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Landscape Disruption and Perceived Urban Bias:
Sources of Opposition to Renewable Energy in South Korea

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Abstract

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Since 2012, South Korea has joined a group of countries with a rapid increase in solar energy facilities and an unprecedented level of local opposition to renewable energy. This is puzzling because in 2021, a survey showed that over 80% of South Korean citizens support the rapid transition from carbon-intensive energy sources to low-carbon renewable energy ones. This dissertation comprises three empirical studies that show landscape disruption from solar farms and perceived urban bias therein are two major sources of opposition to renewable energy facilities and policies in South Korea. Chapter 1 conceptually refines these two sources and overviews how the following chapters empirically analyze them.

Chapter 2 explains a recent case of the diffusion of setback restrictions on solar energy facilities across 129 counties in South Korea from 2012 to 2020. It shows that rural opposition to landscape change from solar farms was a key driver for South Korean county governments to adopt the restriction. The event history analysis across 225 counties from 2012 to 2020 shows that rural counties with a higher chance of landscape change from solar farms, measured with solar farm density, faced a higher risk of adopting the restriction. Interview research further suggests that rural opposition to landscape change has motivated government officials to adopt the setback restriction on solar farms. This finding suggests that landscape disruption represents the negative impact of solar energy facilities on local

communities, which shapes local opposition and local policy barriers against such facilities.

Chapter 3 shows that landscape disruption from solar energy facilities also matters for a renewable energy policy in general, not only for the siting of solar energy facilities. It examines a case of renewable energy surcharge, a representative renewable energy subsidy policy of South Korea introduced in 2012. Drawing on evidence from an original online survey (N=1043), it shows that survey respondents who believe solar farms disrupt the surrounding landscapes are less likely to support the surcharge increase.

Chapter 4 looks at another source of opposition to renewable energy: a perceived urban bias in solar energy facilities. Rural areas bear a growing burden of domestic renewable energy transition by hosting most of the renewable energy facilities in the society. Yet, rural areas consume less electricity than urban areas. This geographical mismatch of energy production and consumption sites may motivate rural residents to perceive urban bias in renewable energy facilities, a notion that those facilities in rural areas are in fact predominantly beneficial for urban areas. The chapter employs a field survey experiment with randomized vignette treatments to explore whether such perceived urban bias reduces support for solar energy among rural residents in South Korea. The results suggest that groups of rural residents exposed to framed messages highlighting that solar farms benefit urban residents are less likely to support government investment in solar energy development than those in a reference group. However, such a framing effect was not found among suburban residents.

Chapter 5 concludes by providing policy implications and suggests an area of future research. First, rural residents' concern over local negative impacts of renewable energy facilities is not just a potential source of barriers to local renewable energy projects: It may undermine the effectiveness of a national-level renewable energy policy as well. Therefore, both the national and subnational governments must coordinate to address their concerns and incorporate measures to mitigate such negative impacts into the existing renewable energy policies and siting regulations. Second, perceived urban bias in solar energy facilities

may also be exhibited in wind energy facilities, as long as the society places more burden of the renewable energy transition on rural communities. To make renewable energy facilities more politically acceptable for rural communities, policymakers should ensure that renewable energy expansion goes hand in hand with (1) enhancing energy efficiency in urban areas and (2) channeling the benefits of renewable energy facilities into rural communities.

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GLOSSARY

CLIMATE JUSTICE: A principle that (1) acknowledges that historically marginalized communities and/or individuals are more vulnerable to both the adverse impacts of climate change and climate mitigation tools and (2) promotes to alleviate such unfair burdens of marginalized communities [33].

ENERGY JUSTICE: A principle that promotes a fair distribution of benefits and burdens associated with the energy system, climate change, and socioeconomic participation by removing the structural barriers to vulnerable communities [112].

LANDSCAPE: A geographical area characterized by its content of observable, both natural and manufactured features, which both have physical-aesthetic and cultural-psychological values to human beings and their activities [57].

NET-ZERO EMISSION: A status where greenhouse gas emissions (or a specific type of greenhouse gas emissions, such as carbon dioxide) produced by a given entity are fully absorbed into carbon sinks or reservoirs so that they do not contribute to global warming.

NET-ZERO EMISSION PLEDGES: Legalized or proclaimed commitments, mostly by national governments but often also by subnational governments, industrial organizations or non-state actors, to achieve net-zero emission by a specific timeline [62].

PERCEIVED URBAN BIAS: A perceived notion that renewable energy facilities predominantly benefit urban areas while rural areas bear most of their local negative impacts.

PLACE-BASED IDENTITY: An identity held and/or shared by individuals in a spatially determined boundary that is in an inter-subjective relationship with such an area [31].

RENEWABLE ENERGY: Energy from renewable sources that are naturally replenished on a human timescale, such as wind and solar.

RENEWABLE ENERGY FACILITIES: Facilities that generate electricity from renewable energy sources.

RENEWABLE ENERGY SURCHARGE: A cost levied upon electricity customers per their electricity consumption to subsidize renewable energy provision.

RURAL OPPOSITION TO RENEWABLE ENERGY: Individual-level, or community-level opposition to renewable energy facilities in their vicinity and/or renewable energy policy in general in rural communities that are expressed publicly or in a social setting, often translated into institutionalized petitions or mobilized protests.

SOLAR FARM: Renewable energy facilities that generate electricity from solar energy, particularly using photovoltaic panels to generate electricity from radiant light. Note that Jefferson suggests not to use the term "solar *farm*" [54], but this dissertation uses this term simply for the sake of brevity.

SETBACK RESTRICTION: Land-use regulations that restrict the siting of certain facilities, buildings or constructions within specific distances from certain features such as property lines, roads, structures, natural features, etc. [99].

UTILITY-SCALE RENEWABLE (ENERGY) FACILITIES: Facilities that generate electricity from renewable energy sources that are large-scale with commercial purposes, often as opposed to renewable energy facilities that are smaller in size with the purpose of electricity for residential use only.

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DEDICATION

To my parents and my partner

Chapter 1

INTRODUCTION

Achieving net-zero emissions requires low carbon energy transition, which means renewable energy facilities should expand rapidly to replace high-carbon energy sources such as fossil fuels [112, 113, 80, 60]. These facilities populate rural areas with low population density because of their land availability and affordability [90, 98]. However, rural communities are increasingly opposing renewable energy projects [118, 131, 85, 105, 63, 106]. Since 2015, the Renewable Rejection Database has reported over 450 cases of rejections or restrictions to wind and solar energy projects in the U.S. [23]. These local oppositions often translate into anti-renewable political and policy outcomes [104, 4]. For instance, 729 U.S. counties have implemented policies that block or restrict the siting of renewable energy facilities until 2022 [66, 65].

This dissertation investigates the sources of rural opposition to renewable energy, focusing on solar energy, in South Korea with three distinctive but closely interrelated empirical studies. The bottom line of these studies is the fact that renewable energy facilities create the global public good of climate mitigation at the expense of potential negative impacts on their local communities. This helps us understand rural opposition as a process and an outcome of distributive conflicts of renewable energy development at a domestic level, particularly between rural and urban areas. In other words, aggressive climate actions by national governments, most notably through renewable energy transition, can be hampered not only by free-riding concerns [91] derived from other governments' inactions but also by domestic distributional conflicts [7] that can be intensified as the society further decarbonizes.

Scholars have long viewed climate change as a "tragedy of the global commons" [47, 94] where global atmosphere as a greenhouse gas (GHG) sink is a form of common pool resources

(CPRs). A straightforward solution to climate change is reducing GHG emissions which produces a stable climate, but its use is non-rivalry and non-excludable. In other words, a stable climate is a global public good which non-providers can free-ride on its provision from providers, i.e., whose provision suffers from collective action problem. Scholars who view the under-provision of public goods as market failure [101, 108] have advocated for the role of strong international institutions [59, 10, 115] that serve as "the government of governments" to reverse the incentives to free-ride. Or, realizing the absence of the de facto world government, others have proposed the diffusion of a more heterogeneous, smaller-scale cooperation, i.e., polycentric climate governance [92, 94], especially because collective action is more difficult to achieve when the group is larger [89]. Even the proponents of these smaller-scale cooperation, such as Nordhaus with climate clubs [86], assert that overcoming free-riding within such smaller clubs (i.e., shirking) is critical for the optimal provision of a stable climate [102].

Scholars who question the way of understanding climate change as a global collective action problem point out that some countries have made ambitious climate actions even when free-riding concerns were pervasive. They understand that climate action at a domestic level creates "winners" and "losers," creating distributional conflicts between winners as "climate proponents" and losers as "climate opponents," and focus on under what conditions climate proponents prevail over climate opponents so that governments can undertake ambitious climate actions [50, 78]. For instance, Aklin and Mildemberger [7] suggest that the drivers of such actions come from domestic political arena where "climate actions are possible regardless of actions undertaken in other countries "when domestic "pro-climate forces are powerful enough to neutralize politically climate reform opponents."

A research on renewable energy opposition aims to look at another form of distributional conflict in climate policy that has been overlooked in the literature. In this research, renewable energy development becomes a center of an analysis [117] as opposed to other types of climate actions such as national climate commitments [45] or carbon pricing policies [74]. Then, drawing on the literature on social acceptance of renewable energy [16, 130, 13], it

embraces the fact that renewable energy facilities exhibit local negative externalities, for example, through landscape disruption [9, 129, 52, 17], deforestation [38, 82], and property value decrease [68, 36] (see, however, Elmallah et al. [37] for regional heterogeneity). This implies that renewable energy development, like a GHG reduction, is a public good yet with local costs, prone to collective action problem among local communities and governments who may wish to free-ride on others' renewable energy installations [128, 16]. Therefore, this research reaffirms that free-riding concerns are still crucial for understanding the impediments to national climate actions as they critically rely on rapid renewable energy transition [60, 80]. In other words, free-riding concerns have never been trivial: they are rather intensifying domestically.

Meanwhile, this research also acknowledges that renewable energy facilities around the world are largely concentrated in rural areas, shouldering more burdens on rural communities than urban areas [90, 98]. Therefore, rural communities are becoming "losers" of renewable energy transition [81, 93]. It is unfair to say that rural communities are always losing out from renewable energy facilities: Community-based renewable energy projects have continuously been reported to benefit rural communities through increased access to low-carbon electricity and alleviating poverty [132]. Yet, when local governments have limited capacity to channel those benefits into rural communities and/or mitigate local negative impacts of renewable energy facilities [51], rural areas will largely remain as losers of renewable energy transition, or "renewable energy opponents." This creates a distributional conflict of renewable energy expansion between urban and rural areas: Urban areas may continue to enjoy low-carbon electricity from rural areas without bearing local costs of renewable energy facilities in their vicinity; Rural areas may continue to oppose a geographical mismatch in where renewable electricity is consumed and produced. This distributional conflict persists under the hood of an increasing number of cases of rural opposition to renewable energy facilities and projects around the world.

This dissertation introduces the research on rural-urban conflict in renewable energy development through the case of South Korea. It aims to explain how rural concentration of

burdens of renewable energy transition poses barriers to siting renewable energy facilities in rural areas, as well as to renewable energy policies including renewable energy subsidies and investment. Chapter 2 and 3 focus on the most representative form of burdens of renewable energy facilities: landscape disruption. Specifically, renewable energy facilities are viewed as disrupting the rural landscape [9, 129], spoiling rural aesthetics, and impacting property values [29, 54, 39, 81, 36]. Chapter 2 argues that rural residents' concerns over such landscape disruption¹ were the key drivers of the diffusion of local setback regulations against them, representing local policy barriers against renewable energy development. This highlights that renewable energy facilities may face both local opposition and siting regulations if their local negative impacts are not mitigated. I test this argument through a mixed-method approach, combining an event history analysis of a novel county-level government data including time-series cross-sectional observations on siting regulations and interview research.

Chapter 3 further argues that concerns over landscape disruption are not only perceivable by rural residents. In an online survey, it asks whether individuals, regardless of whether they live in rural or urban areas, show a lower level of support towards renewable energy policy if they believe solar farms disrupt the surrounding landscapes. Because landscape disruption represents local negative impact of renewable energy facilities, those who perceive such a negative impact should less favor government policies that promote those facilities. The chapter looks at the longest and the most representative renewable energy policy in South Korea, namely renewable energy surcharge. Since 2012, South Korean households have paid the surcharge on their monthly electricity bills which has been spent on promoting renewable energy development, e.g., subsidizing renewable energy portfolio standards (RPS). While the second chapter focuses on an "experienced" form of negative impact, the third chapter explains that both "experienced" and "perceived" negative impacts (that may not be experienced by individuals yet) matter for the social acceptance of renewable energy. In this chapter, I used a Bayesian approach to account for the non-linearity of categorical survey

¹In this dissertation, I use the term "solar farms" to mainly refer to utility-scale solar energy facilities with commercial purposes.

responses which leads to their potential non-linear effect on the outcome variable.

Chapter 4 focuses on another source of opposition to renewable energy: *perceived urban bias*. It refers to the notion that renewable energy facilities benefit urban areas (where much of the electricity is consumed) more than rural areas, while the costs are borne predominantly by rural residents. The chapter employs a field survey experiment with randomized vignette treatments to explore how perceived urban bias in solar farms reduces support among rural residents for solar energy expansion. Specifically, I test two treatment frames that trigger the notion of urban bias in solar farms. The first frame highlights that while solar farms are largely located in rural areas, they are biased toward urban populations in general by producing and transmitting electricity to urban from rural areas. The second frame also highlights that solar farms are largely located in rural areas but are biased toward urban developers that reap profits from such solar farms. The difference between the first and second frames is that they attribute urban bias to a different group of urban populations, the general urban population versus a small group of urban elites. In terms of my empirical strategy, I administered this survey in two villages, one rural and the other suburban, to see if perceived urban bias has varying levels of effect on individual support towards solar energy development in rural and suburban areas.

Chapter 2

LANDSCAPE DISRUPTION AND SETBACK REGULATIONS ON SOLAR FARMS ACROSS SOUTH KOREAN COUNTIES¹

This chapter documents and analyzes a recent case in South Korea where more than half of county governments ² have adopted setback restrictions on solar farms. These restrictions refer to land-use regulations that restrict the siting of solar farms within specific distances from property lines, roads, structures, and natural features [99]. Since 2015, 129 out of 229 county governments have amended their land-use ordinances to include setback restrictions on solar farms. Figure 2.1 illustrates this trend. This is surprising given that the South Korean government introduced a renewable energy policy in 2017 that aims to produce 20% of its total electricity from renewable energy. As county governments have the final authority to issue permits to renewable energy projects, their setback restrictions vastly reduce available lands for solar energy projects. Why did local governments in South Korea enact policy barriers against solar energy development?

Utility-scale renewable facilities may face local opposition when they have negative impacts on local communities [33, 117]. This chapter focuses on the disruptive impact of utility-scale solar farms on the surrounding landscape [39, 52]. Solar farms significantly

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²South Korea has three-tier local governance systems: Tier 1 (province-level or state-level) includes 8 provinces and 7 metropolitan cities, including Seoul. Tier 2 (county-level) includes 226 counties and cities affiliated with the Tier 1 governments, and 2 autonomous jurisdictions (Sejong city and Jeju Island) excluded from the analysis. Lastly, Tier 3 (town-level) governments are affiliated with the Tier 2 governments. The unit of analysis of this chapter is a county-level (Tier 2) government. I will generally refer to these tier 2 governments as “counties,” even though some county-level governments are titled “cities.” Ulleung county is also excluded in the event history analysis to follow since it is an island and therefore cannot account for spatial frailties (N=225).

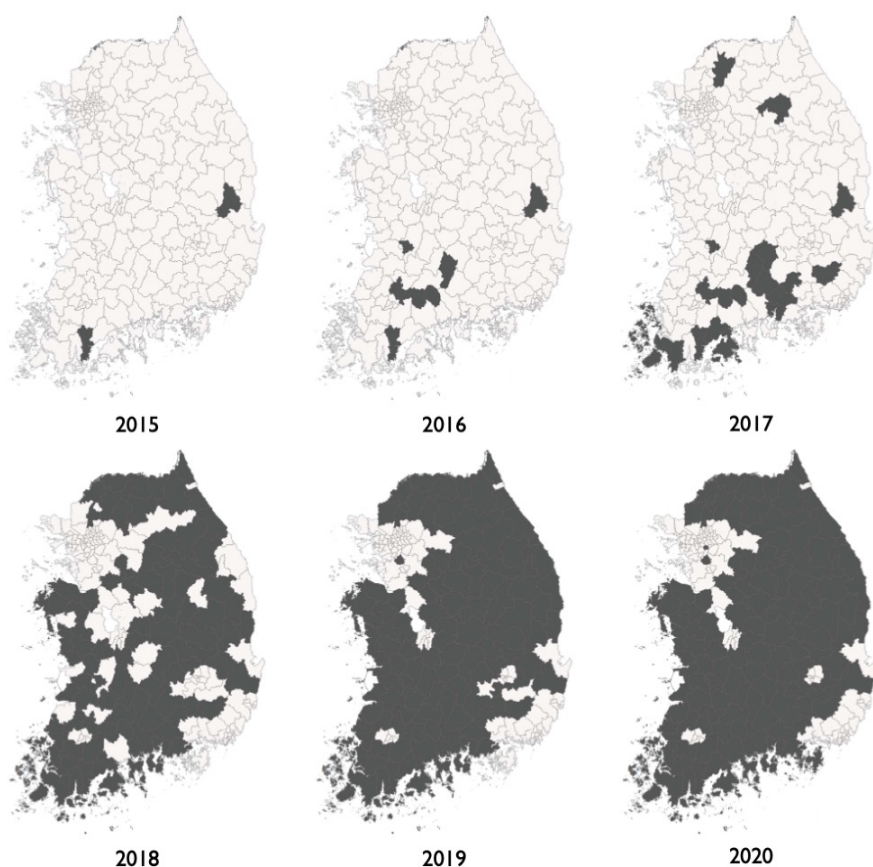


Figure 2.1: The diffusion of setback restrictions on solar farms across South Korean counties, 2015-2020 (counties with restrictions colored black)

change the landscapes of where they locate as they grow in number, but differently in urban and rural areas. Solar farms are more visually alien to rural landscapes as they are manufactured facilities consisting of ceramic and metallic subcomponents. Their visual impact on rural landscapes can be magnified when they replace forests and farmlands in rural areas. Moreover, various studies document that the value of landscape is both economically and psychologically crucial for rural communities [114, 3]. Therefore, solar farms are more likely to face opposition from rural residents than urban residents if they populate the area and are highly visible.

This chapter explores whether rural opposition to landscape change from solar farms motivated county governments to adopt the restriction. Section 2 theorizes how solar farms have different implications for landscape disruption in rural and urban areas. Section 3 summarizes results from an event history analysis to see whether counties with high chances of landscape change from solar farms, measured with solar farm density, have faced a higher risk of adopting the restriction, particularly in rural areas. Section 4 presents evidence from interview research with rural residents and local public officials that rural opposition to landscape change from solar farms was a key driver for county governments to adopt the restriction. Section 5 concludes by discussing the findings and limits of this chapter and provides policy implications.

2.1 Rural landscape change as a driver for opposition to solar farms in rural areas

A landscape is a geographical area characterized by its content of observable, both natural and manufactured features, which both have physical-aesthetic and cultural-psychological values to human beings and their activities [57, 110]. Therefore, a change in the landscape is primarily driven by changes in observable features, be they natural or manufactured. According to this definition, solar farms can cause landscape change as they are observable and manufactured features added to the landscape, bringing industrial transformation.

Studies have identified the visual impact of renewable facilities on the landscape as a critical factor that conditions their social acceptability [130, 22]. Solar farms impact their surrounding landscapes in rural and urban areas differently. First, solar farms are more visually alien to rural landscapes than urban ones [9]. Rural landscapes are typically characterized by natural features such as forests, agricultural vegetation, snow-capped mountains, and streams. In contrast, manufactured features dominate urban landscapes, such as highroads, skyscrapers, bridges, and commercial and industrial complexes [58]. Since solar farms mainly comprise ceramic and metallic sub-components, they are more visually alien to rural

landscapes than urban ones. Also, like any other construction project, solar farms require a massive land-use change [122]. They need various components other than photovoltaic panels to be installed on-site, such as support fixtures and pillars, which require developers to build a new road for their transportation from outside areas. As the number of utility-scale solar farms rises, the more likely they will change their surrounding landscapes. If they replace existing natural features, their visual impact on rural landscapes can be magnified [129].

Furthermore, to achieve cost-efficiency, utility-scale solar farms are sited at a high altitude to garner as much radiation as possible (e.g., on rooftops or hills with less shadowy areas) [119]. If they are placed on rooftops, since the average height of the buildings is lower in rural areas, one can detect solar farms more often in rural areas than urban ones. Urban rooftops are hardly visible when human beings stand on ground level. Or, if they are ground-mount, they should be sited in areas with lower land prices, translating into lower set-up costs (if they purchase lands) or production costs (if they rent them). Areas with lower land prices in rural areas are typically less developed, preserving pristine natural features that provide economic benefits for rural communities [56, 28, 34]. For instance, the rural natural landscape provides amenities that attract new migrants, facilitating local economic activities and employment opportunities [73]. Therefore, replacing or distracting these landscapes with solar farms may provoke resistance by rural residents fearing the loss of their economic value. Drawing on local house price data of the Netherlands from 1985 to 2019, Dröes and Koster [36] find that house prices within 1 km of solar farms decrease by around 2.6% due to visual pollution.

Studies have documented various cases of rural opposition to landscape disruption from manufactured features, including energy facilities and infrastructures. Hess et al. [48] show that among 78 cases of rural opposition to proposed electricity power lines they documented in the U.S. and Canada, 31 cases were motivated by residents' concerns over their effect on landscape disruption. Bessette and Mills [17] also show that wind farm projects in rural communities with higher natural amenities were more likely contentious. In the South Korean context, both solar [96] and wind farms [61], as well as natural gas pipelines [95] have confronted rural opposition driven by landscape change in their construction process.

These studies highlight that proposed renewable projects may be delayed or even canceled when residents have concerns over their disruptive impacts on their surrounding landscapes. However, they overlook the possibility that opposition to existing renewable energy facilities may deter future projects. Local opposition can translate into local regulations or zoning laws that limit available lands for future renewable energy projects to be submitted [4]. When such restrictions are in effect, future renewable energy projects may face challenges even if they incorporate plans to harmonize energy facilities with their surrounding landscapes better. Drawing on the South Korean case, I show how rural residents’ opposition to solar farms due to their disruptive impacts on their surrounding landscapes leads to local policy decisions that limit future renewable energy project proposals.

2.2 *Event history analysis*

To investigate the relationship between local setback restrictions on solar farms and their disruptive impact on the landscape, I analyze the data of 225 South Korean county-level governments from 2012 to 2020 with their restriction adoption records. The analysis covers from 2012 since county-level data on solar energy capacity is available only after 2012. The data includes county governments that have adopted restrictions (i.e., “adopters”) and that have not (i.e., “non-adopters”).

I use the event history analysis to analyze the data to examine what explains the timing of the adoption of setback restrictions. It is important to note that all county governments with setback restrictions have not lifted them as of March 2023. This means that adopters have left the risk set when they have adopted the restrictions, and non-adopters are right-censored (i.e., they have not adopted restrictions until the end of the study period, which is 2020). The dependent variable is a binary indicator whose value is one if a county year has the restriction and zero otherwise. Since observations are annual, we can pool them by yearly intervals. Therefore, I use a piecewise event history model [20].³

³This model is also known as a discrete-time event history model, using either logit or complementary

I set up two main explanatory variables. The first is solar farm density (number of solar farms per hectare) which captures how much solar farms affect the landscape of each county. As their number grows within a specific area, their impact on landscape change should also increase. The second explanatory variable is population density (population per square km), logged to account for the nonlinearity across counties, which should capture whether rural or urban landscapes characterize each county. Consistent with the main argument, I add an interaction term with these two explanatory variables. I hypothesize that solar farm density should increase the likelihood of county governments adopting the restriction on solar farms more highly in rural areas than in urban areas.

The model includes several additional control variables. First, I include the average capacity of solar farms (average kW per solar farm). As solar farms' capacity and physical size go hand in hand, the average capacity of solar farms in a county may proxy for how large solar farms are on average and therefore how intrusive they are for their surrounding landscapes. I also add an interaction term with the average size of a solar farm and population density. Second, I include the share of farmlands in each county year. Areas with a higher share of farmlands are more characterized by rural areas and therefore are more available for solar farms to be sited. Third, whether local governments are responsive to constituents' needs is important, typically measured by mayors' or governors' winning margin [49]. If county government leaders have won the previous election by a smaller margin, they will be more responsive to the opposition when it occurs. Therefore, I include the winning margin variable of mayors' or governors' previous elections. Lastly, I include the average global horizontal irradiation (GHI) between 2007 and 2018, largely unvarying over time. GHI is the total amount of shortwave radiation from above by a surface horizontal to the ground (kWh per square meter), retrieved from Global Solar Atlas 2.0. In counties with higher GHI,

log-log (cloglog) regression. If logit link is used, this model is equivalent to the proportional odds model from which we obtain an odds ratio when exponentiating the coefficient estimates. If the cloglog link is used, we obtain a hazard ratio when we exponentiate coefficient estimates since the model is equivalent to the proportional hazards model. In this chapter, I use the cloglog link function based on the goodness of fit measure as discussed in Appendix A. Therefore, I report hazard ratios instead of odds ratios when interpreting the model results.

solar farms may penetrate more, and local governments may be more unwilling to adopt the restriction, given that solar farms' productivity may be higher.

The model results appear in the first column of the table (Model 4) in Appendix A. Hazard ratios are calculated by exponentiating the coefficient estimates. First, an increase in solar farm density by one per hectare, for instance, is associated with a 1.13 times increase ($e^{(0.119 \times 1)}$) in the risk of adopting the restriction on average. Also, a decrease in population density by 1 percent is associated with a 1.69 times increase ($e^{(-0.528 \times -1)}$) in the risk. Note that the coefficient for the interaction term between these two factors is statistically significant and negative. This means that an increase in population density dilutes the effect of solar farm density on increasing the likelihood of adopting the restriction. This result supports the argument that rural counties, relative to urban ones, are more likely to adopt the restriction when facing high solar farm density.

I created five counterfactual scenarios with varying solar farm and population density levels for a better interpretation of the results. These scenarios help us examine how they differ in the expected likelihood of adopting the restriction from a hypothetical county with all variables held average (i.e., a "baseline county"). The first scenario is when a county has one more solar farm per hectare than the average of all counties. This scenario shows the marginal effect of solar farm density on the likelihood of adopting the restriction. Residents in this counterfactual county should see more solar farms in their surrounding landscape than those in the baseline county. The second and third scenarios assume counterfactual counties with more solar farms per hectare but are more rural than the baseline county. Specifically, the second scenario has one lower percentage, and the third scenario has two lower percentages of population density than the baseline county. I expect their ruralness should intensify the marginal effect of solar farm density. By contrast, the fourth and fifth scenarios assume counterfactual counties that are more urban than the baseline county. The fourth scenario has one higher percentage, and the fifth scenario has two higher percentages of population density than the baseline county. I expect their ruralness should attenuate the marginal effect of solar farm density. All scenario counties share the same values for the

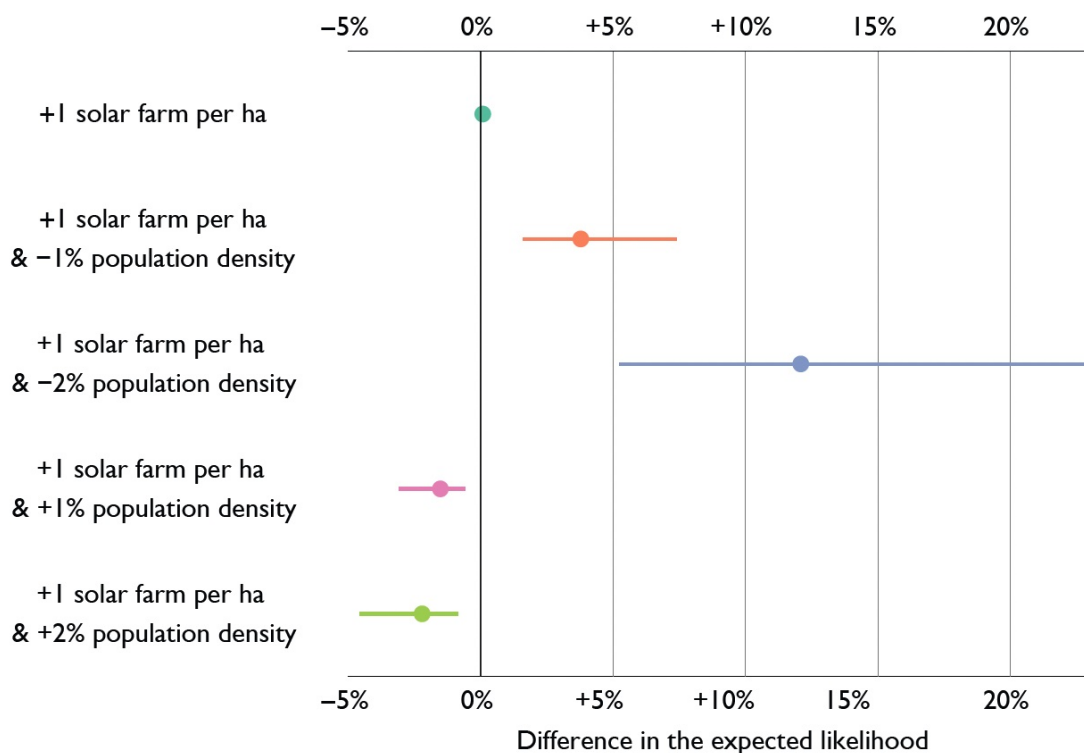


Figure 2.2: Differences in the expected likelihood of adopting the restriction, each scenario vs baseline county

rest of the covariates with the baseline county except for solar farm and population density variables.

Figure 2.2 visualizes the differences in the expected likelihood of adopting the restriction between each scenario versus the baseline county. The likelihood of the first scenario county is higher by only about 0.01% than the baseline county, yet this difference is significantly higher than zero. Whether a solar farm is in rural or urban areas matters when we see four other scenarios. When hosting one more solar farm per hectare, a county with one lower percent of population density (scenario 2) faces a 3% higher likelihood of adopting the restriction than the baseline county, and a county with two lower percent (scenario

3) faces a 12% higher likelihood. A county with one higher percent of population density (scenario 4), however, faces a 1.5% lower likelihood of adopting the restriction than the baseline county when hosting one more solar farm per hectare, and a county with two higher percent (scenario 5) faces a 2.2% lower likelihood. Overall, five scenarios suggest that solar farm density increases the likelihood of county governments adopting the restriction when they are in more rural than urban areas.

Coefficients for other control variables are also noteworthy. First, the effect of the average size of a solar farm is not statistically significant. The interaction term between the average size of the solar farm and population density does not show a statistically significant coefficient either. This result suggests that the number of solar farms, rather than their average size, is more visually salient for residents. Second, a higher share of farmlands is associated with a lower risk of adopting the restriction: a 1 percent point increase in the share of farmlands in a county year is associated with, on average, 0.9 times lower risk ($e^{(-0.098 \times 1)}$) of adopting it. This suggests that not all rural residents oppose solar farms. If rural residents own farmlands in their region, they may face incentives to sell those lands when utility firms offer higher benefits from what they gain from agricultural products. Therefore, it points to the possible heterogeneity across rural areas depending on how much they are dependent on the farming industry. Third, the winning margin is not associated with any significant change in the risk of adopting the restriction. This suggests that two main factors, high solar farm density and more ruralness of a county, were the main drivers of the restriction adoption, regardless of how responsive the government was. Lastly, GHI does not have any significant effect on the risk of adopting the restriction, indicating how much each county is endowed with solar radiation was not an important factor.

The main finding is consistent with additional evidence of landscape disruption by solar farms in South Korea, mainly through deforestation. Park et al. [40] have investigated 4,450 solar farms ($71.1km^2$) that have gone through preliminary environmental impact assessment (EIA) from 2004 to 2018. They found that 60.9% of these solar farm sites have replaced forest lands and 20% have replaced farmlands, mainly in rural areas. The Member of the

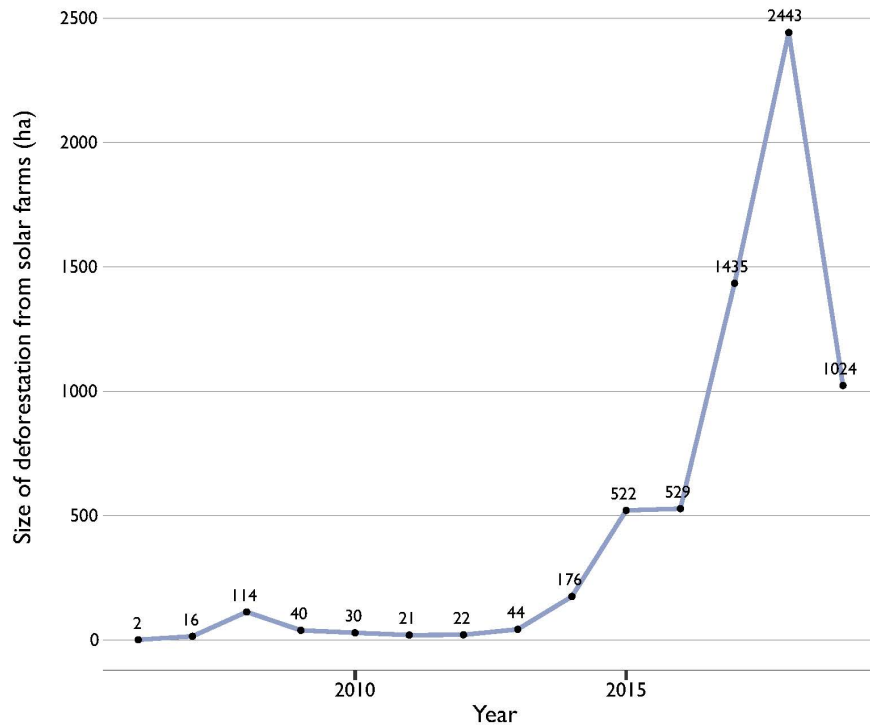


Figure 2.3: Annual trend of deforestation from solar farms, 2006-2019

Parliament Yoon Han-Hong, drawing on the evidence from the Korea Forest Service Agency, has reported that the size of forest lands replaced by solar farms was 6,214ha after 2014, as opposed to 289ha before 2014.⁴ Figure 2.3 visualizes this replacement trend until 2019.

2.3 Interview research

The event history analysis demonstrates that rural counties with higher solar farm density are more likely to adopt the restriction on solar farms. But this finding alone cannot fully

⁴Between 2012 and 2014, the South Korean government had granted a weight of 0.7 to renewable energy certificates (RECs) produced from solar farms sited in forest lands, disincentivizing solar energy developers to locate their solar farms in forest lands. However, in 2014, the government removed such disincentives, allowing more solar energy projects to target forest lands until 2018 when the government revived them.

substantiate the claim that rural opposition to landscape change from solar farms was a key driver for the onset of setback restrictions. Therefore, I interviewed 13 residents and 14 local public officials in 10 rural and urban counties from July to September 2021. The purpose of interviews is to collect first-hand evidence of (1) whether landscape disruption from solar farms was a key motivation for rural residents to oppose them and (2) whether local opposition to landscape disruption motivated county government officials to implement setback restrictions.

I use the following coding scheme to distinguish among interviewees. All interviewees are identified with three letters, e.g., RA-1. The first alphabetic letter represents whether the interviewee is a resident (R) or a public official (P). The following letter represents the county, ranging from A to J. Finally, the number represents the ID of each interviewee arranged by order of interview dates. For instance, PF-9 indicates the 9th interview subject, a public official in F county. Residents include tenured farmers, fishers, and NGO officials. Local public officials include civil servants who are primary regulators of solar farm siting and public energy agency officials. Interview protocols received an IRB review in May 2021 (ID: STUDY00013287).

I used a snowball sampling method for the following practical but essential reasons. First, due to their increased awareness of the COVID-19 crisis, interviewees preferred in-person interviews with people they know. Therefore, I conducted an entry interview with a journalist based in Seoul, who could provide contact information for those living in rural areas. While one could arrange remote interviews to overcome this issue, most interviewees preferred talking in person as they needed more experience in video conferences. For these reasons, all interviews were in-person from July to September 2021.

Throughout the interviews, all residents agreed that solar farms drastically change their rural landscapes in an undesirable or unexpected way. When asked why they think their county needs the restriction, RC-4 and RC-5 have agreed that:

While most of the electricity flows to cities, solar farms are in forests and farm-

lands in rural areas, and they have no benefits for us. Also, we value our landscape and need to enjoy and feel nature, mountains, and the ocean. Because solar farms destroy our landscape, they do not meet our living conditions. We say no to solar farms because they are hideous objects (hyung-mul).

RJ-17 stated while referring to the solar farm sited alongside the road to a town:

Both sides of the road are all covered with PV panels. I feel suffocated. How could we live in this place? I know we cannot get any compensation for this agony, but for us (villagers living in the town), PV panels are right in front of our noses. It feels like there is a blade to our neck.

When asked how their town started to host solar farms, RI-16 noted that:

When urban developers bring their solar farms, they cut down trees in mountains and fields and build fences around them. No people are left behind after they built solar farms. [...] They are not one of ours. They build solar farms here because the lands are cheap here. They do not communicate with us or seem to manage them properly. It feels like an infiltration to me.

Residents who oppose solar farms in their vicinity did not feel they had the opportunity to meaningfully participate in the early planning process of solar energy projects. This could have precluded the possibility of revising proposals to alleviate their concerns over landscape change. Also, residents grew feelings of distrust toward solar energy developers when faced with the lack of participation in the planning process, labeling them as “urban developers” who do not belong to their community.

RD-7 pointed out that solar farms are not only visually incongruent with their rural landscapes but make their lives inconvenient. RD-7 shared an episode where solar farms changed local roads that villagers have shared and used together for a long time:

We (rural villagers) share roads because we must use ours and theirs to get to the farmland. I own some of these roads but let others use them too. We can use them together since we are a part of our community. But urban outsiders do not think about these norms. [...] They get rid of these roads after they purchase their lands.

This excerpt shows that the local road, a feature of the rural landscape which solar farms replaced, had been shared by residents for a long time to achieve the shared goal of “getting to the farmlands.” Residents have perceived it was difficult to communicate the importance of these shared roads when solar farms change rural landscapes, either because their developers are outsiders or do not stay around the sites after they are built.

Interviews with public officials also confirmed that these rural oppositions to landscape change were a major concern for county governments, leading them to consider implementing setback restrictions on solar farms. All public officials in the four counties I interviewed have commonly identified that residents’ opposition to solar farms was a key motivation for them to start working on the restriction. PG-11, for instance, has explained that as solar farms increased, more residents expressed visual distress from them, which gave administrative burdens for officials to mediate conflicts between residents and utility firms, along with burdens from issuing permits for their siting.

PF-9 mentioned that the setback restriction is a commonly used policy tool by county governments to deal with detested facilities, such as manure factories. When there is consistent public resistance to such facilities, county government officials might have found it useful to order them to keep distances from households or roads before careful assessment of their negative externalities. Moreover, a county government is the final authority for implementing and amending ordinances, whose autonomy is protected by the central government through the National Land Planning and Utilization Act. Therefore, county governments may stipulate setback restrictions in land-use ordinances as a cost-efficient and lawful measure to cater to local opposition to solar farms.

The interview with PH-14, however, offered an interesting point. While H County has had solar farm density higher than the average of all county governments in 2020, the county does not have the restriction up to date. Moreover, PH-14 firmly stated that they do not plan to. As of 2020, there were 47 county governments with restrictions but with fewer solar farms in their jurisdictions than H County. According to PH-14 interviewees:

We estimate around 20%- The fraction of total solar farms located in rural towns (affiliated to the city). The rest (80%) are built on the roofs of factories in industrial parks. Or on the roofs of individual houses. But among those in rural towns, most of them are located in industrial complexes. [...] There are almost no petitions from these solar farms.

It is important to note that H County is more characterized by urban than rural landscapes, due to its high level of industrialization with large manufacturing companies, with population density higher than the average of all counties (40-50th percentile). Therefore, the interview with PH-14 interviewee suggests that when urban landscapes characterize a county, a higher number of solar farms may not lead to higher opposition and therefore not a higher likelihood for the onset of the restriction.

In sum, interview research provides evidence that the positive association between solar farm density and the likelihood of adopting the restriction, as the event history analysis suggests, reflects the local opposition to landscape change from solar farms driving the restriction. Moreover, rural counties were more likely to face local opposition to landscape change, consistent with the earlier finding that rural counties were more likely to adopt the restriction when faced with high solar farm density.

2.4 Discussion

This chapter is the first empirical research that explains a recent case in South Korea where local setback restrictions on solar farms have diffused across county governments. It shows

that concerns around landscape disruption have shaped rural opposition to solar farms, which motivated local officials to consider setback restrictions. Specifically, the event history analysis shows that the number of solar farms has increased the likelihood of county governments adopting the restriction more greatly in rural than urban areas. Findings from interview research suggest that county governments have adopted the restrictions that restrict solar farm siting mainly as a response to these rural oppositions. I find consistent support from both qualitative and quantitative evidence to the argument that the negative impact of solar farms on the rural landscape was a key driver for the diffusion of setback restrictions on them in South Korea.

One can argue that since rural areas offer more available lands for solar farms to be sited than urban areas do, local setback restrictions are only relevant for rural areas. Yet, even urban areas can host smaller commercial solar farms that may still disrupt valuable urban landscapes, susceptible to local opposition. Take the example of Suwon City. It is home to 1.3 million population and hosts various historical sites such as the Hwaseong Fortress, built in 1796 by King Jeongjo of the Joseon Dynasty and designated as a World Heritage site by UNESCO in 1997. The city implements a setback restriction on solar farms which stipulates that “any solar energy facilities must be distanced by 100 meters from areas under the protection of Cultural Heritage Protection Act” (Suwon City Zoning Ordinance Art. 22(2)(3)). This stipulation implies that urban areas may implement setback restrictions on solar farms driven by concerns over their disruptive impacts on urban landscapes, particularly when their landscapes host historically and culturally valuable sites. It may also explain the case of H County discussed in Section 4 with over 1 million population with no setback restriction on solar farms even hosting a high level of solar farm installation, possibly because a majority of these solar farms are located on the rooftops of industrial complexes, providing a less disruptive impact on its landscape. The finding of this chapter, however, suggests that the landscape impact of solar farms is more salient in rural areas in South Korea, particularly because solar farms in rural areas tend to be utility-scale and therefore exhibit greater visual impacts.

This chapter joins a growing body of literature that focuses on how renewable energy facilities impact rural communities by changing their landscapes [100, 54, 81, 25]. Yet, few studies examined the possible consequences of such changes and their implications for national renewable energy development. The case documented here suggests that local opposition to solar farms because of their disruptive impacts on the landscape threatens already proposed renewable energy projects and future ones. This is because local governments often do not have the capacity to effectively regulate renewable energy projects so that they protect the integrity of their surrounding landscape. When local opposition is left for local governments only to handle, they may resort to restrictive land-use policies against renewable energy projects. Therefore, a policy implication of this chapter is that central governments should provide active means to support local governments to mitigate the concerns of local residents over the potential negative impacts of renewable energy facilities. One possible area is implementing an a priori assessment of the landscape change from solar farms so that new projects ensure more inclusive participatory planning processes [51].

Several weaknesses of this chapter point to future research areas. First, due to the lack of data availability, this chapter could not test the direct effect of landscape change from solar farms on the likelihood of the onset of restrictions. Both interview research and event history analysis assume that solar farms have largely changed landscapes through deforestation in South Korea when they are sited in rural areas. Yet, there may be a possible variation across rural counties regarding how intrusive solar farms were to their surrounding landscapes. Future studies that link the impact of local costs from renewable facilities on local policy barriers against them should use more direct measures of such costs, such as the amount of deforestation solely attributable to solar farm siting or the loss of fish catch solely attributable to offshore wind power siting.

Because of the same issue, using variables in the event history analysis reveals some limitations. In the event history analysis, I used population density to indicate whether a county is more “rural” than “urban,” which by itself does not capture the totality of “ruralness” [19]. To better capture the idea that more rural counties are likely to adopt the

restrictions, one may use an indicator of ruralness constructed with various measures, such as population dynamics, industry, transportation, and distance [124]. Yet, due to the lack of county-level data for such variables, this chapter only uses population density because rural areas typically have lower population density than urban areas.

Next, it fails to account for more various motivations for which rural residents oppose renewable facilities that previous studies have identified. For instance, Urpelainen [121] and Aklin et al. [6] find that rural villagers in India were largely concerned about exploitative business practices by solar energy firms, which highlights the potential effect of renewable energy injustice on rural acceptability of renewable facilities [111]. The sense of distributive injustice may also decrease rural support for renewable energy by affecting their trust in renewable facilities and their developers [125]. This implies that there are not only explicit motivations for opposing solar farms such as from landscape change but implicit ones which are difficult to examine with observational data. Therefore, future studies should benefit from individual-level or village-level survey research to explain which motivation best explains local policy outcomes against renewable facilities.

Chapter 3

LANDSCAPE DISRUPTION AND PUBLIC SUPPORT FOR RENEWABLE ENERGY SURCHARGE POLICY

Chapter 2 finds local negative impacts of renewable energy facilities matter for their local acceptance and siting regulations. Do they also matter for the public support towards the national renewable energy policy in general? I examine this issue in the context of South Korea's renewable energy surcharge (RES) which households pay in their monthly bills to finance government subsidies for renewable energy. The South Korean government introduced RES in January 2012 to subsidize the renewable energy portfolio (RPS) implementation. Under the RPS scheme, the surcharge supports the RPS-mandated utilities when they purchase electricity or renewable energy certificates (RECs) from renewable energy producers [116]. In South Korea, Korea Electric Power Corporation (KEPCO), a South Korean public utility firm, uses the entire surcharge revenue to compensate for the costs that 24 RPS-mandated utilities have spent on complying with the RPS.

As decarbonization efforts deepen, the government with a surcharge policy may choose to increase its price to accelerate renewable energy production. However, increasing the surcharge price may face domestic political backlash, often leading to climate policy regression [97]. After all, renewable energy policies must cater to public opinion [15]. Some may raise a concern about its regressive impacts [71], which provided a rationale for the German federal parliament to decide on abolishing the surcharge after July 2022. Those that prefer nuclear energy to renewables or other low-carbon energy sources may question the effectiveness of increasing the surcharge prices in delivering the decarbonization outcomes.

What shapes individual support for increasing the RES? The surcharge resembles a carbon tax in that both are imposed upon the consumption of energy (though carbon tax

typically covers both primary and secondary energy consumption). Therefore, studies that examine what factors shape individual support for a carbon tax may provide some insights. Agreeably, individuals care about how revenue generated from the carbon tax is used [8]. This implies that individual support for a carbon tax may be conditional on its revenue expenditure. Dolšak et al. [32] find that devoting the revenue to mitigation increases public support for a carbon tax. How much support can be conditional may also vary by individual characteristics. Nowlin et al. [87] show that conservatives and Republicans care more about how carbon tax revenue is spent than liberals and Democrats do.

Unlike the carbon tax which theoretically could finance a range of projects, the surcharge focuses on financing renewable energy projects only. In other words, there is little room for the surcharge to be used for purposes other than renewable energy expansion. Drawing on this feature, this chapter explores whether perceptions of the costs and benefits of local solar farms shape public opinion on the RES to support national-level renewable energy policy. Since solar farms outnumber wind farms or coal power plants in South Korea, South Korean households frequently interact with solar farms and experience different levels of costs and benefits from them. These daily experiences with solar farms may affect individual opinions on both renewable energy projects in their vicinity and an increase in RES, given that the surcharge facilitates renewable energy development.

To test the argument, I analyze responses in an online survey in South Korea (N= 1,043) with a nationally representative sample in terms of age, gender, and region. The survey provided respondents with information on RES, clearly stating that its revenue is devoted to promoting renewable energy development. The survey went on to ask questions about the costs and benefits respondents perceive from solar farms in their vicinity. This chapter focuses on the disruptive impacts of solar farms on their surrounding landscapes as one of such costs and their capacity to produce less air pollution than fossil fuel plants as one of such benefits. It also asked for individual-level information such as age, household income, education level, and self-identified political ideology.

Individuals may have varying opinions on solar farms and RES depending on how much

they are exposed to solar farms in their vicinity. For instance, individuals who encounter 1 solar farm daily might view the costs and benefits of solar farms differently from those who encounter 10 solar farms. Therefore, in the analysis, I included village-level data on solar capacity density (kW per hectare), population density (population per km²), and forest coverage (%) matched with respondents' current residential addresses which they provided up to the same village level.

The key findings of this chapter are as follows. Respondents who believe solar farms disrupt the landscapes are less likely to support the surcharge increase. On the other hand, those who believe solar farms reduce local air pollution are more likely to support the surcharge increase. These findings suggest that individual opinion on the surcharge increase is shaped by respondents' perceptions of local costs and benefits from solar farms in their vicinity. The rest of the chapter proceeds as follows. Section 3.2 theorizes the link between individual perceptions of the costs and benefits of solar farms in the vicinity and individual support for increasing the surcharge. Section 3.3 reports how online survey data are collected and analyzed. Section 3.4 provides descriptive statistics of the data and summarizes empirical results using a Bayesian approach. Section 3.5 provides a discussion of the findings and concludes.

3.1 Literature review

RES is a cost levied upon electricity customers per their electricity consumption to subsidize renewable energy provision. Several countries have adopted or are adopting RES to support renewable energy. These include South Korea, Germany (before July 2022), Japan [35], China [79], India [46], and Bosnia and Herzegovina [1]. In the US, Connecticut instituted the Renewable Energy Investment Charge in January 2022 [88].

South Korean households pay a RES of KRW 7.3 per kWh (about US\$ 0.01; as of April 2022) which appears on their monthly electricity bill. The average monthly electricity consumption of a family of four in South Korea is 304 kWh, which amounts to the monthly

surcharge price of KRW 1,794 (US\$ 1.29). This surcharge price is very low compared to the German RES of €3.7c/kWh (about US\$ 0.40) before it was revoked. However, electricity consumers remain vigilant for any increases in electricity prices which shape their political feasibility [78, 5, 75]. In January 2023, the South Korean government increased the surcharge price to KRW 9.0 per kWh. As it plans to strengthen the RPS, future increases in the surcharge are inevitable.

What RES aims to achieve is to promote renewable energy development which provides global public goods of climate mitigation [6, 33]. However, renewable energy facilities impose negative externalities and their associated costs on the communities in which they are located [43, 12]. A substantial body of literature has documented cases where renewable energy facilities largely transform their surrounding landscapes [11, 9, 129] due to their extensive land use requirements [30, 120, 122]. These studies highlight that landscape transformations motivate local opposition to renewable energy facilities when residents perceive renewable energy facilities undermine the aesthetic [29, 17] and/or cultural [54, 39] values of pre-existing landscapes. This trend is reinforced by the relative lack of consideration of landscape impacts in the spatial planning of renewable energy facilities [51]. Dröes and Koster [36] further claim that these landscape impacts have negative second-order effects on house prices near renewable energy facilities.

This “geographical mismatch” between the costs and benefits of renewable energy facilities generates a collective action problem in renewable energy development [128]. Individuals benefit marginally from the global public good that renewable energy facilities generate and yet bear substantial local costs. Therefore, residents near proposed renewable energy facilities have incentives to “free-ride” (i.e., oppose their siting) [16]. Concerns about these costs have driven local opposition to proposed renewable energy projects, often delaying or even revoking project proposals [118]. Opponents often succeed in lobbying the government to enact a zoning law that limits or bans new proposals for renewable energy projects [4], as discussed in the previous chapter, which further undermines domestic renewable energy development. Furthermore, opponents in democracies can produce election outcomes that

are unfavorable to renewable energy development [117, 104].

This chapter adds another mechanism through which the geographical mismatch hinders renewable energy development: It may further shape negative opinions on national level renewable energy surcharge. The surcharge represents a modest financial burden on individuals to promote renewable energy development. It follows that how much they are willing to pay the surcharge depends on their perceptions of the local costs and benefits an existing facility might have. It is imperative to reiterate here that RES, unlike a carbon tax, is dedicated to promoting renewable energy development. Therefore, an observable implication is that individuals who perceive higher costs from existing renewable energy facilities might prefer paying less for the surcharge that supports these facilities (which may be located elsewhere). Less public support for RES may lead to less financial resources for the government to promote renewable energy development.

3.2 *Research hypotheses*

This chapter focuses on solar farms among various renewable energy facilities. Solar farms are land intensive: on a per kilowatt basis, they require more land than wind farms or fossil fuel plants [122]. Moreover, unlike wind farms, solar farms are typically not sited offshore. These technical constraints lead to a higher level of exposure to solar farms for residents in their vicinity, compared to wind farms or fossil fuel plants.

As discussed above, the potential disruptive impacts of solar farms on surrounding landscapes contribute to their local costs. It is important to note here that the visibility of renewable energy facilities does not automatically translate into their visual impacts on their surrounding landscapes [129]. Once renewable energy facilities are visible to residents in their vicinity, what matters for their level of support is whether they “perceive” renewable energy facilities undermine the aesthetic and/or cultural values of existing landscapes [25]. To capture this subjective dimension of disruptive impact, this chapter investigates whether the level of support for RES is contingent upon how much individuals “believe” solar farms

disrupt surrounding landscapes. Therefore, the first hypothesis writes:

H1. Respondents who believe solar farms disrupt surrounding landscapes are less likely to support an increase in RES.

Scholars note, however, that renewable energy facilities are not destined to impose negative externalities on local communities only [90]. In addition to producing global public goods, solar farms might also reduce local air pollution. After all, unlike fossil fuel plants, renewable energy facilities emit virtually no air pollutants such as sulfur dioxide (SO₂) or nitrogen oxides (NO_x). Therefore, the second hypothesis writes:

H2. Respondents who believe solar farms produce less local air pollution than fossil fuel plants are more likely to support an increase in RES.

Finally, the third hypothesis looks at the public goods of solar farms. How much individuals value climate mitigation to which solar farms can contribute may depend on how much risk they perceive from climate change. As individuals perceive climate change affects their daily lives, they might be more supportive of policy decisions that promote renewable energy expansion. Therefore, the third hypothesis is:

H3. Respondents who believe climate change negatively affects their daily lives are more likely to support an increase in RES.

3.3 Data and methods

To test these hypotheses, I collected data from an original online survey of a sample of the South Korean adult population, nationally representative in terms of age, gender, and region (IRB ID: STUDY00015587). I hired a survey company, Cint, to administer the survey between July 16 to August 4, 2022.

“Climate Environment Surcharge” appears on your monthly electricity bill since January 2021, which is used to support implementing renewable portfolio standards (RPS), a policy to promote renewable energy expansion in South Korea.

It requires electricity companies above a certain size to produce 9% of their electricity from renewable energy sources such as wind and solar.

Currently, you are paying 7.3 Korean won per kWh of electricity you used every month, which includes 5.9 Korean won per kWh which is used for supporting RPS.

This amounts to KRW 1,794 to be included in the average monthly bill of a family with 4 members.

Figure 3.1: Information on climate environmental surcharge presented to the survey respondents

At the beginning of the survey, respondents read a short paragraph that conveys information on RES, which appears in Figure 1. The objective of this paragraph was to provide the rationale for the surcharge and how its revenue will promote renewable energy projects. Then, respondents answered three comprehensive check questions. Respondents that have provided wrong answers to any of these three questions were screened out from the survey and therefore were not included in the sample. In this way, the initial sample size collected was 1,128. After excluding responses that provided unidentifiable residential addresses and incomplete responses, the sample size was reduced to 1,043.

After reading the short paragraph, the survey asked respondents about their support for increasing the surcharge: “How much do you support/oppose increasing the RES?” Respondents responded with five ordinal categories: strongly oppose (1), oppose (2), neither

oppose nor support (3), support (4), and strongly support (5).

Then, the survey presented three questions that are related to the three main hypotheses of this chapter. All questions asked them to indicate their level of agreement in five ordinal categories with a given statement per each question: strongly disagree (1), disagree (2), neither disagree nor agree (3), agree (4), strongly agree (5). The first question asked about respondents' perceptions of landscape disruption from solar farms with a statement: "I believe solar farms disrupt surrounding landscapes of where they are located." The second question asked about their perceived health benefits from solar farms in comparison to fossil fuel power plants with a statement: "I believe solar farms produce less air pollution than fossil fuel plants." The third question asked about respondents' perception of the severity of global warming with a statement: "I believe global warming is negatively affecting my daily life." Finally, the survey asked standard demographic questions such as household income, education, self-reported gender, age, and political ideology.

3.3.1 Descriptive statistics

Table 3.1 summarizes the sample demographics. The sample is slightly younger than the population's average age of 43.5 as of 2021, partly because the survey was conducted online and therefore could not effectively target populations over 80. It closely mirrors the gender ratio of 99.4 as of June 2022, which indicates the female population is slightly larger than the male population.

The descriptive statistics of the outcome variable show that South Koreans are generally supportive of increasing the surcharge. Among 1,043 respondents, 483 respondents (46.3 percent) are supportive of increasing the surcharge (i.e., answered with "support" or "strongly support"), while 191 (18.3 percent) are not (i.e., answered with "oppose" or "strongly oppose"). Only 48 respondents (4.6 percent) said they strongly oppose the increase. The remaining 369 respondents (35.4 percent) are neither supportive of nor opposing the proposal (i.e., answered with "neither oppose nor support").

Figure 3.2 breaks down each response group to see how many respondents in each group

Table 3.1: Sample demographics

	Descriptive statistics			
	N	%	Mean	St. Dev.
Age	1043	100	42.83	12.87
Gender on government IDs				
Male	514	49.3		
Female	529	50.7		
Monthly household income			4.43	1.47
- \$1000 (1)	44	4.22		
\$1000 - \$2000 (2)	64	6.14		
\$2000 - \$3000 (3)	183	17.5		
\$3000 - \$4000 (4)	218	20.9		
\$4000 - \$5000 (5)	174	16.7		
\$5000 - (6)	360	6.14		
Education			5.65	1.03
Less than elementary school (1)	2	0.19		
Elementary school graduate (2)	5	0.47		
Middle school graduate (3)	4	0.38		
High school graduate (4)	185	17.7		
College (2-year) graduate (5)	116	11.1		
College (4-year) graduate (6)	596	57.1		
Master degree (7)	109	10.5		
Doctoral degree (8)	26	2.49		
Political ideology			2.90	0.74
Very liberal (1)	29	2.78		
Liberal (2)	238	22.8		
Moderate (3)	602	57.7		
Conservative (4)	154	14.8		
Very conservative (5)	20	1.92		

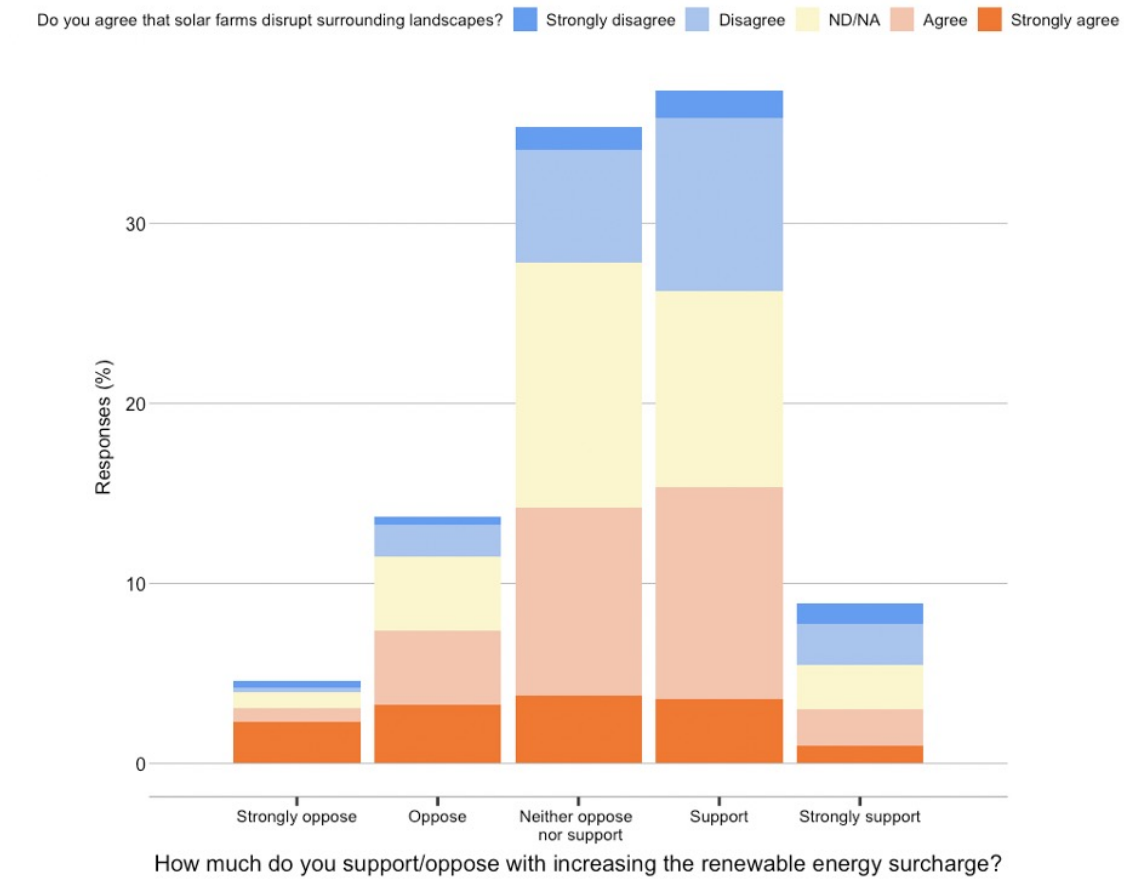


Figure 3.2: Distribution of responses to the surcharge question and the landscape disruption question

believe solar farms disrupt surrounding landscapes. First, it is noteworthy that the number of respondents who strongly agree that solar farms disrupt surrounding landscapes is fairly distributed across the response groups, except for the most supportive group toward the surcharge increase. However, when examining its share in each group, we obtain a different answer. Among respondents in the “strongly oppose” group, those who strongly agree solar farms disrupt surrounding landscapes comprised half of the group. Their share reduces to 23.7 percent in the “oppose” group, 10.5 percent in the “neither oppose nor support” group, and 9.5 percent in the “support” group.

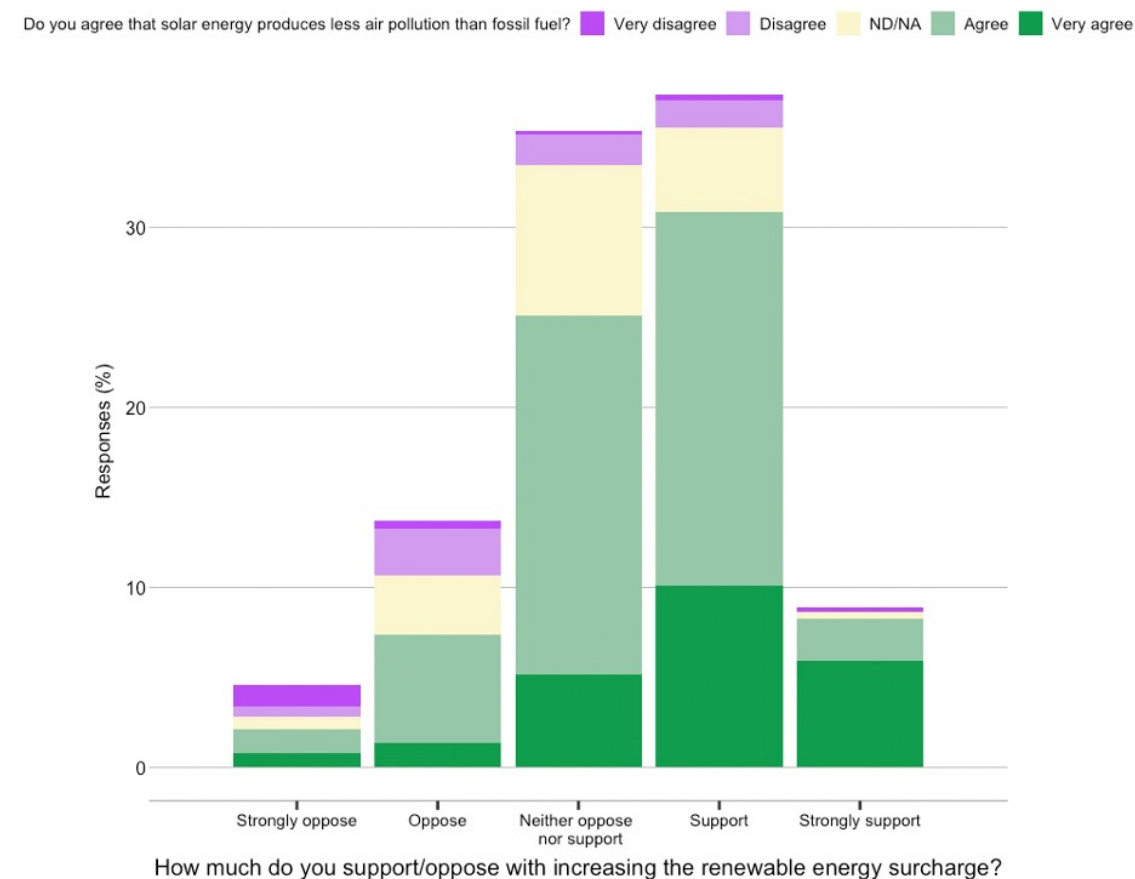


Figure 3.3: Distribution of responses to the surcharge question and the air pollution question

Figure 3.3 shows how many respondents in each response group agree solar energy causes less local air pollution than fossil fuel. The share of respondents who agree that solar energy produces less air pollution than fossil fuel is the largest in the “strongly support” group, which is 92.5 percent. The share of respondents who strongly disagree solar energy produces less air pollution than fossil fuel, however, is the largest in the “strongly oppose” group, which is 39.5 percent.

Finally, Figure 3.4 breaks down each response group to see how many respondents in each group believe climate change is negatively affecting their daily lives. Note that respondents who strongly disagree climate change is negatively affecting their daily lives are only present

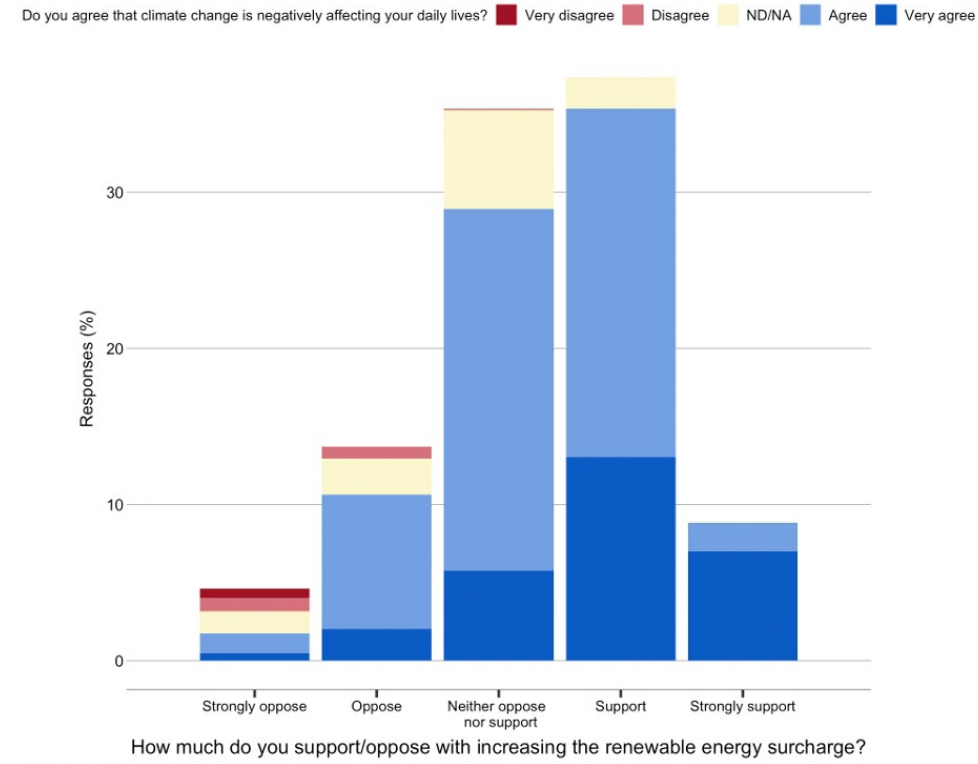


Figure 3.4: Distribution of responses to the surcharge question and the climate change impact question

in the “strongly oppose” group. All respondents in the “strongly support” group believe climate change negatively affects their daily lives.

3.3.2 Bayesian approach

An exploratory analysis of the responses suggests that there is an interesting pattern to navigate between extreme responses, such as a “strongly oppose” response regarding the surcharge question and a “strongly agree” response regarding the landscape disruption question. Data evinces that this is because these categorical responses are not ordered linearly. Treating these responses simply as either nominal or metric may lead to masking the valuable information extractable from the survey. Therefore, I follow the Bayesian approach suggested

by Bürkner and Charpentier [24] which allows us to model the non-linear monotonic effects of ordinal predictors.

When we treat ordinal predictors (i.e., explanatory variables) as linear in regression models such as in standard logit or probit ordinal regressions, we assume that the distance between each ordinal predictor value is the same, and its coefficient represents how much the outcome variable changes on average when the ordinal predictor increases by one unit. However, the distance between “strongly disagree” (1) and “disagree” (2) responses may not be the same as the distance between, say, “neither disagree nor agree” (3) and “agree” (4) responses to the question that asks how strongly a respondent believes solar farms disrupt surrounding landscapes. To avoid relying on this assumption, Bürkner and Charpentier use a Bayesian approach to explicitly model the effect of distances in ordinal predictors. For instance, if an ordinal predictor has five ordered categories, it will have four distances to be estimated whose incremental (i.e., monotonic) effect on the outcome variable may vary from each other. Now, how much the outcome variable changes on average with the ordered predictor is known by multiplying two elements: (1) its common coefficient and (2) its incremental effect which varies by each interval.

I formalize the discussion above as follows.¹ Since the outcome variable is ordered as well, its probability is estimated with the following ordered-logit model:

$$R_i \sim \text{Ordered-logit}(\phi_i, \kappa)$$

Where R_i is a response to the surcharge question by an i th respondent, ϕ_i is a set of terms in a linear model, and κ is a set of intercepts. Suppose we have five categories for the ordered predictor. Let δ_j be the marginal effect of a j th interval, i.e., the marginal effect moving from the j th to the $j+1$ th ordinal category. For instance, the effect of moving from the 1st to the 2nd category can be represented in the linear model as:

¹Adapted from McElreath [72].

$$\phi_i = \delta_1 + \gamma X_i$$

Where X_i is a set of control variables and γ is a set of their coefficients. Then, the probability of the outcome variable of a respondent whose value of the ordered predictor is in the 5th category should be modeled with the following linear model:

$$\phi_i = \delta_1 + \delta_2 + \delta_3 + \delta_4 + \gamma X_i$$

Note that δ_1 through δ_4 can have different values, and they are summed to exhibit the total incremental effects of the ordered predictor on the outcome variable. Finally, let the effect of responding “strongly disagree” (the 1st category) be absorbed into the intercept κ such that $\delta_0 = 0$ in the linear model. Then, we can generalize the linear model for an i th respondent whose value of the ordered predictor is in the j th category:

$$\delta_i = \beta \sum_{j=0}^{J-1} \delta_j + \gamma X_i$$

Where β is the “common coefficient” of the ordered predictor. Note that δ_j now serves as a weight for β that allows us to estimate the varying effect of the ordered predictor by individuals depending on what category their value of the ordered predictor is in. To enable this interpretation, we let δ_j follow a Dirichlet distribution so that all δ_j sum up to 1. Drawing on this approach to model the monotonic effects of categorical responses, the full model with weak priors can be specified as follows:

$$R_i \sim \text{Ordered-logit}(\phi_i, \kappa) \quad (3.1)$$

$$\phi_i = \beta_L \sum_{j=0}^{J-1} \delta_{Lj} + \beta_P \sum_{k=0}^{K-1} \delta_{Pk} + \beta_I \sum_{m=0}^{M-1} \delta_{Im} + \gamma X_i \quad (3.2)$$

$$\kappa_k \sim \text{Normal}(0, 1.5) \quad (3.3)$$

$$\beta_L, \beta_P, \beta_I, \gamma \sim \text{Normal}(0, 1) \quad (3.4)$$

$$\delta_{Lj}, \delta_{Pk}, \delta_{Im} \sim \text{Dirichlet}(2, 2, 2, 2) \quad \forall j, k, m \quad (3.5)$$

Where δ_{Lj} represents the monotonic effect of the categorical responses to the question about landscape disruption, δ_{Pk} is to the question about air pollution, δ_{Im} is to the question about impacts of climate change, β_L , β_P , and β_I are their coefficients, γ is a set of coefficients for the control variables, j , k , and m are the number of the categorical response that an i th respondent gave to each question subtracted by one, and finally, J , K , M are the total number of the possible categorical responses for each question.

3.4 Results

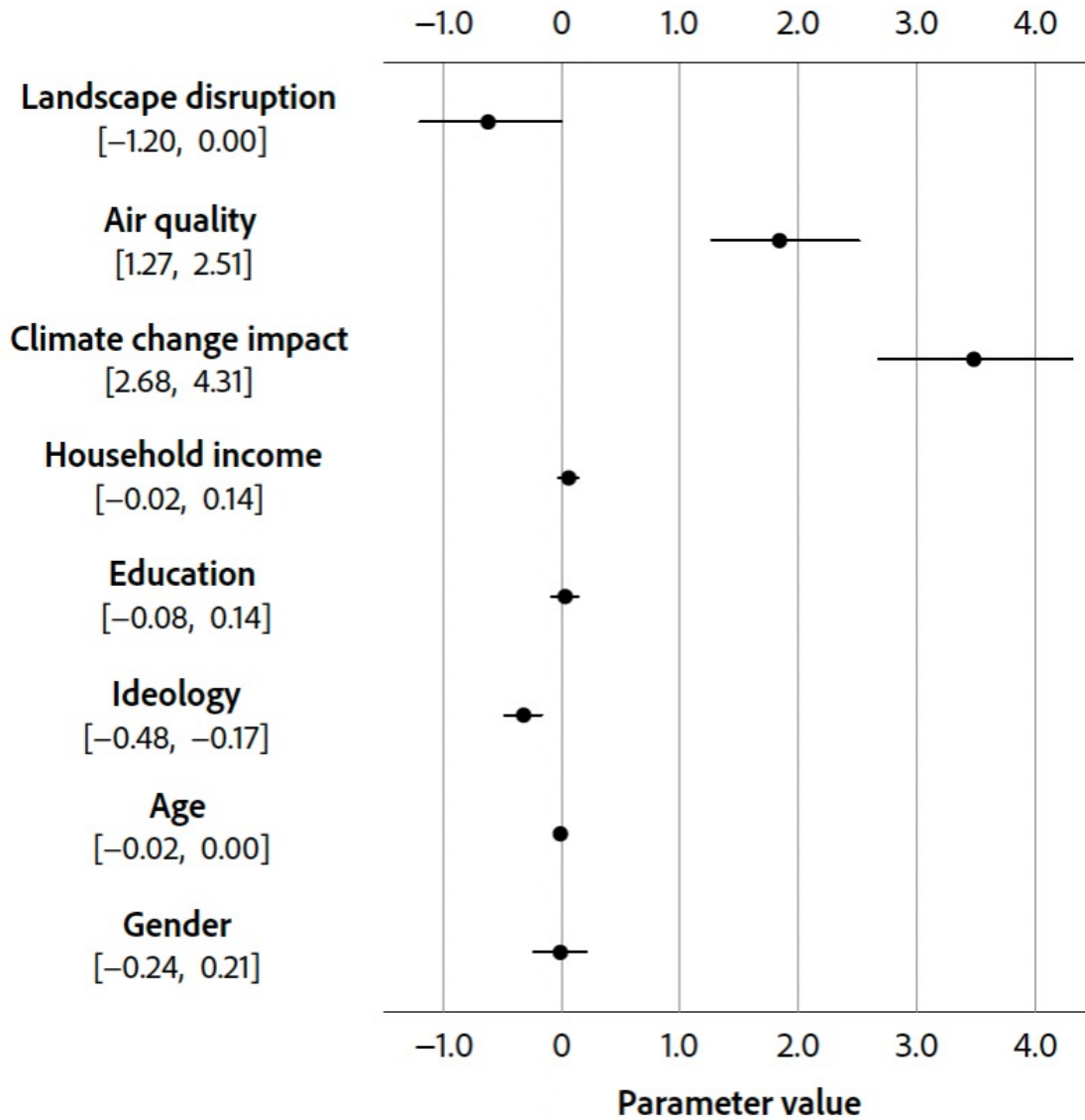


Figure 3.5: Posterior means and 95% credible intervals of each parameter

I employ the Hamiltonian Monte Carlo technique to obtain the posterior distribution of the parameters of interest described in the above model [18]. I run 4 separate Markov chains with 5,000 iterations that provide 20,000 posterior draws for each parameter. All chains

indicate convergence considering the Gelman-Rubin convergence diagnostic [44]. Changing the number of chains or iterations does not significantly change the results to follow. I provide data and R codes that can replicate the results in the supplementary material.

Figure 3.5 summarizes the posterior means of the parameters and their 95 percent credible intervals. Unlike confidence intervals, credible intervals directly show the density of posterior draws from the Markov chains. The posterior mean of the effect of the perception of landscape disruption from solar farms is $-.616$ (s.d.: $.303$), showing that respondents who more strongly believe solar farms disrupt surrounding landscapes are less likely to support an increase in the surcharge. The largest incremental effect exists between “agree” (4) to “strongly agree” (5) responses to the question of landscape disruption ($\delta_L4=.49$, 95% CI: $[.12, .79]$). This mirrors the pattern shown in the descriptive statistics that respondents who believe solar farms have disruptive impacts on surrounding landscapes are the strongest opponents of the surcharge increase. Moreover, when these respondents strengthen their belief about the disruptive impact of solar farms on their surrounding landscapes, their opposition becomes much stronger.

On the other hand, respondents who believe solar energy produces less local air pollution than fossil fuel are more likely to support increasing the surcharge. The posterior mean of the effect of the perception of higher air quality from solar farms is 1.852 (s.d.: $.311$). This shows the perceived local benefit of solar farms concerning air quality is a strong predictor of individual support for the renewable surcharge increase. Similarly, those who believe climate change is negatively affecting their daily lives are also more supportive of the increase. The posterior mean of the effect of the perception of climate change impact is 3.481 (s.d.: $.418$). This shows that individuals do consider the level of public goods they perceive from solar farms seriously when assessing their level of support towards increasing the surcharge price.

Finally, some control variables deserve attention. First, older respondents are less likely to support increasing the surcharge, confirming an age cohort divide concerning pro-climate attitudes in earlier studies [27]. Next, more politically conservative respondents are also less likely to be supportive of an increase in the surcharge. This may be because previous left-

wing governments in South Korea have been more supportive of renewable energy provision as opposed to right-wing counterparts that have favored nuclear energy and fossil fuel provision, which led to the politicization of renewable energy development (Lee 2020).

3.4.1 Geographical variables

Table 3.2: Model results without and with geographical variables

	Model1	Model2
Landscape disruption	-0.62 (-1.20, 0.00)	0.60 -(-1.18, 0.01)
Air quality	1.84 (1.27, 2.51)	1.86 (1.29, 2.52)
Global warming impact	3.48 (2.68, 4.31)	3.55 (2.72, 4.40)
Household income	0.06 (-.00, 0.14)	0.06 (-0.02, 0.14)
Education	0.03 (-0.08, 0.14)	0.04 (-0.07, 0.15)
Ideology	-0.32 (-0.48, -0.17)	-0.32 (-0.47, -0.16)
Age	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.00)
Gender	-0.01 (-0.24, 0.21)	-0.01 (-0.24, 0.21)
Solar farm density	-	0.03 (-0.07, 0.14)
Population density	-	-0.03 (-0.12, 0.05)

Note: Cell entries are the posterior means and 95% credible intervals in parentheses, all of which are rounded off to 2 decimal places.

Respondents may have varying opinions if they are asked about local costs and benefits

from solar farms depending on where they reside. For instance, respondents living in rural areas heavily populated with solar farms might be more visually exposed to solar farms than those living in urban areas with less solar farm density. Therefore, they are more likely to answer the question about landscape disruption with either “strongly agree” or “agree.” This difference, in turn, might lead to variation across individuals in how they respond to the question about the surcharge increase.

To account for this, I included solar capacity density (kW per hectare) and population density (population per km²) by each village where a respondent is currently living. Also, I included county-level data on forest coverage (%) which was not available at the village level.

Table 3.2 compares the results of the Bayesian model without and with geographical confounders. While the upper bound of the 95 percent posterior density of the landscape disruption variable is slightly over zero, the results remain overtly the same in the model with geographical confounders. Also, geographical confounders themselves are not informative predictors of the level of support towards the surcharge increase.

3.5 Discussion

RES helps the government secure valuable resources to promote renewable energy expansion by supporting the implementation of RPS or FIT. However, levying renewable energy expansion costs does not always enjoy public support. Aklin [5] finds that an increase in household electricity bills that followed the expansion of renewable energy capacity in 28 European Union countries undermines public support for renewable energy policy. As RES has a clear purpose of expanding renewable energy capacity, its public acceptance should be contingent upon what impacts renewable energy facilities have on individuals at a local level.

Drawing on a novel online survey in South Korea, this chapter examined what factors shape public support for increasing RES. Empirical results show how much local cost and

benefit individuals perceive from renewable energy facilities well predict how much they support the surcharge. Specifically, individuals who believe solar farms disrupt surrounding landscapes are less likely to support an increase in the surcharge, and the strongest opposition comes from those who most strongly believe so. However, those who believe solar energy provides superior local air quality relative to fossil fuel are more likely to support it. These findings highlight that local-level impacts of renewable facilities can condition both social acceptance of specific renewable projects and national-level renewable energy policies. Their policy implication is that the government must ensure that local renewable energy projects provide observable benefits to the local community so that they translate into political support for renewable energy policies [126]. This also implies that local governments will be playing a larger role in securing political support for renewable energy policies as they manage local renewable energy projects in their jurisdictions.

This chapter did not fully investigate other types of costs and benefits from renewable facilities that can also be salient for public support toward the surcharge, such as environmental degradation or financial gains from profit-sharing renewable projects. Future studies may investigate, for instance, whether residents who have participated in community renewable energy projects and earn profits from them are more likely to support an increase in the surcharge than those who do not have such experience. Also, the findings do not entail any causal relationships between variables used in this chapter. Building on Aklin et al [6], one can employ a framing survey experiment that randomly assigns subjects with different frames about renewable energy projects in their vicinity and investigate whether their level of support for the surcharge varies. For instance, frames that highlight potential costs from projects might decrease support for the surcharge, while those that highlight benefits may increase.

Chapter 4

PERCEIVED URBAN BIAS IN SOLAR FARMS

A growing number of countries are making net-zero emission pledges (NZEPs) to limit the global temperature rise to 1.5C by 2050 compared to the pre-industrial records. These commitments, even if all of them were to be met, are highly unlikely to contribute to the 1.5C pathways [103]. This is because NZEPs do not follow a standardized format and therefore vary in their stringency, allowing loopholes. Also, countries with a higher share of renewable energy in their energy mix are more likely to make more stringent NZEPs [62]. Therefore, domestic renewable energy development is crucial for countries to make substantial decarbonization outcomes [112, 42, 60] and enhance their political ambition of doing so.

However, countries face domestic opposition to utility-scale renewable energy facilities, primarily from rural communities [106, 81, 118]. Because utility-scale renewable energy facilities are land-intensive, rural communities host most of them due to their land affordability and availability [30, 122, 90]. Studies have examined the sources of rural opposition to renewable energy facilities, one of which this dissertation focuses on is rural residents' concern over potential disruptive impacts on the rural landscape [9, 81, 39, 51, 84] with both material [36, 37] and non-material [54, 129] values for rural communities. These disruptive impacts of renewable energy facilities on the rural landscape illustrate an example of the increasing burdens that rural communities bear from the domestic renewable energy transition.

Meanwhile, renewable energy facilities may also have positive impacts on rural communities [90], particularly if they are designed to channel their benefits into those communities. One example is community renewable energy facilities in rural areas, both for commercial and residential purposes, which are typically owned and whose associated benefits (e.g., prof-

its from electricity sold or electricity consumption itself) are shared by local communities [126, 77, 109]. The government policy can also steer renewable energy facilities to share their benefits with local communities. For example, China has launched the solar energy for poverty alleviation program (SEPAP) to fund village-level solar (photovoltaic) energy projects since 2013, which increased per capita disposable income in rural communities by 7-8% [132]. The policy requires that government-funded solar energy facilities be owned by communities and that any profits from electricity sales be directly distributed to eligible poverty-stricken households. This example reaffirms findings from previous studies that government policy plays an important role in designing community renewable energy facilities to be conducive to local interests [76, 41].

In the absence of such direct benefits, however, rural residents may grow a sense of distributive injustice in renewable energy facilities in their neighborhoods. Because urban areas remain the largest consumption sites of electricity in society [98], rural residents may claim that electricity produced from renewable energy facilities is transmitted predominantly to urban areas if they cannot consume it. Moreover, they may understand that renewable energy developers claim all electricity sales profits if not shared with rural communities. These notions comprise what this chapter calls a “perceived urban bias” in renewable energy facilities. An uneven distribution of benefits and costs from renewable energy facilities between rural and urban residents may be a crucial, though less-studied, source of rural opposition to renewable energy facilities [6, 33].

This chapter employs a survey experiment in two counties in South Korea to examine whether perceived urban bias in solar farms decreases individual support for solar energy. The experiment randomly assigns one of three vignettes about solar farms to survey participants, two of which are designed to prime urban bias. Specifically, the first vignette highlights that while solar farms are largely located in rural areas, urban areas consume most of their electricity produced, and the second vignette highlights that urban solar energy developers claim the most profits from their electricity sales. The third vignette simply explains the technical difference between photovoltaic (PV) and solar heat generation. After

participants read one of these three vignettes, they are asked how much government investment should be placed on solar energy as opposed to nuclear energy to promote low-carbon energy development.

The main argument of this chapter is that residents in more rural counties are less supportive of solar energy investment when they are exposed to the first or second vignette that primes urban bias in solar farms. However, these effects may not be found among residents in suburban counties. This is because the urban bias frame relies on a clear delineation of in-group (rural) versus out-group (urban). In areas where such a delineation is not applicable, such as in suburban areas where both rural and urban characteristics coexist, the urban bias frame may be less salient and therefore less relevant to residents' support for solar energy investment.

4.1 *Perceived urban bias*

Rural areas are growingly burdened with renewable energy installations around the world since they provide much more affordable lands for land-intensive utility-scale renewable energy facilities than urban areas [90]. However, they impose potential negative impacts on local communities such as disruptive impacts on the surrounding landscapes [9, 129] and their second-order negative effect on property values [36, 37]. Particularly, rural residents' concerns over landscape disruption have motivated them to oppose renewable energy facilities in their vicinity [81, 52, 17], which often leads to a mobilized group of opposition lobbying the local governments to adopt land-use restrictions against renewable energy facilities to limit their future proposals in the area (e.g., the second chapter of this dissertation). The rural landscape is a valuable source for rural residents regarding their material well-being [107, 73] and group-based identity with place attachments to its natural features [61].

A rural concentration of renewable energy facilities has a serious implication for their distributive (in)justice across rural and urban areas [93, 111], given that highly urbanized areas consume most of the electricity produced in society [98]. As long as rural areas offer

lower land prices and larger open-space lands than urban areas, urban areas may continue enjoying access to low-carbon electricity without shouldering the burdens of nearby renewable energy installations. While governments have invented various policies to incentivize rapid renewable energy installations, other policies that mitigate their potential negative impacts on local communities have been relatively lagging [51].

Facing this uneven distribution of costs and benefits, rural residents may grow a sense of distributive injustice in renewable energy facilities which may undermine their social acceptance in rural areas. In other words, they may share what this chapter calls “perceived urban bias in renewable energy facilities,” defined as “a perceived notion that renewable energy facilities predominantly benefit urban areas while rural areas bear most of their local negative impacts.” The concept draws from the well-established literature on urban bias in development studies [70, 14, 21] in which scholars argue that rural countrysides are “squeezed” for the sake of urban-led industrialization and economic growth, particularly in developing worlds (see, however, Varshney [123] for its critiques). By the same token, perceived urban bias entails a notion that rural areas are disproportionately burdened by an increasing number of renewable energy facilities as the society decarbonizes while urban areas do not bear their local costs. Studies have shown that the sense of distributive justice is a key factor that shapes individual preferences toward renewable energy [55, 118]. For instance, Yenneti and Day [131] analyzed the case of the Charanaka Solar Park in rural India where Charanaka villager communities bear a larger share of burdens than solar energy developers with fewer benefits associated with the project, largely undermining their local social acceptance. Therefore, perceived urban bias may be an additional source of rural opposition to renewable energy along with rural residents’ concern over landscape disruption.

There are two distinctive characteristics of perceived urban bias. First, rural residents may target various urban residents who benefit from renewable energy facilities in rural areas. It may be urban residents in general as electricity consumers, enjoying continued access to low-carbon electricity without bearing their local negative impacts. Or it may be renewable energy developers located in urban areas who raise profits from electricity

sales from renewable energy facilities. Therefore, one should examine the effect of perceived urban bias in renewable energy facilities on individual attitudes toward renewable energy with varying urban beneficiaries.

Second, it might only resonate with rural residents because of their group-consciousness-based perspectives on rural/urban distinctions [127, 53]. Cramer [127], for instance, has coined the term “rural consciousness” to explain why rural voters in the U.S. favor limited government despite their lower-income status and finds that rural resentment of the lack of political and economic opportunities in rural areas lowers their level of trust towards government actions, shaping their policy preferences in favor of limited government intervention in rural areas. Moreover, Jacobs and Munis [53] find that this rural resentment motivates a strong out-group hostility against urban residents and therefore is shared only among in-group members (i.e., rural residents). Similarly, since perceived urban bias in renewable energy facilities entails the perception of an unfair situation regarding renewable energy installations between rural and urban areas, it should also be salient among rural residents only in shaping their social acceptance of renewable energy facilities. Therefore, one should examine whether the effect of perceived urban bias in renewable energy facilities on individual attitudes toward renewable energy is found only among rural residents.

4.2 Data and methods

4.2.1 Survey design

To examine the effect of perceived urban bias in renewable energy facilities on individual attitudes toward renewable energy, this research draws on a survey experiment with vignettes randomly assigned to survey participants in two South Korean counties, Wando and Yeosu (IRB No: STUDY00015587). The survey was conducted in person rather than online so that the level of digital literacy does not impact the sample collection, which is a crucial issue in rural Korea. The researcher visited and resided in a town in each county in September

and November 2022 to recruit potential survey participants. I recruited survey participants by canvassing and visiting community centers. The survey plan was pre-registered (<https://osf.io/4rkj2>).

The survey randomly assigns one of three vignettes that convey information on solar farms, as shown in Figure 1. The first two vignettes serve as treatments that are designed to prime an urban bias in solar farms, and the third vignette serves as a control (reference). All vignettes are presented in Korean with the same word counts. They begin by addressing that solar farms produce less greenhouse gas (GHG) emissions than fossil fuel to produce the same amount of electricity, helping mitigate climate change. Then, the first vignette highlights that urban areas consume most of their electricity, while the second vignette highlights that urban solar energy developers claim most of the profits from electricity sales. These two vignettes mention that a large number of solar farms in South Korea are in rural areas. The third vignette does not imply anything about the urban-rural dimensions of solar farms and simply explains the difference between PV and solar heat generation. The experiment also includes three attention check questions to make sure participants who fully understood the vignette are analyzed. There were 240 survey participants in total, leaving 151 effective samples after excluding 55 incomplete responses and 34 attention check failures, as outlined in Table 4.1.

Table 4.1: The number of responses and their types in each county

	Wando County			Yeoju City			Total
	Control	Treatment 1	Treatment 2	Control	Treatment 1	Treatment 2	
Total responses	36	45	39	44	34	42	240
Incomplete responses	6	13	9	10	9	8	55
Attention check failures	4	6	3	8	6	7	34
Effective responses	26	26	27	26	19	27	151

Next, the survey participants are asked the following question of which answer serves as

Treatment 1: “Solar farms help mitigate climate change by producing less amount of greenhouse gas emissions (GHG) than fossil fuel energy to generate the same amount of electricity. Meanwhile, solar farms are largely located in rural areas, while sending most of the electricity to urban areas for urban residents to consume.”

Treatment 2: “Solar farms help mitigate climate change by producing less amount of greenhouse gas emissions (GHG) than fossil fuel energy to generate the same amount of electricity. Meanwhile, solar farms are largely located in rural areas, while urban developers earn profits from selling their electricity to the electricity market.”

Control (Reference): “Solar farms help mitigate climate change by producing less amount of greenhouse gas emissions (GHG) than fossil fuel energy to generate the same amount of electricity. Meanwhile, there are two types of solar farms: those that use photovoltaic (PV) panels, and those that use concentrated heat from the sun.”

Figure 4.1: Three vignettes used in the survey experiment

an outcome variable of interest in this chapter:

“The South Korean government plans to invest in (1) expanding new solar farms (solar energy investment) and (2) renewing existing nuclear energy facilities (nuclear energy investment) to mitigate greenhouse gas emissions. If it were to invest 10 billion Korean won, which energy source do you think should be more invested and by how much?”

Then, they are asked to write down the number in billions to allocate 10 billion Korean won (e.g., 3 billion for solar energy investment vs 7 billion won for nuclear energy investment) to the first and second options of energy sources, respectively. The survey asked that the participants make sure the numbers sum up to 10 billion won. Including nuclear energy in the survey imposes a resource constraint on survey participants’ decisions on which type of

energy investment they are more supportive of [6]. It also reflects the political environment in South Korea where there is a widely conceived trade-off relationship between renewable energy and nuclear energy, in line with its theoretical discussions [112]. The previous Moon government aimed to actively expand renewable energy to reduce reliance on nuclear energy via so-called the “nuclear phase-out” policy [69]. However, the current Yoon government has revoked the policy and proclaimed to bring nuclear energy expansion back into its energy mix, clearly prioritizing it over renewable energy. Therefore, nuclear energy serves as a reference choice for government investment in comparison with solar energy. The survey ensured that the vignettes above do not deliver any information on nuclear energy.

I also included five questions that may affect how survey participants respond to both the vignette they were given and the outcome variable question. All questions asked participants to answer with five categories: (1) “Strongly agree,” (2) “Agree,” (3) “Neither agree nor disagree,” (4) “Disagree,” and (5) “Strongly disagree.” The first question, “How much do you agree climate change impacts your daily life?”, asks about the level of individual perception of climate risks. The second question, “How much do you agree renewable energy facilities produce less local air pollution than fossil fuel plants?” examines how strongly participants believe that renewable energy facilities offer superior air quality at a local level as opposed to fossil fuel plants. The third question, “How much do you agree nuclear energy is a more reliable source of electricity over renewable energy?”, examines participants’ predisposed level of support for renewable energy in comparison with nuclear energy. This question is particularly important for checking if certain treatment (or control) groups are sampled with participants who are more supportive of nuclear energy than renewable energy compared to other groups. The fourth question, “How much do you agree the government policy has been in favor of urban areas as opposed to rural areas?”, surveys participants’ prior belief in the urban bias in government policy. The last question, “How much do you agree there is a widening gap between urban and rural areas in terms of economic growth”, also surveys their prior belief in the future level of the urban-rural gap.

Finally, the rest of the survey included additional questions to collect information on par-

ticipants' sociodemographic backgrounds. This information helps determine whether there is a balance in various individual-level factors across treatment and control groups, such as gender, level of income, education, political ideology, and age. The survey also asks for years of residence at the current address, whether participants were born at the current address, and whether they have direct family members living in Seoul.

4.2.2 Survey area

Wando County is in the Southern part of South Korea, affiliated with Jeonnam Province. It is located 361.63 km away from the Seoul Metropolitan area with 66,978 populations. The total size of solar energy installation in Wando County is 73.84 MW. Yeosu City (County-level jurisdiction) is in the middle of South Korea, affiliated with Gyunggi Province. It is located closer to the Seoul Metropolitan area than Wando County (61.62 km) with 115,358 populations, generally construed as more suburban than Wando County. The total size of solar energy installation in Yeosu City is 113.78 MW. The farming population in Wando County is 14,423 (21.5%) while that in Yeosu City is 18,155 (15.7%). The survey was conducted in a township-level area in each county, namely Yaksan-myeon (town) in Wando County and Yeohung-dong (town) in Yeosu City.

Two counties were selected to have varying levels of ruralness with similar distances from the nearest nuclear power plant in South Korea. Wando County is distanced about 125 km away from Hanbit Nuclear Power Plant in Youngkwang County, Jeonnam Province. Yeosu City is distanced 144 km away from Hanwool Nuclear Power Plant in Uljin County, Gyeongbuk Province. This is to make sure survey participants in two counties have as similar perceptions as possible of geographical proxy and the potential risks of nuclear energy plants in local communities.

A field survey experiment can often be susceptible to the violation of the stable unit treatment value assumption (SUTVA). Particularly, if survey participants who have completed the survey communicate or interact in person with potential participants who may be invited to the survey later, they may share information about their vignettes and questions,

causing unmodeled spillovers. To prevent this, I visited one village (a smaller administrative unit than townships) for one day at a time to recruit potential survey participants and did not recruit any further from the village already visited. This is because each village can be “contaminated” after the survey, allowing the interaction between survey participants who already participated in the survey and potential ones who are yet to participate. For instance, if I recruited 15 participants in Woodoo-ri (village) in Yaksan-myeon for one day, the survey did not take place any longer in Woodoo-ri. The next round of the survey took place in, say, Haedong-ri, where residents there would not frequently interact with residents in Woodoo-ri because of the distance between these two villages.

4.2.3 Survey participants’ characteristics

Table 4.2 provides the balance statistics across treatment and control groups in each county. I used the one-way ANOVA test to check if each variable across different groups is statistically distinguishable. Specifically, if $p > 0.05$, we cannot reject its null hypothesis that the three means of each variable in each town are statistically equal. The balance statistics suggest that there is no significant difference in all variables retrieved from the survey across treatment and control groups. Comparing all six groups across two counties renders the same results. This ensures that the experiment provides average treatment effects (ATE) of vignettes that prime the urban bias in solar farms.

Moreover, to what frame a respondent is exposed does not predict whether the respondent has failed the attention check. The one-way ANOVA test between whether a respondent has failed it and what frame the respondent read fails to reject the null hypothesis (p -value=0.776). However, two statistically different factors exist between the attention-check failure group and the non-failure group. The non-failure group participants more strongly believe climate change is affecting their daily lives than their failure group counterparts. Also, the non-failure group participants more strongly believe the government policy has been biased toward urban areas than their failure group peers. This implies that excluding the attention-check failure groups from the analysis may lead to results where the association

between the dependent variable and these two factors can be biased.

Table 4.2: Balance statistics for all combinations of treatments in each county

	Wando County				Yeoju City			
	Control	Treatment 1	Treatment 2	P-value	Control	Treatment 1	Treatment 2	P-value
Responses to survey questions								
Climate change impact	3.96	3.69	4.22	0.30	4.15	4.47	3.81	0.07
Local air pollution from renewable vs fossil fuels	3.46	3.12	3.44	0.55	3.85	4.21	3.89	0.44
Local economic benefits from nuclear power plants	3.27	2.69	3.04	0.18	3.12	3.21	3.22	0.95
Urban bias in government policy	4.15	3.81	3.78	0.46	3.85	3.95	3.96	0.92
Deepening rural-urban gap	4.04	3.62	3.78	0.40	3.88	4.32	4.19	0.27
Demographic characteristics								
Age	53.5	60.4	53.8	0.19	49.8	55.9	56.1	0.19
Government ID Gender (1=male, 0=female)	0.73	0.54	0.48	0.16	0.69	0.79	0.74	0.83
Monthly household income	2.27	2.23	2.56	0.62	2.85	3.11	3.59	0.25
Final education level	4.19	3.65	3.67	0.35	5.08	5.05	4.59	0.34
Political ideology	2.69	2.85	2.74	0.82	2.96	2.74	2.93	0.65
Years of current residence	26.4	26.0	31.2	0.82	32.2	39.0	37.6	0.52
Born in current residence	0.73	0.42	0.56	0.08	0.50	0.58	0.44	0.68
Family members living in Seoul	0.38	0.61	0.63	0.14	0.46	0.53	0.44	0.86

Note: Cell entries are subgroup means for each variable, and the p-value is derived from the one-way ANOVA test.

4.3 Results

I examine the effects of two treatments using ordinary least squares (OLS) models. Table 4.3 summarizes the full results. I use different models based on what samples of survey participants they use. Namely, Model 1 uses a full sample of all survey participants in two counties, while Model 2 uses a subgroup of survey participants from Wando County and Model 3 uses its subgroup from Yeoju City. These models help examine whether the size of the treatment effects varies by where survey participants reside.

Using the full sample, survey participants who were exposed to either the first or second vignette that primes the urban bias in solar farms with different urban beneficiaries are less

Table 4.3: OLS results

Variables	Model 1 (All counties)	Model 2 (Wando County)	Model 3 (Yeoju City)
Treatment 1 vs control	-11.612 (4.830)**	-16.124 (5.918)***	-2.071 (7.763)
Treatment 2 vs control	-8.876 (5.021)*	-18.108 (7.192)**	3.644 (8.945)
Climate risk perception	1.020 (2.143)	-1.000 (0.726)	6.744 (5.599)
Superior air quality	7.933 (1.937)***	7.555 (2.306)***	5.012 (4.493)
Nuclear energy	-6.546 (1.951)***	-1.988 (3.469)	-10.160 (2.949)***
Urban bias in policy	2.159 (2.270)	0.863 (3.244)	1.408 (4.139)
Urban-rural gap	-0.211 (0.930)	-1.108 (3.533)	-1.279 (5.130)
Gender	1.208 (3.738)	-0.708 (5.617)	-3.679 (7.417)
Income	0.456 (1.367)	1.189 (2.119)	-1.072 (1.926)
Education	2.452 (2.163)	2.568 (3.153)	-1.205 (3.485)
Political ideology	-3.406 (2.322)	-2.696 (3.130)	-3.076 (4.499)
Age	-0.106 (0.205)	-0.238 (0.348)	0.192 (0.385)
Years of residence	0.113 (0.131)	0.174 (0.192)	-0.209 (0.323)
Place of birth	-3.842 (5.047)	-1.944 (7.631)	0.902 (10.613)
Family in Seoul	-9.073 (4.142)**	-10.126 (5.254)*	-1.843 (6.832)
Intercept	37.402 (18.926)*	44.141 (24.730)*	56.711 (0.111)
Adjusted R-squared	0.2915	0.2935	0.2416
N	151	79	72

Note: Heteroskedasticity-adjusted standard errors are reported in parentheses. *- $p < 0.1$; **- $p < 0.05$; ***- $p < 0.01$.

likely to support government investment in solar energy relative to nuclear energy. However, these treatment effects are primarily driven by rural residents in Wando County than suburban residents in Yeosu City. Specifically, survey participants in Wando County exposed to the first vignette allocated 16.142 billion Korean won of government investment less to solar energy than those exposed to the reference vignette. Also, Wando participants exposed to the second vignette allocated 18.108 billion Korean won of government investment less to solar energy than those exposed to the control vignette. However, survey participants in Yeosu City exposed to either the first or second vignette did not allocate government investment to solar energy relative to nuclear energy distinctively from those exposed to the control vignette. Figure 4.2 visualizes the size of different treatment effects across models.

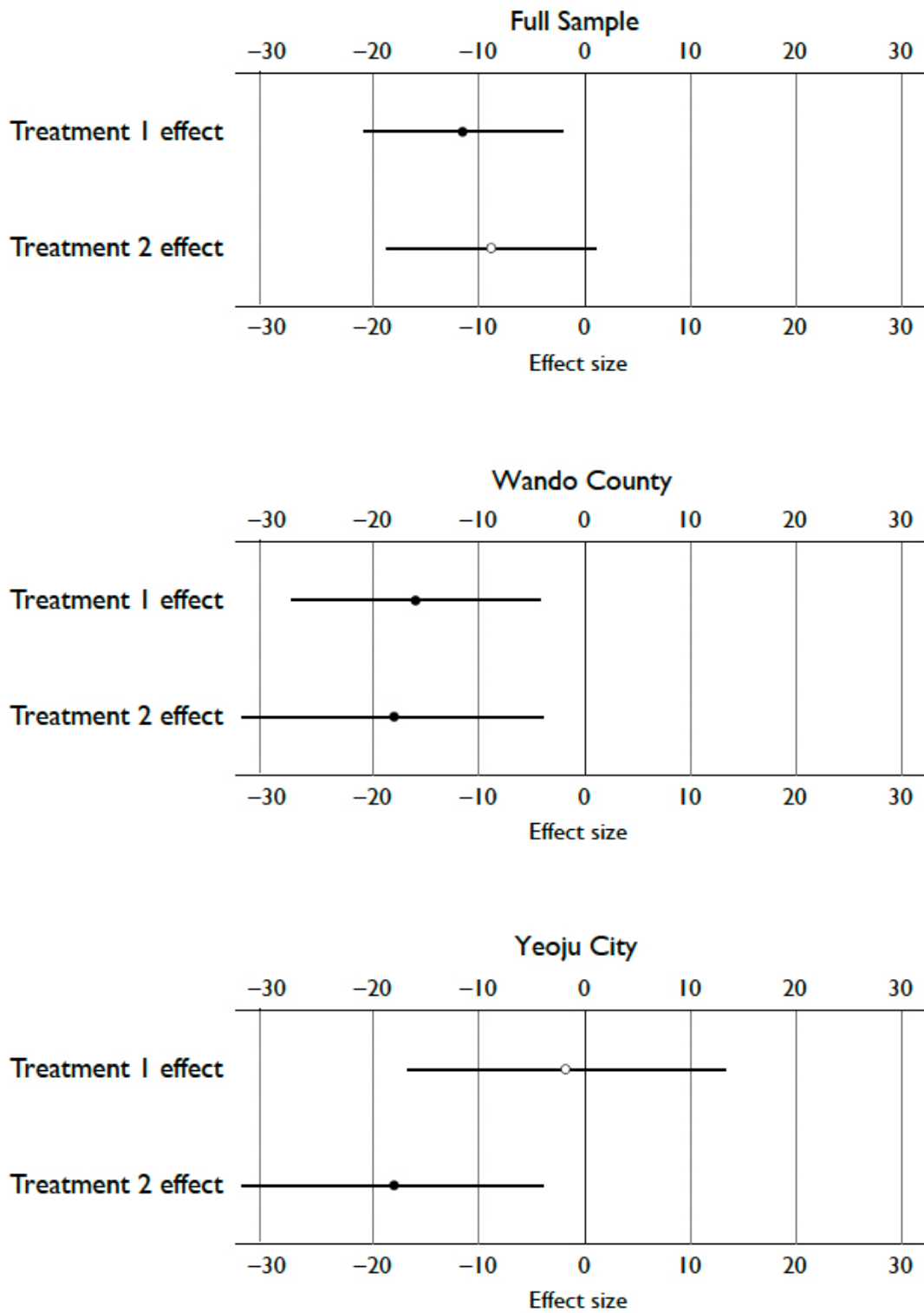


Figure 4.2: Average treatment effects of treatments 1 and 2 in each model

The OLS results suggest that when rural residents perceive the urban bias in solar farms, they are less supportive of solar energy as a low-carbon energy source compared to nuclear energy. However, the effect of perceived urban bias in solar farms was not found among suburban residents who live much closer to the Seoul Metropolitan area than Wando residents. This finding is consistent with the expectation that perceived urban bias in renewable energy facilities will only be a salient driver of opposition to renewable energy in rural areas. An even distribution of the costs and benefits from renewable energy facilities should only resonate with rural residents who perceive clearer urban-rural distinctions and therefore feel a larger burden of renewable energy facilities than they believe urban residents have. However, suburban residents share place-based identities as both rural and urban residents, as they can frequently travel to metropolitan areas and live in suburbanized settings. This may lead to a less clear perception of urban-rural distinction which makes urban bias in solar farms less salient among suburban residents than among rural residents.

4.4 Discussion

This chapter draws on a field survey experiment in two counties in South Korea with varying levels of ruralness in terms of population, distances from metropolitan areas, and farming population. Survey participants were randomly assigned one of three vignettes, two of which were designed to prime the urban bias in solar farms. The urban bias is defined as the notion that solar farms in rural areas predominantly benefit urban residents by either (1) providing urban residents with access to low-carbon electricity or (2) providing urban solar energy developers with profits from electricity sales, both without imposing potential negative impacts from solar farms at a local level. OLS analysis with data collected from the survey experiment shows that vignettes that prime such urban bias lower support towards solar energy as opposed to nuclear energy only among rural residents.

While rural attitudes toward climate policies have been growingly important for their effective implementation [31], there has been less scholarly interest in what shapes them.

This finding contributes to the literature on the social acceptance of renewable energy in rural areas by showing that (1) perceived urban bias in renewable energy facilities can be a crucial source of rural opposition to renewable energy in addition to rural residents' concern over their disruptive impacts on the surrounding landscapes, and (2) perceived urban bias in renewable energy facilities is only salient among rural residents. The second finding is particularly interesting given that previous studies have found similar findings where rural resentment is only relevant for rural residents when explaining their voting behaviors or policy preferences [127, 53].

This finding has an important policy implication for an accelerated renewable energy transition. First, government policies should consider how to mitigate the potential negative impacts of renewable energy facilities in rural communities as well as how to channel their potential benefits into them. Rural residents' concerns over the unfair distribution of the costs and benefits from renewable energy facilities can only be alleviated when both their cost- and benefit-related issues are addressed from the early planning process of renewable energy projects. Second, rapid renewable energy installations in rural areas should be coupled with government policies to make urban areas less reliant on external sources of electricity or enhance their energy efficiency. As long as urban areas consume the most electricity in society as opposed to rural areas, renewable energy installations in rural areas may continue confronting local opposition because of their lack of political legitimacy.

Chapter 5

CONCLUSION

This dissertation provides evidence that (1) landscape disruption and (2) perceived urban bias are two major sources of opposition to solar energy facilities and renewable energy policy in South Korea. These work as impediments to national climate actions by (1) making it more difficult to site renewable energy facilities and (2) lowering public support towards domestic renewable energy policies. While Chapter 2 and 4 find that these two sources of opposition may drive the distributional conflicts in the process of renewable energy transition between urban and rural areas, Chapter 3 does not explicitly test the argument in the context of urban-rural divide. Instead, it notes that landscape disruption may concern not only rural residents but urban ones and affect their level of support towards renewable energy surcharge.

Urban-rural gap has been little studied in the literature on distributional conflicts of climate actions [7]. However, energy and climate justice literature has long been aware that rural communities, as well as historically and politically marginalized communities such as low-income ones and communities of color, may enjoy less benefits from and experience more costs of ambitious climate actions [55, 13, 111, 33]. Zooming in on the urban-rural gap in the study of distributional conflicts of climate actions helps us better understand why rural communities are growingly opposing renewable energy facilities and policies, despite the fact that they remain the most vulnerable communities to climate-induced natural disasters [83, 67]. This is because renewable energy opposition is not equal to climate reform opposition: Rather, renewable energy opposition reflects rural residents' desire to protect the quality and integrity of rural life [54]. Therefore, to alleviate urban-rural conflicts in renewable energy transitions, the government must incorporate rural needs into renewable energy policies and siting regulations of renewable energy facilities.

Lessons from Chapter 2 point that local governments are not always capable of addressing local concerns on renewable energy facilities in a timely manner. As Aklin and Mildenerger [7] and Mildenerger [78] note, climate reform challenges the status quo. A rapid expansion of renewable energy facilities in their jurisdiction has caused a great deal of administrative burdens on civil servants and incumbents in county-level governments. Under such circumstances, relying on a setback restriction on solar farms was perhaps nationally sub-optimal but arguably locally optimal policy intervention to address rural opposition to renewable energy facilities. This implies that the central government must assist local governments in addressing local concerns from renewable energy facilities, such as through providing siting guidelines and empowering the existing Environmental Impact Assessment (EIA) to better mitigate their landscape impacts.

Chapter 3 highlights that landscape disruption can concern both rural and urban residents and affect their level of support towards renewable energy surcharge. In countries where rural-urban delineation is harder (mostly due to their smaller sizes), urban residents can better relate to the disruption of rural landscapes from renewable energy facilities, particularly if they travel to rural areas more often. Also, as the discussion section of Chapter 2 notes, urban landscapes may also be disrupted by renewable energy facilities, particularly if they host culturally valuable sites and heritages. This is not to say rural-urban conflicts are exaggerated because urban residents also share the burdens of landscape disruption: An inconvenient truth is that most renewable energy facilities are located in rural areas, thus their landscape impact is mostly on rural landscapes. While rural communities share a larger share of burden from renewable energy expansion than urban residents, landscape disruption is what siting regulations of renewable energy facilities must prioritize to address, given that it affects individual support for renewable energy surcharge among both rural and urban voters. In other words, findings of Chapter 3 clearly emphasize the point made by Chapter 2 that concerns over landscape disruption can be a major impediment to renewable energy transition, and therefore more ambitious national climate actions.

Chapter 4 is the first study that finds a causal effect of perceived urban bias in renewable

energy facilities on public acceptance of renewable energy. An interesting point is that such an effect is found only among rural residents but not among suburban residents. As its discussion section notes, the finding implies that rural consciousness [127] or rural-as-place-based identity [54, 31] may also shape rural residents' preferences over low-carbon energy options, just like they shape their preferences on other government policies. What these earlier studies find is that the effect of rural identity on policy preferences is only found among rural residents [53], which is what this chapter has shown as well. A practical implication for both policymakers and renewable energy developers is that understanding rural identity matters for carrying out both renewable energy projects at a local level and renewable energy policy at a broader level. Particularly, policymakers must ensure that rural communities receive substantial amount of benefits from renewable energy projects so that they less perceive urban bias in renewable energy. The benefits, however, should not mean unreasonably higher business and governance costs for renewable energy developers, as it may slow down renewable energy expansion. Therefore, policymakers should find an optimal mix of private and public funds to channel the benefits of renewable energy projects through rural communities. Or, they may expand government investment in community-based renewable energy projects that are owned by members of the rural communities.

Lastly, this dissertation looks at the South Korean case only, hence the generalizability might be of question. The research on urban-rural distributional conflicts in renewable energy transition, however, can be extensively applied to cases beyond South Korea. Most notably, there are 27 countries with at least one local-level government with siting restrictions on renewable energy facilities, most of which are advanced economies. Therefore, one can conduct a similar study to Chapter 2 to examine what local-level (or even country-level) factors explain the temporal and spatial variation in the adoption of local-level siting restrictions across different countries and localities. Also, Chapter 4 can be further developed into mixed-methods study where the survey experiment is complemented with in-depth interviews with cases beyond South Korea. As rural identity is largely a place-based identity, each rural community provides an interesting opportunity to investigate different types of

rural identities, and therefore, an opportunity to test whether perceived urban bias in renewable energy also exists in each case. This should help understand whether perceived urban bias is specific to South Korean context, or can explain a broader range of cases of rural opposition to renewable energy.

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Appendix A

COMPARISON OF THE DISCRETE EVENT HISTORY MODELS IN CHAPTER 2

Another important factor for adopting restrictions is policy contagion. When residents in “A” county dislike solar farms, they may be alarmed if their neighboring counties adopt the restriction, as solar energy developers will avoid those areas and seek out other available counties, one of which may be “A” county. Therefore, there is a potential spatial autocorrelation in adopting the restrictions. One can use the dependent variable of contiguous counties (i.e. restrictions of counties that share borders) as an additional independent variable to account for this. However, spatial autocorrelation may be conditional on whether counties share borders and how close they are to each other. For instance, “A” and “B” counties may not share borders because there lies “C” county in between, but close enough to be affected by the presence of each other’s restriction. Therefore, I let the model tell us how much spatial correlation varies depending on the distance between counties, not just their contiguity.

To account for this, I include Matérn random effects in the model which represent pairwise correlations calculated by the Matérn function at the scaled Euclidean distance between any paired observations. I used coordinate centroids for each county to calculate pairwise distances. Matérn random effects are easy to handle with piecewise event history analysis since it is identical to analyzing censored data with a generalized linear model where Matérn random effects have been commonly used. I show that the model that includes Matérn random effects provides consistent results with those that rely on contiguity assumption for incorporating spatial autocorrelation but shows a better fit to the data.

I compare the results of the main model (Model 4) with results from three other models

Table A.1: Comparison of the discrete event history models

	Model1	Model2	Model3	Model4
Solar farm density	0.123** (0.016)	0.141** (0.016)	0.095** (0.012)	0.119** (0.013)
Population density, logged	-0.602** (0.142)	-0.536** (0.158)	-0.615** (0.135)	-0.530** (0.150)
Average capacity per solar farm (kW)	0.000 (0.002)	0.000 (0.002)	0.000 (0.002)	0.000 (0.002)
Winning margin (%)	-0.013 (0.007)	-0.013 (0.008)	-0.012 (0.007)	-0.013 (0.007)
The share of farmlands (%)	-0.099** (0.022)	-.104** (0.025)	-.086** (0.019)	-.099** (0.023)
GHI	0.001 (0.005)	-0.010 (0.008)	0.000 (0.005)	-0.009 (0.007)
Solar farm density x Population density	-0.013** (0.002)	-0.015** (0.002)	-0.010** (0.002)	-0.013** (0.002)
Average capacity per solar farm x Population density	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Intercept	-0.285	14.105	0.196	13.433
Link function	logit		cloglog	
Spatial frailties	CAR	Matérn	CAR	Matérn
Maximum Likelihood	-289.35	-283.84	-285.12	-278.52
AIC	1197.41	1179.35	1180.48	1158.09

** , * , denote significance at the 1% and 5% level, respectively. Standard errors are denoted in parentheses.

(Model 1-3). Model 1 uses a logit link with conditional autoregressive (CAR) correlation to account for spatial autocorrelation, and Model 2 uses the same link with Matérn random effects. CAR correlation uses an adjacency matrix to account for the spatial autocorrelation between contiguous counties, and Matérn random effect does that using Euclidean distances between county centroids. Model 3 uses a complementary log-log (cloglog) link with CAR correlation, and Model uses the same link with Matérn random effects. All models obtain coefficient estimates of explanatory variables (fixed effects) via maximum likelihood (MLE) and random effect parameters by restricted maximum likelihood (REML). I used Akaike Information Criteria (AIC) to measure the goodness-of-fit which shows Model 4 outperforms the rest of the models.

Figure A1 visualizes the effect by plotting the estimated correlations against the Euclidean distance between counties. It shows that the correlation is higher when two counties are closer. This finding is consistent with the expectation that the presence of the restriction may affect the likelihood of closely located governments adopting the same.

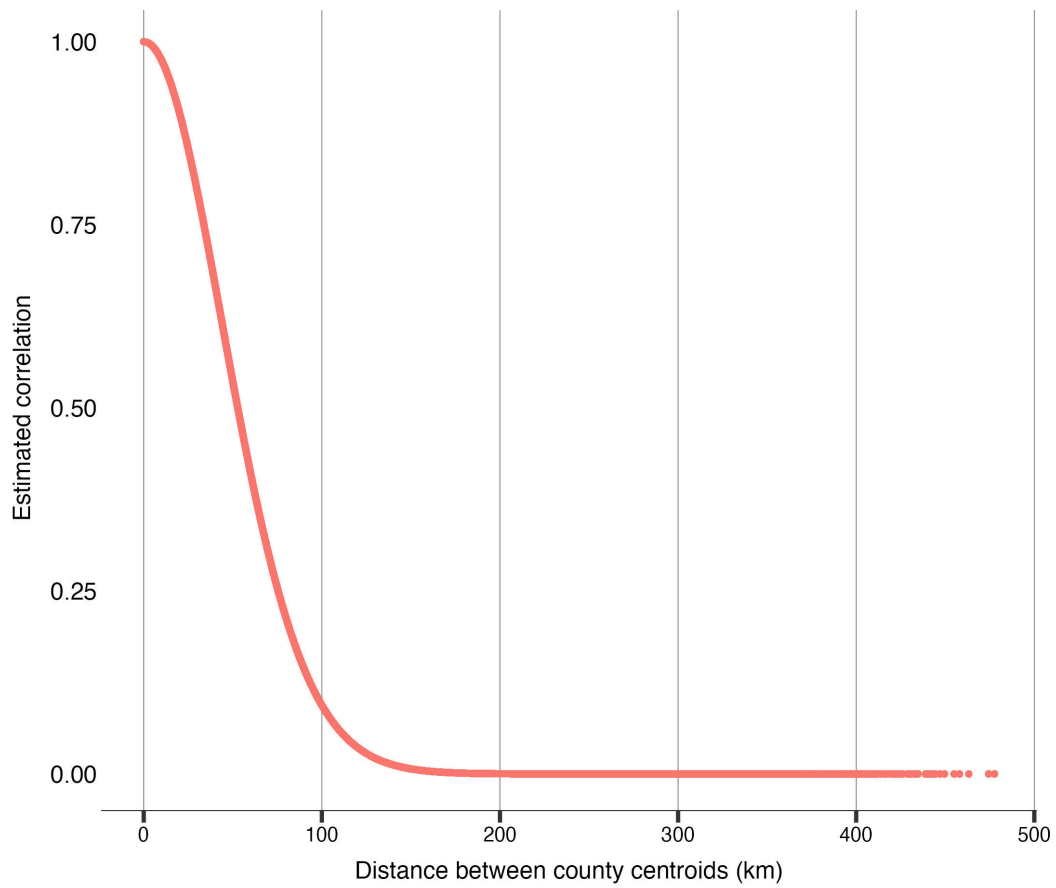


Figure A.1: Estimated spatial autocorrelation against Euclidean distance between county centroids.

Appendix B

WHERE TO FIND THE FILES

The `uwthesis` class file, `uwthesis.cls`, contains the parameter settings, macro definitions, and other \TeX commands which allow \LaTeX to format a thesis. The source to the document you are reading, `uwthesis.tex`, contains many formatting examples which you may find useful. The bibliography database, `uwthesis.bib`, contains instructions to BibTeX to create and format the bibliography. You can find the latest of these files here: <https://github.com/UWIT-IAM/UWThesis>.

The data and R code to replicate the analysis in Chapter 2, 3, and 4 are accessible via below URLs:

- Chapter 2: <https://doi.org/10.7910/DVN/Z3S4EQ>
- Chapter 3: <https://doi.org/10.7910/DVN/CGSCMD>
- Chapter 4: <https://doi.org/10.7910/DVN/YKLAEW>

If any of the links above is not working, it is because the associated manuscript is under review or further modification. Please contact the author to check the status.

VITA

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