**IPC–MERCATOR ANALYSIS** June 2022

# GREEN ENERGY & REGIONAL DEVELOPMENT I: AN EMPIRICAL INVESTIGATION OF TURKISH PROVINCES

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## Executive Summary

This analysis examines the empirical relationship between green power transitions and socio-economic development at the province level in Turkey. Using propensity-score matching (PSM) and exact matching (CEM), it was found that provinces with a higher share of wind and solar power in their overall electricity production exhibit higher levels of socio-economic development. On the contrary, provinces with a higher share of hydroelectric power in their overall electricity output do not exhibit any significant differences in socioeconomic development compared to their respective control group. This study provides a framework for analyzing the developmental and cross-regional aspects of energy transitions with a focus on Turkey.

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## Introduction

The positive socioeconomic impact of energy transitions on the Turkish economy is shown through a calibrated macroeconomic model. These simulations suggest that Turkey can be carbon-free by 2050 and that the benefits of this transition drastically outweigh its costs.[1] This analysis provides the initial framework for the analysis of the socioeconomic dimensions of wind, solar, and hydroelectric power transitions, which are considered the most significant both in terms of volume of energy produced and their share in overall electricity production. Using the 81 provinces of Turkey as the main unit of analysis (in Turkish, *il*), I observe a positive and significant empirical relationship between dependence on wind and solar power production and socioeconomic performance at the province level. This is particularly the case for average income, for which a positive and significant average treatment effect is reported both with a propensity-score matching (PSM) and a coarsened exact matching (CEM) estimator.

Globally, subnational politics and institutions have played a crucial role in the speed of energy transitions. For example, evidence from Brazil, a centralized governance system, indicates that the decentralization of energy policy decisions has the potential to accelerate energy transitions and familiarize citizens with the advantages of green energy use.[2] In the same direction, Bradshaw and Jannuzzi[3] indicate that Brazilian states can provide significant support for the acceleration of energy transitions at the federal level and efficiently coordinate with the central government in terms of setting new priorities in green energy policy-making. Nevertheless, regional energy transitions are not always without problems and oftentimes require the institutional support of central administrative agencies.[4] While energy justice and equitable access to natural resources remains an overarching normative issue for developing economies,[5] the role of regional energy transitions is becoming increasingly important and central to our understanding of sustainability as a phenomenon conditional on specific geographic, market, institutional, and cultural characteristics of each locality or province. Coenen et al. provide a conceptual framework on the differential effects of energy transitions across regions of the same country[6]; the comparison between urban and rural localities as well as their respective institutional environments may explain why some regions are faster or more successful in achieving sustainable economic outcomes than others. At the same time, in recent years rural regions have become the epicenter of energy transitions, as they host more renewable energy infrastructure such as wind farms, transmission grids, and biogas plants.[7] Moreover, the decentralization of energy transitions underscores the interaction of cities with their surrounding areas and provides novel incentives such as economic and ecological transformation for local and regional governments and civil society.

Therefore, regions may play a positive role in central governments' efforts to achieve the United Nations' Sustainable Development Goals (SDGs). The structural transformation of Chinese regions, for example, has provided significant impetus for the Chinese government's 2030 carbon emission goals.[8] Nevertheless, environmental conflicts that capture clashes between regional and local societal interests, on the one hand, and environmental protection, on the other, may also obstruct central-level policies; evidence from Chile suggests that economic and human development dimensions of sustainability are not always in harmony with each other.[9] This is why regional development strategies within the same country may reflect different priorities given the presence of diverse ethnic, geographic, and economic conditions. This "transition topology" reveals the institutional complexity of energy transformations at the regional level, particularly when there is a strong prior propensity to conflict.[10]

The distribution of wind farms, solar, and hydroelectric power plants in Turkey is related to prior climate and geographic conditions as well as the economic and demographic capacity of specific provinces in the overall performance of the Turkish economy. As Figure A.1 and Table A.3 indicate, propensity-score matching (PSM) achieves a high level of covariate balancing after matching between the treatment and control groups. The only issue is observed in the wind energy graph as well as quantitative information reported in Figure A.1

and Table A.3, respectively. The discrepancy has to do with the much higher population density in the treatment than in the control group of Turkish provinces, which is not fully alleviated with matching. Wind farms appear to contribute significantly to the overall electricity production of provinces with a much higher population density compared to the average in Turkey.

The Aegean, Marmara, Central Anatolia, and Mediterranean regions (in Turkish, *bölge*) of Turkey have the highest concentration of wind farms, while the Central Anatolia, Southeastern Anatolia, Mediterranean, and Aegean regions score the highest in the distribution and production capacity of solar power infrastructure. The Eastern Anatolia, Southeastern Anatolia, Black Sea, and Mediterranean regions are the most dependent on hydroelectric power contributions to their overall electricity generation. The heterogeneity of those regions, as well as that of the provinces that each of them incorporates, render the proposed matching analysis a powerful start for the evaluation of the socioeconomic dimensions of green transitions at the subnational level.

## Descriptive Statistics & Empirical Strategy

Tables A.1-2 provide an overview of the profile and the descriptive statistics of the data utilized in this analysis. Outcome variables at the province level (*i*) include average income per capita, school attendance rate, share of higher education graduates, Gini coefficient, infant mortality rate, birth rate, heating degree days, and cooling degree days. While the first six outcomes capture the socioeconomic profile of the respective provinces, the last two outcomes offer qualified temperature measurements related to the evolution of climate change. I utilize soil elevation and population density at the province level as control variables. For the solar power estimations, I also include air temperature, as this may be related to the socioeconomic and climate impact of solar power transitions.

The ranked dependence from wind, solar, and hydroelectric power, respectively, defines the treatment variables used in this study. For example, provinces with an above-the-median wind power share in overall electricity generation are classified as part of the treatment group, whereas provinces with a below-the-median or equal-to-the-median wind power share with respect to their overall electricity output are included in the control group. The same method is used also for the creation of the solar and hydroelectric power treatment variables. In Figures 1-3, I provide a visual representation of the treatment and control groups for wind, solar, and hydroelectric power, respectively. It is interesting to observe the different regional arrangements of green power transitions; while wind power dependence is higher in western and central provinces, hydroelectric power dependence is higher in eastern and central provinces. At the same time, the treatment group with respect to solar power dependence is spread uniformly across Turkish provinces. The Central Anatolia, Aegean, and Mediterranean regions of Turkey appear to be the forerunners of energy transitions in all three dimensions examined: wind, solar, and hydroelectric. On the contrary, the Marmara, Southeastern Anatolia, and Black Sea regions seem to concentrate on wind, solar, and hydroelectric power transitions, respectively.

Propensity-score matching (PSM) and coarsened exact matching (CEM) are my main empirical strategies. The limited number of observations (81 or less) does not allow for the performance of the full set of possible robustness checks. Nevertheless, I use the PSM results as my benchmark and the CEM results as a robustness check. The main obstacle to causality remains the possibility of selection bias with respect to the covariates. While PSM computes the probability of assignment to the treatment rather than the control group, CEM eliminates imbalance across covariates.[11]

**Figure 1: Wind Power Transitions: Treatment vs. Control Group**


**Figure 2: Solar Power Transitions: Treatment vs. Control Group**

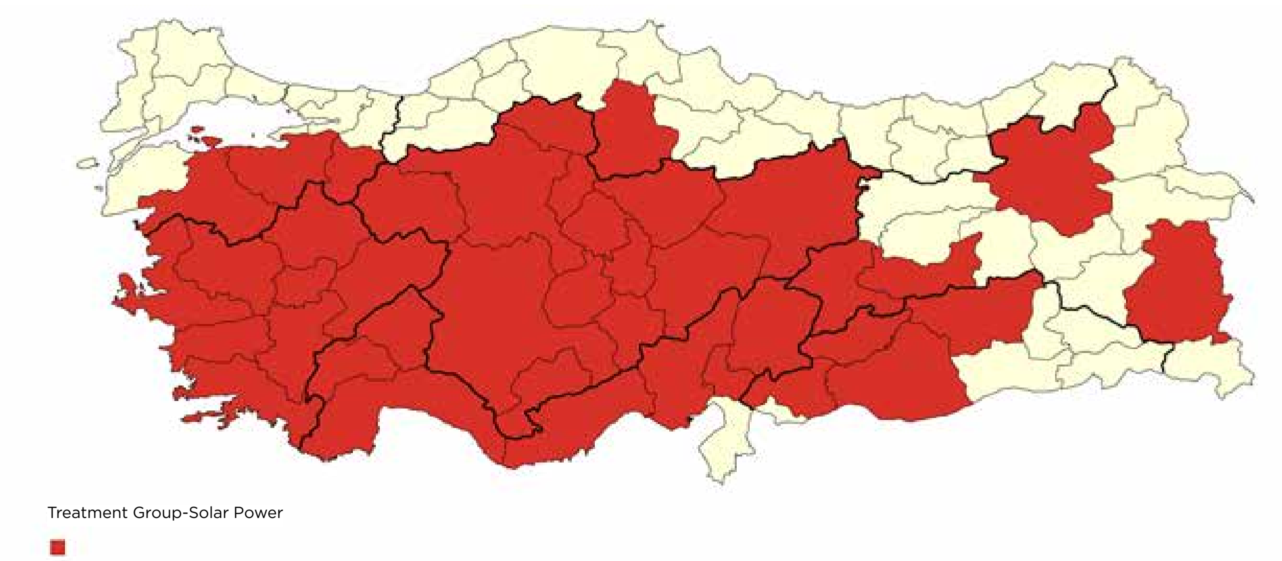


**Figure 3: Hydroelectric Power Transitions: Treatment vs. Control Group**

## Results

### *Wind Power*

The PSM estimates for wind power in Table 1 underscore the positive effect of wind power transformation on socioeconomic development and environmental quality at the province level. Average income per capita is higher in provinces with a higher share of wind power in their overall electricity production by an average difference of 20.6 log points, which is statistically significant at the 5 percent level.

There are also significantly higher shares of higher education graduates as well as school attendance rates in the wind power-intensive provinces of Turkey, which exhibit average differences of 113.1 percent and 47.4 percent at the 1 and 5 percent levels, respectively. In addition, I observe a significantly higher CDD index in provinces with higher shares of wind power, which confirms the positive environmental impact of Turkey's wind power transformation. The CEM results (Table 2) corroborate the positive impact of wind energy transitions on province-level economic performance; there is an average difference of 16 log points, which is statistically significant at the 5 percent level.

### *Solar Power*

The PSM estimates for solar power in Table 1 suggest a significant development impact of solar power transitions at the province level. Average income per capita is higher in provinces with high shares of solar power by an average difference of 17.9 log points, which is statistically significant at the 10 percent level. School attendance is also significantly higher in solar power-intensive provinces by an average difference of 41.4 percent, which is statistically significant at the 10 percent level. A similar observation is seen for birth rates: there is a positive and significant difference in favor of provinces that have high solar power shares in their electricity output. While this is an important demographic finding, further exploration of the mediating mechanisms would solidify the empirical relationship between solar power transformation and birth rates at the subnational level.

The CEM results (Table 2) corroborate my PSM estimates on average income per capita and birth rate. Provinces with a strong solar infrastructure component in their overall electricity generation are wealthier and exhibit lower birth rates. There is an average income per capita difference of 17.9 log points, which is positive and statistically significant at the 10 percent level. Furthermore, the average difference in birth rates between the treatment and the control group is negative and statistically significant at the 5 percent level.

**Table 1: Average Treatment Effects (ATT) – Green Energy & Regional Development**

| Panel A: Wind Power | | | |
|---|---|---|---|
| Outcome | ATT | Number of Treated | Number of Control |
| Average Income per Capita | 0.206<br>(2.61)** | 39 | 42 |
| Higher Education Graduates | 1.131<br>(1.90)* | 39 | 42 |
| School Attendance | 0.474<br>(2.16)** | 39 | 42 |
| Gini Inequality | 0.003<br>(0.36) | 39 | 42 |
| Infant Mortality | 0.556<br>(0.64) | 39 | 42 |
| Birth Rate | -1.865<br>(-1.26) | 39 | 42 |
| Heating Degree Days | -44.128<br>(-0.19) | 39 | 42 |
| Cooling Degree Days | 189.718<br>(1.82)* | 39 | 42 |
| Panel B: Solar Power | | | |
| Outcome | ATT | Number of Treated | Number of Control |
| Average Income per Capita | 0.179<br>(1.76)* | 40 | 41 |
| Higher Education Graduates | 1.147<br>(1.41) | 40 | 41 |
| School Attendance | 0.414<br>(1.86)* | 40 | 41 |
| Gini Inequality | 0.005<br>(0.67) | 40 | 41 |
| Infant Mortality | -0.458<br>(-0.58) | 40 | 41 |
| Birth Rate | -3.998<br>(-2.66)*** | 40 | 41 |
| Heating Degree Days | -178.25<br>(-0.66) | 40 | 41 |
| Cooling Degree Days | 63.375<br>(0.56) | 40 | 41 |
| Panel C: Hydroelectric Power | | | |
| Outcome | ATT | Number of Treated | Number of Control |
| Average Income per Capita | -0.003<br>(-0.03) | 40 | 41 |
| Higher Education Graduates | 0.767<br>(1.23) | 40 | 41 |
| School Attendance | -0.248<br>(-0.56) | 40 | 41 |
| Gini Inequality | 0.013<br>(1.25) | 40 | 41 |
| Infant Mortality | 0.140<br>(0.19) | 40 | 41 |
| Birth Rate | -0.360<br>(-0.25) | 40 | 41 |
| Heating Degree Days | -27.65<br>(-0.12) | 40 | 41 |
| Cooling Degree Days | -9.275<br>(-0.08) | 40 | 41 |

Note: Significance levels: *** p<0.01, ** p<0.05, * p<0.1. t-values are in parentheses. Algorithm: Nearest Neighbor Matching (NNM=1). Covariates include soil elevation and population density for panels A and C, and air temperature, soil elevation, and population density for panel B.

### *Hydroelectric Power*

Neither PSM nor CEM estimates (Panel C in both Tables 1 & 2) suggest a significant and positive socioeconomic or environmental impact in provinces with high shares of hydroelectric power in their overall electricity production.

The reported results do not provide robust evidence in the direction of causal inference. Nevertheless, they suggest that the positive and significant empirical relationship between wind and solar power transitions, on the one hand, and socioeconomic performance, on the other hand, may provide a useful framework for the analysis of energy transitions at the subnational level of governance. The mapping of socioeconomic and climate characteristics of energy transitions underscores the necessity for data aggregation at the district level.

**Table 2: Coarsened Exact Matching (CEM) – Socio-economic Estimates of Green Energy Impact**

| Panel A: Wind Power | | | | | | |
|---|---|---|---|---|---|---|
| Outcome | Multivariate Imbalance Measure | Coefficient | Std. Err. | t | Observations | R-squared |
| Average Income per Capita | 0.278 | 0.160** | 0.064 | 2.50 | 71 | 0.083 |
| Higher Education Graduates | 0.278 | 0.511 | 0.584 | 0.87 | 71 | 0.011 |
| School Attendance | 0.278 | 0.562 | 0.341 | 1.65 | 71 | 0.038 |
| Gini | 0.278 | 0.004 | 0.007 | 0.49 | 71 | 0.004 |
| Infant Mortality | 0.278 | 0.574 | 0.600 | 0.96 | 71 | 0.013 |
| Birth Rate | 0.278 | -1.413 | 1.000 | -1.41 | 71 | 0.028 |
| Heating Degree Days | 0.278 | -102.652 | 158.676 | -0.65 | 71 | 0.006 |
| Cooling Degree Days | 0.278 | 136.078 | 82.854 | 1.64 | 71 | 0.038 |
| Panel B: Solar Power | | | | | | |
| Outcome | Multivariate Imbalance Measure | Coefficient | Std. Err. | t | Observations | R-squared |
| Average Income per Capita | 0.509 | 0.121* | 0.065 | 1.87 | 67 | 0.051 |
| Higher Education Graduates | 0.509 | 0.944 | 0.606 | 1.56 | 67 | 0.036 |
| School Attendance | 0.509 | 0.201 | 0.266 | 0.76 | 67 | 0.009 |
| Gini | 0.509 | 0.008 | 0.007 | 1.11 | 67 | 0.019 |
| Infant Mortality | 0.509 | -0.008 | 0.569 | -0.01 | 67 | 0.000 |
| Birth Rate | 0.509 | -2.126** | 0.917 | -2.32 | 67 | 0.076 |
| Heating Degree Days | 0.509 | -27.531 | 202.204 | -0.14 | 67 | 0.000 |
| Cooling Degree Days | 0.509 | 41.126 | 89.011 | 0.46 | 67 | 0.003 |
| Panel C: Hydroelectric Power | | | | | | |
| Outcome | Multivariate Imbalance Measure | Coefficient | Std. Err. | t | Observations | R-squared |
| Average Income per Capita | 0.181 | 0.022 | -0.068 | -0.99 | 77 | 0.013 |
| Higher Education Graduates | 0.181 | 0.020 | 0.028 | 0.71 | 77 | 0.023 |
| School Attendance | 0.181 | -0.180 | 0.431 | -0.42 | 77 | 0.002 |
| Gini | 0.181 | 0.011 | 0.007 | 1.64 | 77 | 0.035 |
| Infant Mortality | 0.181 | 0.299 | 0.590 | 0.51 | 77 | 0.003 |
| Birth Rate | 0.181 | 0.574 | 1.023 | 0.56 | 77 | 0.004 |
| Heating Degree Days | 0.181 | -148.533 | 192.949 | -0.77 | 77 | 0.008 |
| Cooling Degree Days | 0.181 | 70.467 | 83.118 | 0.85 | 77 | 0.010 |

Note: Significance levels: *** p<0.01, ** p<0.05, * p<0.1. For the Panel A results, refer also to table A.4. For the Panel B results, refer also to table A.5. For the Panel C results, refer also to table A.6.

## Implications

In this study, I show that green energy and regional development in Turkey are positively intertwined. There is supporting evidence that sustainability can indeed be positively associated with higher income levels under differential cultural, geographic, and political conditions. Moreover I find that human development indicators such as schooling or higher education are also positively linked to wind and solar power transformations. When it comes to wind power specifically, there is also evidence for a positive environmental impact, as it is associated with a higher number of cooling degree days, which intuitively suggests higher efficiency in energy consumption. Furthermore, solar power transitions are robustly associated with lower birth rates; however, patterns of female education and employment in solar power-intensive provinces need to be further explored to shed light on the demographic dimensions of green transitions.

Regional development has become increasingly relevant for our global understanding of energy transitions. Turkey has a centralized economic system; at the same time, it is characterized by soil diversity, cultural discontinuities, and resource inequalities. There is a lot of potential to develop this study in the direction of causal inference. An expansion of the dataset used in this study at the district (in Turkish, *ilçe*) level is the next necessary step to increase the analytical power of the proposed estimations. That way, it will be possible to establish causal channels and provide explanatory mechanisms that do not relate to vertical bureaucratic decision-making but rather to municipal policies and civil society responses. This will be explored in part II of this IPC Analysis. The geolocation of wind farms, solar, and hydroelectric power plants will allow for a refined evaluation of the green transition across district boundaries within the same province. Moreover, the results will provide the baseline information to explore the extent to which energy efficiency and local communities' involvement can be directed in the long run toward the creation and consolidation of sustainable and smart energy markets.

## Acknowledgments

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# Appendix

### Table A.1: Data Profile & Sources

| Variable | Unit | Period | Data source | Notes |
|---|---|---|---|---|
| Average Income per Capita | USD | 2020 | TÜIK | Logarithmic transformation, base year: 2009 |
| Higher Education Graduates | % | 2020 | TÜIK | Share of higher education graduates in a province's population |
| School Attendance | % | 2020 | TÜIK | Primary school enrolment rate in a province's population |
| Gini | % | 2020 | TÜIK | |
| Infant Mortality | % | 2019 | TÜIK | |
| Birth Rate | % | 2020 | TÜIK | |
| Heating Degree Days | Degree Days | 2021 | SolarGIS | Technical Index |
| Cooling Degree Days | Degree Days | 2021 | SolarGIS | Technical Index |
| Wind Power | MW | 2005-2020 | www.enerjiatlasi.com | Wind-based electricity production |
| Solar Power | MW | 2014-2020 | www.enerjiatlasi.com | Solar-based electricity production |
| Hydroelectric Power | MW | 2002-2020 | www.enerjiatlasi.com | Hydro-based electricity production |
| Soil Elevation | Meters | 2021 | SolarGIS | |
| Population Density | Inhabitants/ $km^2$ | 2019 | TÜIK | |
| No. of Facilities | | 2020 | TC Ministry of Environment & Urbanization | Continuous Emissions Measurement Systems (CEMS) |
| No. of Chimneys | | 2020 | TC Ministry of Environment & Urbanization | Continuous Emissions Measurement Systems (CEMS) |
| Air Temperature | Degrees Celsius | 2021 | SolarGIS | According to Global Temperature Report 2021, average air temperature in 2021 was similar to 2018 (berkeleyearth.org). |
| Sunlight Time | Hour-Year | 2018 (2021) | GEPA Enerji İşleri Genel Müdürlüğü | |
| Radiation | $KWh/m^2$-year | 2018 (2021) | GEPA Enerji İşleri Genel Müdürlüğü | |

**Table A.2: Descriptive Statistics**

| Variable | Full Sample | | | | |
|---|---|---|---|---|---|
| | N | Min | Max | Mean | SD |
| Average Income per Capita | 81 | 2901 | 13914 | 6685.346 | 2229.714 |
| Higher Education Graduates | 81 | 9.94 | 24.89 | 15.492 | 2.680 |
| School Attendance | 81 | 79.9 | 94.3 | 92.669 | 1.838 |
| Gini | 81 | 0.283 | 0.451 | 0.352 | 0.032 |
| Infant Mortality | 81 | 3.000 | 16.200 | 8.890 | 2.575 |
| Birth Rate | 81 | 8.455 | 28.286 | 13.253 | 4.489 |
| Heating Degree Days | 81 | 794 | 4972 | 2537.247 | 863.1242 |
| Cooling Degree Days | 81 | 106 | 1658 | 722.580 | 354.659 |
| Wind Energy | 81 | 0 | 1758 | 177.889 | 321.120 |
| Solar Energy | 81 | 0 | 918 | 87.901 | 129.926 |
| Hydroelectric Energy | 81 | 0 | 3128 | 387.175 | 605.220 |
| Soil Elevation | 81 | 4 | 1893 | 690 | 546.169 |
| Population Density | 81 | 11.391 | 2986.772 | 132.190 | 333.325 |
| No. of Facilities | 81 | 0 | 37 | 3.790 | 5.937 |
| No. of Chimneys | 81 | 0 | 114 | 8.802 | 16.071 |
| Air Temperature | 81 | 5.1 | 20.3 | 13.983 | 3.032 |
| Sunlight Time | 81 | 1.303 | 3.508 | 2.688 | 0.284 |
| Radiation | 81 | 2.124 | 1.66 | 1.496 | 0.104 |

Note: SD is standard deviation.

**Table A.3: Balance Diagnostics I – PSM Covariates (Mean & Variance)**

| Variable | Sample | Mean | | Standardized Difference | Variance | | Ratio |
|---|---|---|---|---|---|---|---|
| | | Treated | Control | | Treated | Control | |
| Panel A: Wind Power | | | | | | | |
| Soil Elevation | Unmatched | 488.385 | 877.214 | 0.407 | 197679.3 | 324264.8 | 61.691 |
| | Matched | 488.385 | 474.974 | -0.761 | 197679.3 | 211615.7 | 0.934 |
| Population Density | Unmatched | 202.738 | 66.681 | 0.407 | 221735.80 | 2149.014 | 103.180 |
| | Matched | 202.738 | 101.744 | 0.302 | 221735.80 | 3594.307 | 61.691 |
| Panel B: Solar Power | | | | | | | |
| Soil Elevation | Unmatched | 746.3 | 635.073 | 0.204 | 219448.3 | 376376.8 | 0.583 |
| | Matched | 746.3 | 844.575 | -0.180 | 219448.3 | 298175.6 | 0.736 |
| Population Density | Unmatched | 95.422 | 168.061 | -0.219 | 6162.742 | 213531 | 0.029 |
| | Matched | 95.422 | 80.363 | 0.045 | 6162.742 | 6347.166 | 0.971 |
| Air Temperature | Unmatched | 14.575 | 13.405 | 0.391 | 8.683 | 9.230 | 0.941 |
| | Matched | 14.575 | 14.04 | 0.179 | 8.683 | 8.311 | 1.045 |
| Panel C: Hydroelectric Power | | | | | | | |
| Soil Elevation | Unmatched | 712.55 | 668.00 | 0.081 | 292954.3 | 309966 | 0.945 |
| | Matched | 712.55 | 655.525 | 0.104 | 292954.3 | 234925.4 | 1.247 |
| Population Density | Unmatched | 91.311 | 172.072 | -0.244 | 4822.707 | 214206.9 | 0.023 |
| | Matched | 91.311 | 93.177 | -0.006 | 4822.707 | 5149.395 | 0.937 |

**Table A.4: Matching Results for Wind Power Coarsening**

| | | | Treated | | | | Control |
|---|---|---|---|---|---|---|---|
| Number of strata: | 9 | | | | | | |
| Number of matched strata: | 5 | | | | | | |
| All | | | 39 | | | | 42 |
| Matched | | | 37 | | | | 34 |
| Unmatched | | | 2 | | | | 8 |
| Multivariate Imbalance Measure: | L1 = 0.278 | | | | | | |
| Univariate Imbalance Measures: | | | | | | | |
| Variable | L1 | Mean | Min | 25% | 50% | 75% | Max |
| Soil Elevation | 0.014 | 5.451 | -7.00 | -11.00 | -20.00 | -12.00 | -54.00 |
| Population Density | 0.150 | 33.922 | 10.99 | 6.700 | 14.631 | 39.626 | 133.6 |

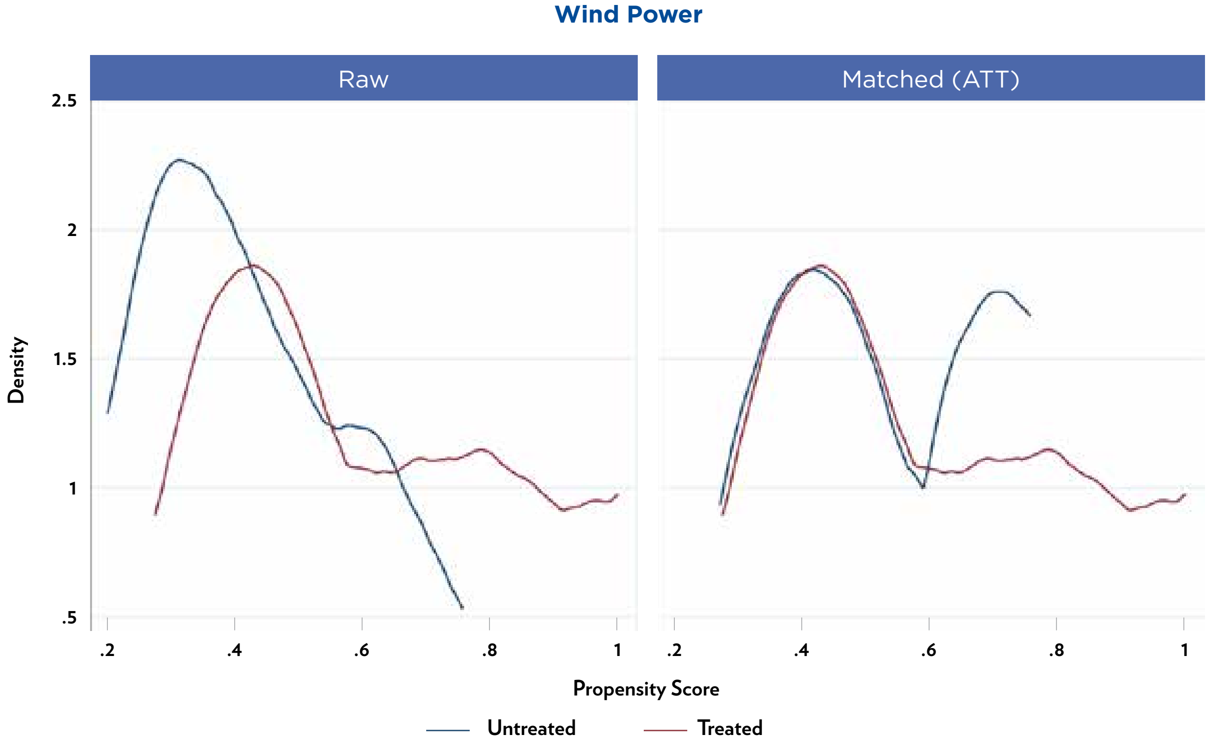
### Table A.5: Matching Results for Solar Power Coarsening

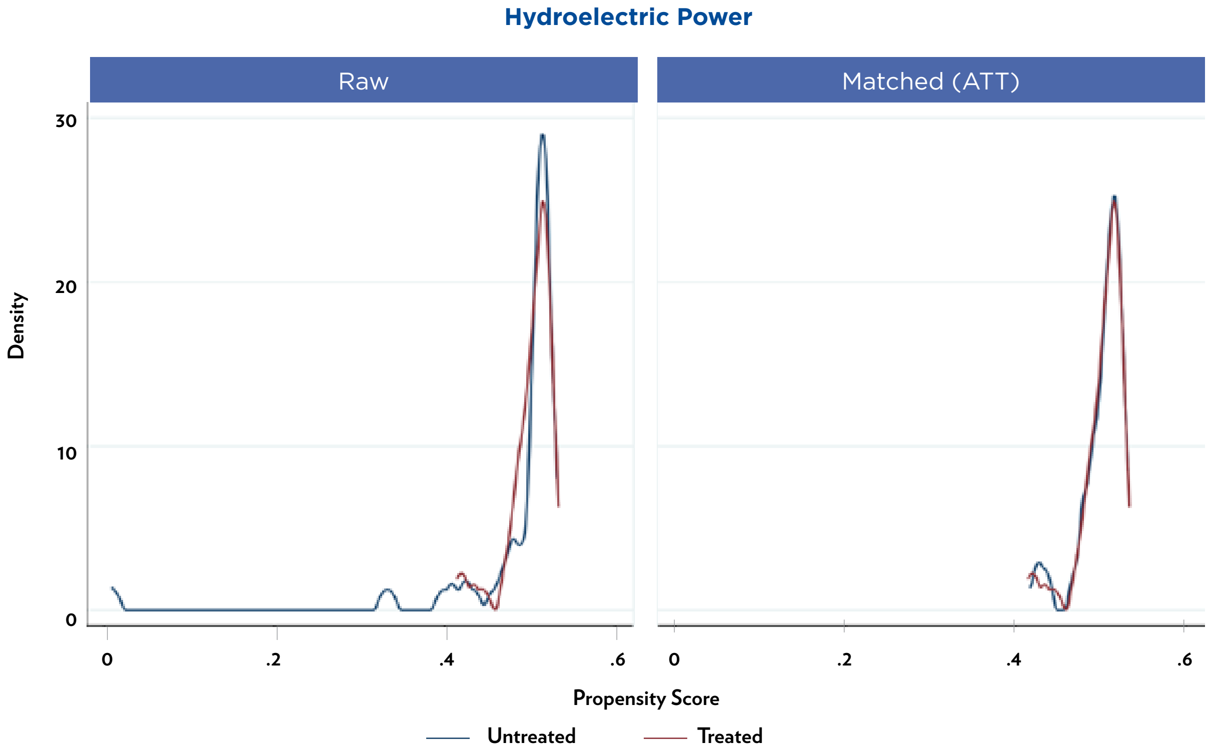
| | | | Treated | | | | Control |
|---|---|---|---|---|---|---|---|
| Number of strata: | 24 | | | | | | |
| Number of matched strata: | 11 | | | | | | |
| All | | | 40 | | | | 41 |
| Matched | | | 37 | | | | 30 |
| Unmatched | | | 3 | | | | 11 |
| Multivariate Imbalance Measure: | L1 = 0.509 | | | | | | |
| Univariate Imbalance Measures: | | | | | | | |
| Variable | L1 | Mean | Min | 25% | 50% | 75% | Max |
| Soil Elevation | 0.189 | 51.114 | 10 | 180.00 | 73.00 | 86.00 | 68.00 |
| Population Density | 0.135 | -6.605 | 10.99 | -1.372 | 7.602 | -14.002 | 43.65 |
| Air Temperature | 0.150 | -0.009 | 1.5 | 0.40 | 0.300 | -0.700 | 0.900 |

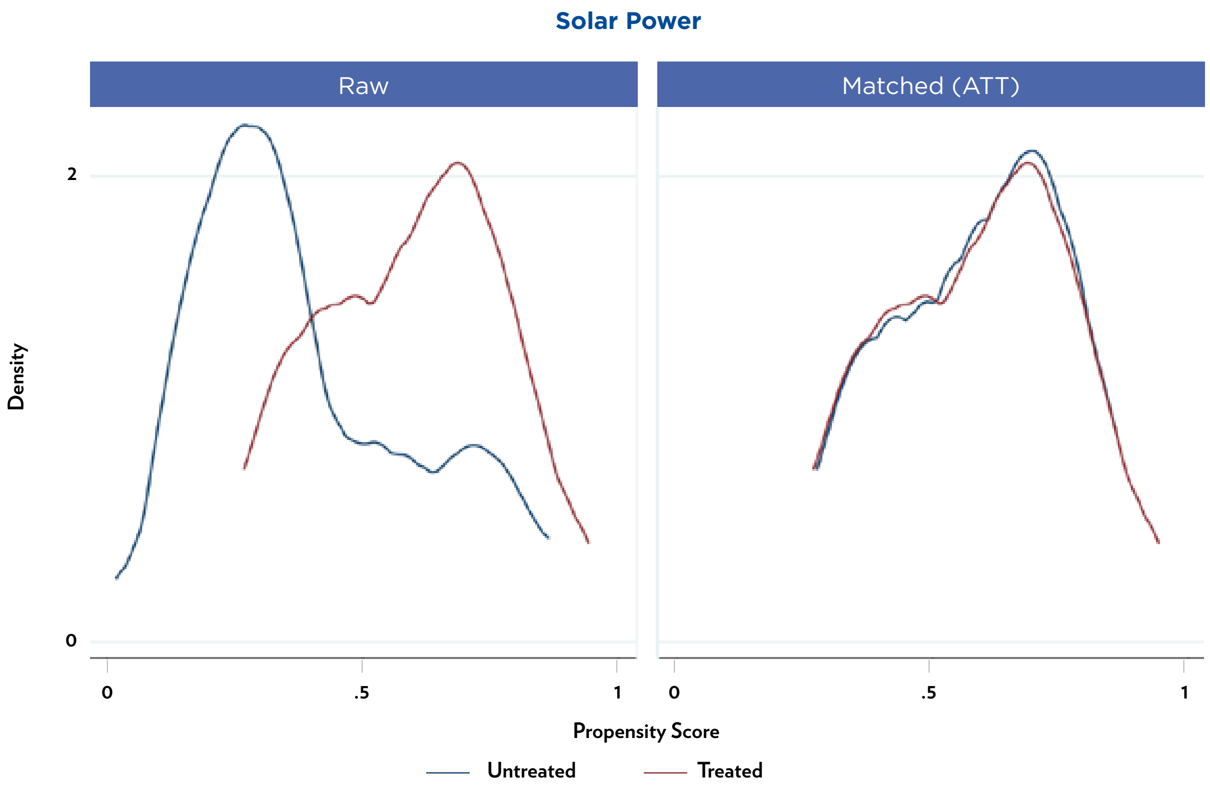
### Table A.6: Matching Results for Hydroelectric Power Coarsening

| | | | Treated | | | | Control |
|---|---|---|---|---|---|---|---|
| Number of strata: | 9 | | | | | | |
| Number of matched strata: | 6 | | | | | | |
| All | | | 40 | | | | 41 |
| Matched | | | 40 | | | | 37 |
| Unmatched | | | 0 | | | | 4 |
| Multivariate Imbalance Measure: | L1 = 0.181 | | | | | | |
| Univariate Imbalance Measures: | | | | | | | |
| Variable | L1 | Mean | Min | 25% | 50% | 75% | Max |
| Soil Elevation | 0.035 | 2.149 | 8.708 | -9.068 | 12.276 | 69.00 | 202.00 |
| Population Density | 0.137 | 13.859 | 7.00 | -89.00 | -10.00 | 19.069 | -60.104 |

### Figure A.1: Balance Diagnostics II – Density Graphs




Solar Power
Raw
Matched (ATT)
Density
2
0
0
.5
1
0
.5
1
Propensity Score
Untreated
Treated

## Notes

1 | Yael Taranto et al., *Socioeconomic impact of the power system transition in Turkey* (Istanbul: SHURA Energy Transition Center, 2021). Electric utilities operating on fossil fuels may produce different types of pollutants. These are not GHG; however, they constitute a significant danger to people's health, e.g., gases such as sulfur dioxide (SO2) and nitrogen oxide (NOx) as well as particulate matter (PM). See also Imran Qaiser and Theocharis Grigoriadis, "Measuring the Ecological Efficiency of Thermal Power Plants: Evidence from Pakistan," *Asia Development Review* 37, no. 1 (2020): 159–184; Samir Amous et al., "Expert Group: Non-CO2 Emissions from Stationary Combustion," in J. Penman et al., *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Methodology Report, 1–95, published for the IPCC by the Institute for Global Environmental Strategies, Japan, 2000.

2 | L.L.B. Lazaro, "Energy transition in Brazil: Is there a role for multilevel governance in a centralized energy regime?" *Energy Research & Social Science* 85 (2022).

3 | Amanda Bradshaw and Gilberto de Martino Jannuzzi, "Governing energy transitions and regional economic development: Evidence from three Brazilian states," *Energy Policy* 126 (2019): 1–11.

4 | Camilla Chlebna and Jannika Mattes, "The fragility of regional energy transitions," *Environmental Innovation and Societal Transitions* 37 (2020): 66–78.

5 | Siddharth Sareen and Håvard Haarstad, "Bridging socio-technical and justice aspects of sustainable energy transitions," *Applied Energy* 228 (2018): 624–632.

6 | Lars Coenen, Teis Hansen, Amy Glasmeier, and Robert Hassink, "Regional foundations of energy transitions," *Cambridge Journal of Regions, Economy and Society* 14, no. 2 (July 2021): 219–233.

7 | Matthias Naumann and David Rudolph, "Conceptualizing rural energy transitions: Energizing rural studies, ruralizing energy research," *Journal of Rural Studies* 73 (2020): 97–104.

8 | Jiali Zheng et al., "Regional development and carbon emissions in China," *Energy Economics* 81 (2019): 25–36.

9 | Iván Franchi-Arzola, Javier Martin-Vide, and Cristián Henríquez, "Sustainability Assessment in Development Planning in Sub-National Territories: Regional Development Strategies in Chile," *Sustainability* 10, no. 5 (2018): 1398.

10 | Simone Strambach and Gesa Pflitsch, "Transition topology: Capturing institutional dynamics in regional development paths to sustainability," *Research Policy* 49, no. 7 (2020): 104006.

11 | For a detailed comparison between PSM and CEM in terms of their properties, advantages, and disadvantages, see Q. Gao, F. Zhai, S. Yang, and S. Li, "Does Welfare Enable Family Expenditures on Human Capital? Evidence from China," *World Development* 64 (2014): 219–231.

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