create the most jobs. Therefore, the start of the construction stage is set as the initial treatment period. In the sample, the construction stage lasts between 2 and 6 years, depending on the project size.[36] The data is collected roughly every second year, which means that one period in the data is translated into approximately two years. Hence, the construction stage lasts between one and three periods (in the sample, only one plant took three periods to be built).

To mitigate the problem of selection into treatment, Abadie (2005) proposed the weighted difference-in-differences estimator to find control groups with similar pre-treatment characteristics to treated groups, such that both groups have a similar probability of being treated based on these observable factors. To determine what factors are relevant to estimate the weights, a balance is employed.[37] Different factors are included, like electricity infrastructure (e.g., transmission lines and number of substations), Indigenous political representation, river water distribution, among others.[38] In this estimation, each observation represents the pre-treatment county-level average. The variables were chosen based on previous literature (Faria et al., 2017; de Alburquerque et al., 2019) and factors that may especially apply to the Chilean case (e.g., Indigenous variables). The detailed results of the balance test are in Appendix 4.

[34]CASEN has a variable that indicates each household member's relationship to the household head. The family chooses the household head, typically the working adult (e.g., father or mother).

[35]Renting and owning a property accounts for, on average, 93% of total types of ownership, which is relatively stable over time. While it cannot be ruled out that composition changes over time in treated and control counties, it is assumed that the proportion of other types of ownership is sufficiently small not to impact the results significantly.

[36]The duration of the construction stage is approximated and based on a informal documents.

[37]In essence, the balance test analyzes if the means reported in Tables 2 and 3. are statistically different from each other.

[38]Refer to Appendix 3 for a complete list of the variables included in the balance test.

The main takeaway of the balance test results is that electricity infrastructure and Indigenous presence are critical factors determining the location of the projects. For instance, counties with more electricity infrastructure and less conflicts are more likely to be treated. Additionally, the results show that the county's water distribution is not significantly different between treated and control counties. This may be explained by the relatively homogeneous distribution of water resources along the country (except in the extreme north and south, where water resources are more scarce and abundant, respectively). The results of the balance test are used to estimate the weights. Subsequently, these weights are included in the primary model.

To obtain the average treatment effect on the treated, the primary specification relies on a TWFE difference-in-differences estimator. However, as de Chaisemartin and D'Haultfoeuille (2020) and Goodman-Bacon (2021) point out, the standard TWFE difference-in-differences estimator is not robust when treatment is not constant over time. In this case, there are strong arguments for believing that the effects of hydro projects are heterogeneous over time, particularly comparing the construction and post-construction periods. Therefore, a new version of this estimator proposed by de Chaisemartin and D'Haultfoeuille (2022) is used. This estimator is a generalization of the event-study approach that allows for continuous treatment and heterogeneous treatment effects over time and across treated units. The estimated effects post-treatment are relative to the first period before the treatment started.

Adapting de Chaisemartin and D'Haultfoeuille's model to this study, let us start by considering individual observations $i = 1, ..., N$ for each county $c = 1, ..., C$ at time $t = 1, ..., T$.[39] Note that in repeated cross-sectional data, individuals in a given county vary over time. Let F_c be the period where treatment started (i.e., years 2000, 2006, 2009, or 2011, depending on the treated county) and $Y_{ict}(d_1, ..., d_t)$ be the potential outcome of individual i, from county c at time t, with $(d_1, ..., d_t)$ being the treatment status from period 1 to t. In this design, once a county becomes treated at period F_c, all county individuals remain treated for every period after that.

In their model, de Chaisemartin and D'Haultfoeuille (2022) define $D_{ct} = I_c 1\{t \geq F_c\}$ as the treatment indicator for county c at time t, where I_c represents the county specific intensity of treatment. This represents the continuous nature of the treatment indicator and, for the purpose of this paper, it is defined as MW for each 1,000 inhabitants: $D_{ct} = \left(\frac{I_c 1\{t \geq F_c\}}{population_{ct}}\right) 1,000$.[40] This treatment definition is one of the main departures of de Chaisemartin and D'Haultfoeuille (2022) from a standard event-study model. Let $\delta_{ict} = E(Y_{ic,F_c+l} - Y_{ic,F_c+l}(D_{c,1}, ..., D_{c,1}))$ be the difference between the outcome of individual i at county c at $F_c + l$ periods and the unobserved outcome of the same individual if the treatment in county c would have

[39] In this case, time t represents the year of the survey.

[40] If population increases because of the hydro project the results would be biased downwards. This means that the results would be a lower bound. Nevertheless, no statistically significant difference in population is observed before and after the hydro project.

remained the same as period 1 (i.e., untreated). Given that the counterfactual world where the county is not treated is not observed, we use the estimator proposed by Chaisemartin and D'Haultfoeuille (2022) is employed to estimate this value.

To estimate δ_{ict} de Chaisemartin and D'Haultfoeuille (2022) propose to compare the $F_c - 1$-to-$F_c + l$ outcome evolution between county c and counties whose treatment has not changed in F_c+l and started $t = 1$ with the same treatment as county c (i.e., untreated in this paper). Additionally, placebo tests are conducted to test for the pre-treatment parallel trend assumption on which the estimator relies. The following equation represents the first stage:

$$Y_{ict} = \alpha + \sum_{t=-q}^{F_c-1} \kappa_t D_{ct} + \sum_{t=F_c}^{T} \gamma_t D_{ct} + \lambda_t + \mu_c + X_{ict} + \epsilon_{ict}, \tag{3}$$

where Y_{ict} is one of the four outcome variables. α represents the intercept, κ is the coefficient of the placebo estimators for each pre-treatment period from $t = -q$ to $t = F_c - 1$. This main specification includes three leads and four lags. The κ coefficient allows us to test the fundamental parallel trend assumption of a difference-in-differences design. γ is the coefficient of the treatment effects for each $t \geq F_c$. Treatment D is defined as above. λ and μ are time and county fixed effects, respectively. X is a vector of control variables.[41] As the treatment occurs for the whole county simultaneously, the error term, ϵ, is clustered at the county level.

The estimator described in equation (1) represents the average effect for each period, but it does not have a direct interpretation. This average effect depends on the number of MW built per $1,000$ inhabitants in each period. For instance, if the estimator for period one is 0.1, it means that the average effect of hydro projects in period one is 0.1 by the number of MW built per $1,000$ inhabitants in period one. If there were two MW per $1,000$ inhabitants built in period one, this means that the effect of each MW built per $1,000$ inhabitants was 0.05. Therefore, to estimate the effects of each MW built per $1,000$ inhabitants, the reduced-form event-study estimator described in equation (1) is complemented with a first-stage event study where the treatment indicator acts as the outcome variable. The estimators of this first-stage event study represent the average value of the treatment across all groups, which is defined as the average MW of capacity per $1,000$ inhabitants built in each period (by definition, this treatment is zero for all pre-treatment periods). Therefore, the interpretation of the γ coefficients in equation (1) will depend on the average treatment estimator of each post-treatment period, and it is calculated following:

$$ATET_t = \gamma_t \left(\frac{MW\ cap \cdot 1,000}{population} \right) \left(\frac{1}{\overline{MW\ added_t}} \right), \tag{4}$$

[41] The controls for salary are age, gender, education, and the number of members in the household. For the probability of being employed, the controls are age, gender, and education. For the probability of renting versus owning a house, the controls are the household salary, education, and age. Finally, for the probability of visiting a doctor, household salary, age, and gender are included as control variables.

where $ATET_t$ is the average treatment effect on the treated at period t. γ_t is the estimator effect in period t. $MW\ cap$ and $population$ are the capacity of the hydroelectric plants in the sample and the population of the counties, respectively (in this sample, the average $MW\ cap = 79$ and the average $population = 27,000$). Additionally, $\overline{MW\ added}_t$ represents the average MW per 1,000 inhabitants added from period zero to t. Intuitively, equation (2) transforms the estimator effect, γ_t, into a "per MW effect", and then scales it up by the population-adjusted plant size. To obtain the effects per MW per $1,000$ population, one sets $MW\ cap = 1$.

Aside from this main specification, this paper analyzes heterogeneity effects by industry, county's income level, and share of the Indigenous population. The industry analysis includes mining, manufacturing, construction, agriculture (including the fishing industry), and hospitality and commerce because these are the most relevant industries in the treated counties.[42] Only industries reported by employed individuals are observed, so the industry analysis is focused on salary (and not employment). The pre-treatment poverty share of counties estimated by Agostini et al. (2008) is used to group counties per income level. Using their estimates, six treated and 38 control counties are below the poverty average of 26.7% in 2000, and there are three treated and 114 control counties above the poverty average. Finally, the CASEN survey started asking questions about Indigenous identification in 2000. This information helps to divide counties according to their share of Indigenous population.[43] The average Indigenous population was 7% in 2000 and 2003 (pre-treatment periods). This yields 136 control and six treated counties below the national average and 29 control and three treated counties above the average.

The county samples vary when analyzing the effects of the hydro plants by income levels and Indigenous population. Therefore, new balance tests are performed for these specifications to re-estimate the weights.[44] The balance test for counties below the poverty average yields the following relevant variables: average river water, number of electricity substations, number of electricity substations per km^2, and the km of electricity transmission lines per km^2. The relevant variables for counties above the poverty average are the share of the rural population, average river water, number of electricity substations per km^2, km of electricity transmission lines per km^2, km of electricity transmission lines per $1,000$ inhabitants, and the number of Indigenous conflicts.

Similarly, the relevant variables for counties with a share of Indigenous population below the average are the share of the rural population, number of electricity substations per km^2, number of electricity substations per $1,000$ inhabitants, and km of electricity transmission lines per km^2. Finally, the variables for counties

[42]The most important industries in Chile are mining, entrepreneurial and financial services, manufacturing, construction, agriculture (including fishing and forestry), and hospitality and commerce (Banco Central de Chile, 2020).

[43]The Indigenous identification variable started in 2000, so the two counties treated that year are excluded from the analysis.

[44]The weights are similar for all samples, which leads to robust results across the set of weights used.

with a share of Indigenous population above the average are the share of the rural population, the number of electricity substations per $1,000$ inhabitants, km of electricity transmission lines per km^2, km of electricity transmission lines per $1,000$ inhabitants, MW of capacity per km^2, the number of Indigenous conflicts, and the number of Indigenous politicians running for office.

Appendix 4: Balance Test Results

The variables are defined as:

- Rural/Urban: it shows the proportion of people living in rural areas in each county.
- Mean water: it represents the annual mean amount of water from all the main rivers of each county. It is measured by cubic meter per second per day.
- Total water: it represents the annual sum of the water in the main rivers of each county. It is measured by cubic meter per second.
- Substation: it represents the total number of substations per county.
- Substation per geographic area: it represents the number of substations per kilometer squared of each county.
- Substation per capita: it represents the number of substations per 1,000 inhabitants of each county.
- Line per geographic area: it represents the lines (in KM) per kilometer squared of each county.
- Lines per capita: it represents the lines (in KM) per inhabitant of each county.
- Capacity per geographic area: it represents the total capacity (in MW) per kilometer squared of each county.
- Capacity per capita: it represents the total capacity (in MW, including all types of generation) per inhabitant of each county.
- Conflicts: it represents the total number of conflicts involving indigenous people per year in each county.
- Total politicians running for office: it represents the total number of indigenous politicians running for office in each county. For elections held in a year between my sample, I add them to the following year with data (e.g., if I have data of 2000 and 2003, and an election happens in 2002, I count the number of running politicians towards 2003).

- Total politicians elected for office: it represents the total number of indigenous politicians elected for office in each county. Both, the running and elected politicians are for four political positions: senators, deputy, mayor, and councilor. All of these positions last four years, so I account for this according to the timing of the elections.

Table 4: Balance Test All Treated Counties

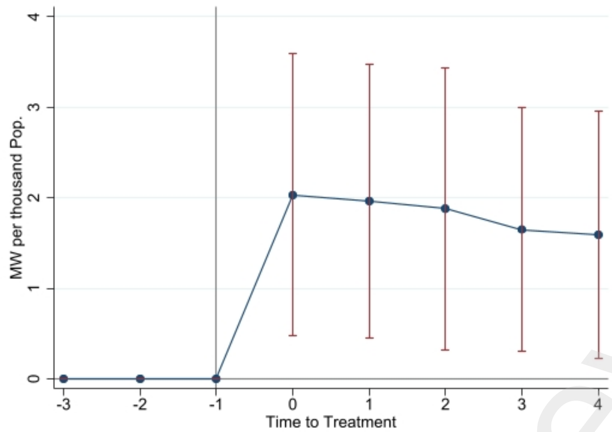
Variable	P-Value	Observations	Direction of Difference
Rural/Urban	0.13	1,616	41% rural population in control vs. 29% in treated
Mean Water	0.80	576	49 m^3/s per day in control vs. 45 m^3/s per day in treated
Total Water	0.85	576	16,719 m^3/s in control vs. 15,670 m^3/s in treated
Substations	0.00	1,616	1.19 substations in control vs. 3.45 in treated
Substations Area	0.14	1,616	0.002 substations per km^2 in control vs. 0.001 in treated
Substations Per Capita	0.26	1,616	0.11 substations per 1,000 pop. in control vs. 0.20 in treated
Line Area	0.00	1,311	0.07 km of line in control vs. 0.02 in treated
Line per Capita	0.11	1,311	0.008 km of line per inhabitant in control vs. 0.003 in treated
Capacity Area	0.21	1,616	0.03 MW per km^2 in control vs. 0.06 MW in treated
Cap. per Capita	0.12	1,616	0.002 MW per inhabitant in control vs. 0.01 in treated
Conflicts	0.00	1,616	0.5 conflicts per year in control vs. 0 in treated
Politician Running	0.23	1,616	0.58 running politician in control vs. 0.39 in treated
Politician Elected	0.59	1,616	0.10 elected politician in control vs. 0.14 in treated

Note: The main specification includes 11 treated counties and 175 control counties.

Appendix 5: First-Stage Results

Figure 12 shows the first-stage event-study results. The graph indicates that at periods zero and one, the average treatment intensity is about 2 MW per $1,000$ inhabitants (i.e., on average, there were 2 MW per $1,000$ inhabitants built in periods zero and one). After the post-treatment period two, the treatment intensity decreases, reaching 1.6 MW per $1,000$ inhabitants in period four. The estimates of Figure 2 represent the term $\overline{MW\ added}_t$ in equation (2).

Figure 12: First-Stage Event Study



Notes: The 95% confidence intervals are represented by the vertical red lines. Blue line represent the period-by-period trend.