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The Introduction of Wind Power Generation in a Local Community: An Economic Analysis of Subjective Well-Being Data in Chōshi City

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Abstract

In this study, we analyze the external effects of wind turbines, which are often considered detrimental to the promotion of wind power generation. Understanding these externalities is essential for reaching a consensus with residents who live near the planned site of a wind turbine. We conducted a mail survey in Chōshi City in Chiba Prefecture to examine the external effects of wind turbines, adopting a subjective well-being index to measure respondents' well-being. Regression analysis suggests that a view of wind power turbines has a positive effect on the subjective well-being of local residents. Moreover, results indicate that such well-being increases with increasing distance from wind turbines. In other words, except for scenic elements, we found that wind turbines are not always considered desirable by residents. As such, it is important to further clarify the external influence of wind turbines as well as other facilities in the neighborhood.

JEL: D62, I31, R11, Q20, Q51

Key Words: Subjective Well-Being, Wind Turbines, Renewable Energy, Externalities, Life Satisfaction Approach, Local Residents

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1. Introduction

Rapid introduction of renewable energy is strongly expected from the perspective of climate change and energy security. Despite remarkable growth of solar photovoltaic energy via a feed-in-tariff (FIT) scheme, the installed capacity for renewable energy has not been fully utilized. Therefore, introduction of other renewable energy such as wind or geothermal power generation has been strongly expected. However, the operation of wind power generation facilities would bring negative externalities to the local community. For example, Ministry of the Environment, Japan (2011) reported typical damage or negative impacts of building or operating wind turbines including destruction of view, noise, low-frequency sounds, impact on animals and plants, and shadow flicker. These pose negative externalities to local residents and hence, lead to conflicts regarding their construction.

Given the current situation, it is critical to develop a framework to deal with the conflicts related to turbine construction in order to accelerate the introduction of wind turbines. One option is to share the benefits related to the construction and operation of wind turbines. As such, it is necessary to examine possible negative externalities of wind turbines and review relevant studies that can be used for discussion with residents. As far as we know, such studies have not been conducted in Japan. Therefore, this study aims at examining whether and how wind generation results in negative externalities in Japan.

While wind power mitigates negative externalities of conventional electricity technologies, notably emission of CO_2 or other air pollutants, it entails externalities itself (Zerrahn, 2017). There are many studies on the externalities of wind turbines, for example on its visual pollution (Devine-Wright, 2005; van Rensburg et al., 2015; Mattmann et al., 2016), noise pollution (Knopper and Ollson, 2011; Bakker et al., 2012; McCunney et al., 2014; Schmidt and Klokker, 2014; Onakpoya et al., 2015), or impacts on wildlife (Pearce-Higgins et al., 2012; Northrup and Wittemyer, 2013; May et al., 2015; Schuster et al., 2015). Wind turbines may disturb natural landscape. Several studies investigate their negative impacts on landscape aesthetics (Devine-Wright, 2005; Wolsink, 2007; Jensen et al., 2014; van Rensburg et al., 2015; Mattmann et al., 2016). While there have been several studies on noise impact of wind turbines (Knopper and Ollson, 2011; Bakker et al., 2012; McCunney et al., 2014; Schmidt and Klokker, 2014; Onakpoya et al., 2015), many studies report that annoyance does not provide evidence of causal health effects (Zerrahn, 2017). Wind turbines may change the habitat of wildlife such as birds or bats and many studies examine whether and how wildlife is impacted (Pearce-Higgins et al., 2012; Northrup and Wittemyer, 2013; May et al., 2015; Schuster et al., 2015). However, it is uncertain whether the general effect on wildlife is positive or negative (Zerrahn, 2017).

On the other hand, wind turbines do not always bring about only negative externalities to residents. They could induce positive externalities by stimulating the tourism industry if they can create a special landscape. There are numerous studies about such effects on tourism, but evidence on local tourism effects for different countries remains mixed (Zerrahn, 2017). Some case studies establish negative impacts on local touristic appeal (Ladenburg, 2010; Jensen et al., 2014; Broekel and Alfken, 2015), while others detect negligible effects or enhanced touristic attractiveness (Dalton et al., 2008; Lilley et al., 2010; Frantál and Kunc, 2011; Landry et al., 2012; Nordman and Mutinda, 2016).

There are typically two types of research methods for wind turbine externalities. First, there is the Contingent Valuation Method (CVM), which clarifies the value of a wind turbine from the willingness to pay (WTP) to prevent its construction or the willingness to accept (WTA) wind turbine construction. Many CVM studies have shown that neighboring residents perceive negative externalities to wind turbines (Groothuis et al., 2008; Jones and Eiser, 2010; Meyerhoff et al., 2010; Mattmann et al., 2016). However, this method of investigation may strongly influence the analysis, including local residents' opposition to the construction. In that case, the results would be greatly biased. On the other hand, some studies show that consumers have positive WTP for wind turbines as green electricity (Borchers et al.,2007; Ma et al., 2015; Soon and Ahmad, 2015; Sundt and Rehdanz, 2015).

A second method involves using a hedonic method of analysis (Rosen, 1974). When people select housing, they make decisions considering environmental factors including noise levels and landscape. As such, the hedonic method is an analysis method based on the premise that land prices include people's WTP for the environment. By using this method, we can assess how the externalities of wind turbines, such as noise or landscape, affect land prices (Day et al., 2007). Jensen et al. (2014) analyze the impact of the presence of wind farms on land prices using Denmark's land price data. In this study, they analyze the negative influence of wind turbines in terms of landscape and noise separately. Numerous other studies also use the hedonic method, including Sims and Dent (2008) in the UK, Heintzelman and Tuttle (2012) in the USA, Dröes and Koster (2016) in Netherlands, Sunak and Madlener (2016) in Germany, and Gibbons (2015) in England and Wales. However, using the hedonic method of analysis is difficult in the context of Japan. This is because there are only a few cases of introducing wind power generation facilities near housing in Japan and very little data on housing near wind power generation facilities.

In recent years, the life satisfaction approach (LSA) using subjective well-being attracts attention as a new analytical method. Compared to the CVM and hedonic approach, the LSA avoids bias resulting from the expression of attitudes or the complexity of valuation, as well as misconceptions regarding the real estate market (Villamagna and Giesecke, 2014; Krekel and Zerrahn, 2017). Several studies use LSA, for example, to analyze air pollution (Levinson, 2012; Ferreira et al., 2013; Ambrey et al., 2014), landscape amenities (Kopmann and Rehdanz, 2013), noise pollution (van Praag and Baarsma, 2005; Rehdanz and Maddison, 2008), and flood disasters (Luechinger and Raschky, 2009).

Kunimitsu (2015) provides an analysis of the positive influence of physical capital existing in the area of well-being while Brereton et al. (2008) show the positive impacts of airports on well-being. On the other hand, some studies show that the Not in My Back Yard (NIMBY) syndrome has a negative impact on well-being. For example, roads (Brereton et al., 2008; Smyth et al., 2008; Tanaka et al., 2013), dumping grounds (Brereton et al., 2008), and nuclear power plants (Tsurumi et al., 2013) have a negative impact on well-being.

A handful of studies also use LSA for wind turbines in Germany (Krekel and Zerrahn, 2017; von Möllendorff and Welsch, 2017). These studies found negative effects of wind turbines on happiness, but such effects appeared both spatially and temporally limited (Krekel and Zerrahn, 2017; von Möllendorff and Welsch, 2017; Zerrahn, 2017).

In this study, our analysis focuses on the relationship between subjective well-being and wind turbines, similar to Krekel and Zerrahn (2017) and von Möllendorff and Welsch (2017).

The first feature of this study is that we use detailed distance data similar to Krekel and Zerrahn (2017). Since the degree of externality of the wind turbines may vary greatly depending on the distance from people's place of residence, we also consider this point in the analysis.

Secondly, we examine what elements of wind turbines affect well-being. Krekel and Zerrahn (2017) focus on the distance between well-being and the existing wind power generation. On the other hand, in this study, we focus on not only the distance from the wind turbines but also whether the residents can see or hear the wind turbines. Even if residents live close to the wind turbine, it is possible that the influence of the wind turbine may differ depending on whether they can see them visually.

In addition, as compared with Krekel and Zerrahn (2017) and von Möllendorff and Welsch (2017), we analyze the area where wind power generation has been operated for a long time as a feature of this study. Krekel and Zerrahn (2017) point out that although the well-being of people in the area where the wind turbines was introduced will be negative in the short term, the influence will decrease over time. Therefore, in this study, we analyze the relation between wind turbines and the degree of well-being of people in areas with long operational wind turbines. Specifically, we analyze Chōshi city; currently, the oldest wind turbine in Chōshi City has been in operation since 2001 (NEDO, 2017). In other words, Chōshi City is a region where wind turbines have existed for more than for more than a decade.

To analyze the relationship between wind turbines and the residence of the local residents, it is necessary to grasp their positional relationship. Therefore, in this study, we adopted a survey mailing approach to gather completed questionnaires. By gathering more data on subjective well-being from residents who live near or moderately close to the wind turbine, we are able to analyze this relationship.

The rest of this paper proceeds as follows. Section 2 presents our survey design. The survey results follow in Section 3. Section 4 explains the empirical results. Next, we summarize our findings in Section 5.

2. Research Context: Subject Area and Wind Power Generation Facility

Chōshi city, the subject area of our study, belongs to Chiba Prefecture in Kanto area, which comprises seven prefectures including Tokyo (see Figure 1). Chiba Prefecture is in the East of Kanto area and Chōshi city is located in the Far East, about 100 km away from central Tokyo. Similar to other municipalities in Japan, Chōshi city has experienced problems related to a declining birth rate and aging population; its population was about 64,000 as of 2017 (Chōshi city, 2017), although it used to have more than 80,000 people in 1995. In terms of age distribution, the age group of 65 to 69 years forms the largest group across both genders and amounts to a higher share of aged population compared to the national average (Ministry of Internal Affairs and Communications, 2015).

According to “The Wind Power Generation Facilities and Installations Report in Japan” (NEDO, 2017), there were 35 wind firm generation facilities operating in Chōshi city, as of March, 2017. Indeed, the East has seen a concentration of commercial facilities since long ago (see Figure 2). Average output of wind firm facilities is 1,500 kw in the city; however, some facilities have an output of 2,400 kw.

The offshore wind farm was first introduced in Japan in the East, offshore of Chōshi city, and it has been operational since 2013. They were also introduced in Asahi and Kamisu cities, which are located to the west and north of Chōshi city, respectively. Given the number of wind farms that have been introduced around Chōshi city, it appears reasonable that its residents are familiar with wind farms. It also indicates that there were few conflicts with residents regarding the introduction of wind farms. Therefore, we chose Chōshi city as the survey area.

3. Survey Design and Data

We specified the survey area in order to collect information from residents who lived close to wind turbines. Based on the location of the turbines, we selected 25 out of 166 towns, of which wind turbines are located relatively close to three areas and further from the remaining 22 towns. Using basic residence registers, we randomly selected 300 people from each area, respectively. Questionnaires were sent to each potential respondent by mail.

The survey included questions on subjective happiness, individual attributes, and wind turbines. Regarding the latter, we asked respondents for their evaluation of wind turbines, whether they were visible from their homes, and evaluation of visual, sound, and low frequency sounds emitted by them. We also applied the same questions to buildings, other than wind turbines, located near their homes. To develop the questions on the evaluation of wind turbines, we referred to the materials published by Ministry of the Environment (2011), which discloses public complaints regarding wind turbines. We also included the same questions for buildings other than wind turbines.

Since our objective is to examine the relationship between the distance from wind turbines and residents’ happiness, we needed information on distance from wind turbines to their home or residential areas, which were measured using Google Maps. For the three towns located near the wind turbines, we used street number data to measure the distance between individual homes and the turbines, whereas for the other 22 towns, we used postal codes to measure the distance between the town and the closest wind turbine.

We mailed the questionnaire to 600 people and obtained 229 responses, at a response rate of 38%. Figure 3 shows the income distribution of our sample compared with population (national level) statistics obtained from “Comprehensive Survey of Living Conditions” (Ministry of Health, Labor and Welfare, 2016). Our sample contains a larger share of people who earned an annual income of 2 to 3 million Japanese Yen and a lower share of those who earned more than 7 million Japanese yen compared to the population. Figure 4 shows the age distribution of our sample versus population (Ministry of Health, Labor and Welfare, 2016). Comparing the national age distribution, we have a smaller share of young respondents, especially in the age group of 10-19 years because only people who are older than 18 years old are subject to our survey. On the other hand, our sample contains more people aged 50 and above, especially greater than 70 years. In summary, we have a greater share of respondents who earn less income and are older than the actual population. This could partially be because the rate of aging in Chōshi city (33.7%) is higher than the national average (26%). Nonetheless, the difference in demographic information between sample and national population should be noted when interpreting estimation results.

Figure 5 shows the distribution of distance from residential area to wind turbines. It can be seen that the largest number of respondents live in areas that are 1,500 to 2,000 meters away from wind turbines. The second largest group comprises people who live within 1,000 to 1,500 meters of wind turbines. At the extremes, some respondents live more than 2,000 meters away from the turbines while others live within 500 meters of them. Figure 6 graphically summarizes the residential environment related to the existence of wind turbines and other large-sized buildings, such as visibility and audibility. Almost half of all respondents are able to see wind turbines from their respective homes. Additionally, large-sized buildings are also visible from 44% of all respondents' homes. Only a small proportion of respondents can hear the noise or low-frequency sounds of wind turbines. On the other hand, 57% and 29% of respondents indicated that they can hear the noise and low-frequency sounds, respectively, originating from large-sized buildings other than wind turbines.

Figure 7 summarizes the evaluation of wind turbines, their view, and that of other large-sized buildings. For each question, if a respondent is indifferent, he/she scores it a zero. On the other hand, respondents who feel positively or negatively towards the subject in question, answer with positive and negative values, respectively. Larger values indicate a larger intensity of the positive or negative feeling. Results show that the majority of respondents are indifferent towards wind turbines, as well as towards the view of wind turbines and of other large-sized buildings from their home. Nonetheless, more respondents answered with negative values.

Figure 8 shows the evaluations of noise and low-frequency sounds generated from wind turbines and other large-sized buildings. Only a few respondents reported negative values in the case of wind turbines, while a greater number of respondents felt uncomfortable with the noise and low frequency sounds emerging from other large-scaled buildings.

Summarizing the results from Figures 6, 7, and 8, approximately half of the respondents can see wind turbines from their homes and its view is not necessarily perceived negatively. Although noise and low-frequency sounds are often considered issues associated with wind turbines, the survey respondents did not perceive these as issues related to wind turbines but rather, to the other buildings considered in our survey. Based on the results of the open-ended questions, many respondents are concerned about sounds generated from factories and from cars or trucks driving near their homes.

4. Estimation Model and Results

4.1 Estimation Model

This study examines the relationship between happiness and conditions of wind turbines based on the following estimation model.

$$H_i = \boldsymbol{VIEW_i'}\boldsymbol{\gamma} + \beta_1 dist_i + \beta_2 noise_i + \boldsymbol{X_i}'\boldsymbol{\theta} + \alpha_i + \varepsilon_i \quad (1)$$

The dependent variable represents the absolute well-being of individual *i* on a scale of zero to ten. Independent variable, $\boldsymbol{VIEW_i'}$, is a vector that include dummy variable for View (whether the residents can see wind turbines from their houses) and interaction terms of the dummy variables for View × Distance (≤ 1,500 m) or View × Distance (> 1,500 m). Distance (≤ 1,500 m) or Distance (> 1,500 m) represent that respondents live within 1,500 meters or over 1,500 meters from wind turbines. $dist_i$ is a set of dummy variables based on the distance between wind turbines and respondents' homes. The base group is "within 500 meters" and indicates that a wind turbine is located within 500 meters from their home. We also construct four dummy variables that are equal to one if people live "500 to 1,000 meters," "1,000 to 1,500 meters," "1,500 to 2,000 meters," or "beyond 2,000 meters," respectively, from the wind turbines. $noise_i$ is a dummy variable that is equal to one if the respondent can hear the sound generate from wind turbines and other factors in their residential areas, and 0 otherwise.

$\boldsymbol{X_i}$ is a vector of individual attributes that include dummy variables for male, employment status, education level of at least high school, married, annual income and the duration for which the respondents have been living at that particular home. It also includes the age variable and its squared term. α_i is a constant term and ε_i represents the error term. $\boldsymbol{\gamma}$, β_1, β_2 and $\boldsymbol{\theta}$ are estimation parameters.

We used five estimation models based on Equation 1 above. In Models 1 and 2, we used a dummy variable that takes on value 1 if the respondent can see the wind turbines from his/her home as a proxy for $view_i$. On the other hand, in Models 3 and 4, we used two interaction terms instead: dummy variable that is equal to one if the respondent's home is within 1,500 meters from wind turbines times the dummy variable that is equal to one if he/she can see the wind turbines from home, and dummy variable that is equal to one if the respondent's home is further than 1,500 meters from the wind turbines times the dummy variable that is equal to one if he/she can see the wind turbines from home. $noise_i$ is used in Models 2 and 4. We construct Model 5 without $view_i$ and $noise_i$ to confirm the robustness of other variables. Table 1 shows the descriptive statistics of the data that we have used for estimation.

4.2 Estimation Results

Table 2 presents the results of the regression analysis. Regarding visibility of wind turbines, the estimation result of Model 1 shows that the dummy variable (View) representing whether people can see the wind turbines from their home is positive and statistically significant at 10%. However, it is not significant in Model 2, which has an additional variable representing noise. In terms of distance, the dummy variable indicating a distance of 1,000 to 1,500 meters from wind turbines is positively significant at 5% and 10% levels in Models 1 and 2, and Models 3 and 4, respectively. For Models 3 and 4, the interaction terms of the dummy variable for within 1,500 meters and View are statistically significant at 5%, whilst those of the dummy variable for distance of over 1,500 meters and View are not statistically significant. Dummy variables for 1,500 to 2,000 meters and more than 2,000 meters, both positively affect well-being at 10% level. Compared to these two, the coefficient of the dummy variable for more than 2,000 meters is larger than the one for 1,500 to 2,000 meters. We do not find any significant impact of noise on well-being in any model.

While Table 1 indicates that more than half the respondents could hear noises, based on the regression results (Table 2), this did not affect their perceived level of well-being. Regarding any impacts of individual attributes, we can observe similar results in all models. Our estimation results suggest that the dummy variable for male is negatively related to well-being, whilst those for employment and marital status are positively related. The coefficient of *Ln Age* is estimated to be negative. On the other hand, its squared term is estimated to have a positive. The results of *Ln Age* and its squared term showed that the well-being of the 30s was the lowest. Regarding annual income, setting "Less than 2 million JPY" as the base group, annual incomes of 4 to 5 million JPY, 5 to 7 million JPY, and 7 to 10 million JPY are estimated to be significantly positive. On the other hand, we found that the dummy variable for more than 10 million JPY is not related to well-being. Lastly, it is found that respondents who have lived in their current homes for 10 to 20 years or 20 to 30 years have higher well-being compared to lived in their current homes for less than 10 years.

4.3 Discussion

Contrary to expectations, our study found that the existence of wind turbines did not negatively affect the well-being of residents. This could be the case because few negative evaluations towards noise and low-frequency sounds were observed. Moreover, noises other than those from wind turbines did not affect well-being suggesting that the noise may be considered to be at an acceptable level in Chōshi city. There are two possible explanations. First, it is conceivable that the noise level existing in Chōshi city is generally acceptable for its residents. Second, although there are noises including those from wind turbines in Chōshi City, residents are already used to their environment and hence, possibly their well-being remains unaffected. In order to clarify this point, it is necessary to analyze the data using a quantitative measure of noise level.

We also found that the view of wind turbines is positively related to well-being. Especially, it was shown that wind turbines scenery within 1,500 m from home has the most positive influence on well-being. Our estimation result is consistent with that of Jensen et al. (2014) who show that a view of wind turbines from a certain distance is positively related to well-being. We suggest that positive evaluations towards wind turbines, as shown in Figure 7, could contribute to the estimation results. Moreover, it is found that the respondents did not negatively evaluate other large-sized facilities either.

Based on these estimation results, wind turbines should be constructed in areas with some pre-existing noises or low-frequency sounds in order to ensure residents' acceptance.

5. Conclusion

This study investigated the externalities of wind turbines, which is an essential procedure to develop a framework for reaching a consensus with local residents. Using the subjective well-being index to measure well-being of respondents, we examined how wind turbines affect well-being. We collected data for analysis through questionnaires distributed via mail to randomly selected residents in Chōshi city.

Contrary to expectations, our survey results suggest a mixed assessment of the view of wind turbines. Additionally, noise and low-frequency sounds, often considered the externalities of wind turbines, do not attract much attention from respondents.

The regression analysis suggests that the view of wind turbines positively affects respondents' well-being. In particular, it was shown that there is a big positive influence on people who can see the wind turbine from a distance of within 1,500 m. On the other hand, the impact of noise on happiness could not be shown in this analysis.

With these estimation results in mind, it is recommended that the acceptability of wind turbines should be assessed in the planned construction sites. Especially, preferences towards the potential factors of conflict, such as noise, should be carefully examined. This survey reveals that our respondents did not consider noise or low-frequency sounds as serious issues.

Furthermore, if wind turbines can increase tourist satisfaction, the municipal government might be able to develop them as tourist attractions. This study suggests that it is important to consider such externalities for residents when developing the construction plan for wind turbines.

A limitation of this study is that our survey targeted an area where wind turbines have been in place for several years. Krekel and Zerrahn (2017) suggested that negative impacts of wind turbines on well-being would decrease with time. While this may well apply to Chōshi City, we cannot effectively conclude this to be the case since we did not conduct the survey immediately after the wind turbines were built.

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Reference

Ambrey, C. L., Fleming, C. M., Chan, A. Y-C. (2014). Estimating the cost of air pollution in South East Queensland: an application of the life satisfaction non-market valuation approach. Ecological Economics, 97, 172-181.

Bakker, R. H., Pedersen, E., van den Berg, G. P., Stewart, R. E., Lok, W., Bouma, J. (2012). Impact of wind turbine sound on annoyance, self-reported sleep disturbance, and psychological distress. Science of the Total Environment, 425, 42-51.

Borchers, A. M., Duke, J. M., Parsons, G. R. (2007). Does willingness to pay for green energy differ by source? Energy policy, 35 (6), 3327-3334.

Brereton, F., Clinch, J. P., Ferreira, S. (2008). Happiness, geography and the environment. Ecological Economics, 65 (2), 386-396.

Broekel, T., Alfken, C. (2015). Gone with the wind? The impact of wind turbines on tourism demand. Energy Policy, 86, 506-519.

Chōshi city (2017). https://www.city.choshi.chiba.jp/sisei/about_choshi/toukei/ (accessed on 9 August 2018).

Dalton, G. J., Lockington, D. A., Baldock, T. E. (2008). A survey of tourist attitudes to renewable energy supply in Australian hotel accommodation. Renewable Energy, 33 (10), 2174-2185.

Day, B., Bateman, I., Lake, I. (2007). Beyond implicit prices: recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model. Environmental and Resource Economics, 37 (1), 211-232.

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy, 8 (2), 125-139.

Dröes, M. I., Koster, H. R. A. (2016). Renewable energy and negative externalities: the effect of wind turbines on house prices. Journal of Urban Economics, 96, 121-141.

Ferreira, S., Akay, A., Brereton, F., Cuñado, J., Martinsson, P., Moro, M., Ningal, T. F. (2013). Life satisfaction and air quality in Europe. Ecological Economics, 88, 1-10.

Frantál, B., Kunc, J. (2011). Wind turbines in tourism landscapes: Czech experience. Annals of Tourism Research, 38 (2), 499-519.

Gibbons, S. (2015). Gone with the wind: Valuing the visual impacts of wind turbines through house prices. Journal of Environmental Economics and Management, 72, 177-196.

Groothuis, P. A., Groothuis, J. D., Whitehead, J. C. (2008). Green vs. green: measuring the compensation required to site electrical generation windmills in a viewshed. Energy Policy, 36 (4), 1545-1550.

Heintzelman, M. D., Tuttle, C. M. (2012). Values in the wind: a hedonic analysis of wind power facilities. Land Economics, 88 (3), 571-588.

Jensen, C. U., Panduro, T. E., Lundhede, T. H. (2014). The vindication of Don Quixote: the impact of noise and visual pollution from wind turbines. Land Economics, 90 (4), 668-682.

Jones, C. R., Eiser, J. R. (2010). Understanding ‘local’ opposition to wind development in the UK: how big is a backyard? Energy Policy, 38 (6), 3106-3117.

Knopper, L. D., Ollson, C. A. (2011). Health effects and wind turbines: a review of the literature. Environmental Health, 10 (1), 78.

Kopmann, A., Rehdanz, K. (2013). A human well-being approach for assessing the value of natural land areas. Ecological Economics, 93, 20-33.

Krekel, C., Zerrahn, A. (2017). Does the presence of wind turbines have negative externalities for people in their surroundings? Evidence from well-being data. Journal of Environmental Economics and Management, 82, 221-238.

Kunimitsu, Y. (2015). Regional factors affecting the satisfaction of residents: Evidence from structural equation model in Japan. Social Indicators Research, 120 (2), 483-497.

Landry, C.E., Allen, T., Cherry, T., Whitehead, J.C. (2012). Wind turbines and coastalrecreation demand. Resour. Energy Econ. 34, 93–111.

Ladenburg, J., (2010). Attitudes towards offshore wind farms — the role of beach visits on attitude and attitude and demographic relations. Energy Policy, 38, 1297–1304.

Levinson, A. (2012). Valuing public goods using happiness data: the case of air quality. Journal of Public Economics, 96 (9–10), 869-880.

Lilley, M. B., Firestone, J., Kempton, W. (2010). The effect of wind power installations on coastal tourism. Energies, 3 (1), 1-22.

Luechinger, S., Raschky, P. A. (2009). Valuing flood disasters using the life satisfaction approach. Journal of Public Economics, 93 (3–4), 620-633.

Ma, C., Rogers, A. A., Kragt, M. E., Zhang, F., Polyakov, M., Gibson, F., Chalak, M., Pandit, R., Tapsuwan, S. (2015). Consumers' willingness to pay for renewable energy: a meta-regression analysis. Resource and Energy Economics, 42, 93-109.

Mattmann, M., Logar, I., Brouwer, R. (2016). Wind power externalities: a meta-analysis. Ecological Economics, 127, 23-36.

May, R., Reitan, O., Bevanger, K., Lorentsen, S-H., Nygård, T. (2015). Mitigating wind-turbine induced avian mortality: sensory, aerodynamic and cognitive constraints and options. Renewable and Sustainable Energy Reviews, 42, 170-181.

McCunney, R. J., Mundt, K. A., Colby, W. D., Dobie, R., Kaliski, K., Blais, M. (2014). Wind turbines and health: a critical review of the scientific literature. Journal of Occupational and Environmental Medicine, 56(11), e108-e130.

Meyerhoff, J., Ohl, C., Hartje, V. (2010). Landscape externalities from onshore wind power. Energy Policy, 38 (1), 82-92.

Ministry of Internal Affairs and Communications (2015). Population Census 2015. http://www.stat.go.jp/data/kokusei/2015/kekka.html (accessed on 9 August 2018).

Ministry of Health, Labor and Welfare (2016). Comprehensive Survey of Living Conditions 2016. https://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/index.html (accessed on 9 August 2018).

Ministry of the Environment (2011). https://www.env.go.jp/press/files/jp/17727.pdf (accessed on 9

August 2018).

Nordman, E., Mutinda, J. (2016). Biodiversity and wind energy in Kenya: revealing landscape and wind turbine perceptions in the world's wildlife capital. Energy Research & Social Science, 19, 108-118.

Northrup, J. M., Wittemyer, G. (2013). Characterising the impacts of emerging energy development on wildlife, with an eye towards mitigation. Ecology letters, 16 (1), 112-125.

Onakpoya, I. J., O'Sullivan, J., Thompson, M. J., Heneghan, C. J. (2015). The effect of wind turbine noise on sleep and quality of life: a systematic review and meta-analysis of observational studies. Environment International, 82, 1-9.

Pearce-Higgins, J. W., Stephen, L., Douse, A., Langston, R. H. W. (2012). Greater impacts of wind farms on bird populations during construction than subsequent operation: results of a multi-site and multi-species analysis. Journal of Applied Ecology, 49 (2), 386-394.

Rehdanz, K., Maddison, D. (2008). Local environmental quality and life-satisfaction in Germany. Ecological Economics, 64 (4), 787-797.

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy, 82, 34-55.

Schmidt, J. H., Klokker, M. (2014). Health effects related to wind turbine noise exposure: a systematic review. PLOS ONE, 9 (12), e114183.

Schuster, E., Bulling, L., Köppel, J. (2015). Consolidating the state of knowledge: a synoptical review of wind energy's wildlife effects. Environmental Management, 56 (2), 300-331.

Sims, S., Dent, P. (2007). Property stigma: wind farms are just the latest fashion. Journal of Property Investment & Finance, 25 (6), 626-651.

Smyth, R., Mishra, V., Qian, X. (2008). The environment and well-being in urban China. Ecological Economics, 68 (1-2), 547-555.

Soon, J-J., Ahmad, S-A. (2015). Willingly or grudgingly? A meta-analysis on the willingness-to-pay for renewable energy use. Renewable and Sustainable Energy Reviews, 44, 877-887.

Sunak, Y., Madlener, R. (2016). The impact of wind farm visibility on property values: a spatial difference-in-differences analysis. Energy Economics, 55, 79-91.

Sundt, S., Rehdanz, K. (2015). Consumers' willingness to pay for green electricity: a meta-analysis of the literature. Energy Economics, 51, 1-8.

Tanaka, R., Hashimoto, S., Hoshino, S., Shimizu, N., Kuki, Y. (2013). How do regional characteristics affect residents' subjective well-being? The Association of Rural Planning, 32, Special Issue, 167-172.

The New Energy and Industrial Technology Development Organization (NEDO) (2017). http://www.nedo.go.jp/library/fuuryoku/index.html (accessed on 9 August).

Tsurumi, T., Kuramashi, K., Managi, S. (2013). Monetary value evaluation using life satisfaction approach: subjective well-being and nuclear power plant. Society of Environmental Science, Japan, 26 (6), 571-578.

Villamagna, A., Giesecke, C. (2014). Adapting human well-being frameworks for ecosystem service assessments across diverse landscapes. Ecology and Society, 19 (1) .

van Rensburg, T. M., Kelley, H., Jeserich, N. (2015). What influences the probability of wind farm planning approval: evidence from Ireland. Ecological Economics, 111, 12-22.

van Praag, B. M. S., Baarsma, B. E. (2005). Using happiness surveys to value intangibles: the case of airport noise. The Economic Journal, 115 (500), 224-246.

von Möllendorff, C., Welsch, H. (2017). Measuring renewable energy externalities: evidence from subjective well-being data. Land Economics, 93 (1), 109-126.

Wolsink, M. (2007). Wind power implementation: the nature of public attitudes: equity and fairness instead of "backyard motives." Renewable and Sustainable Energy Reviews, 11 (6), 1188-1207.

Zerrahn, A. (2017). Wind power and externalities. Ecological Economics, 141, 245-260.

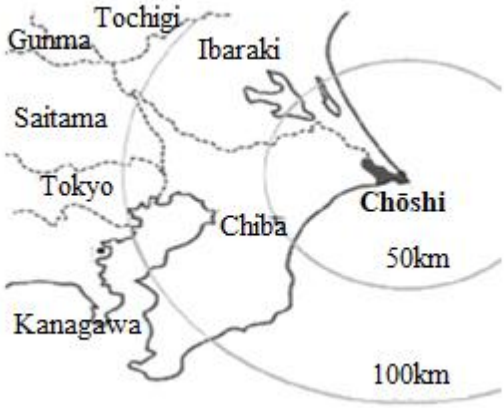

Figure 1. Map of Tokyo Metropolitan Area and Chōshi

Source: Chōshi City, 2017

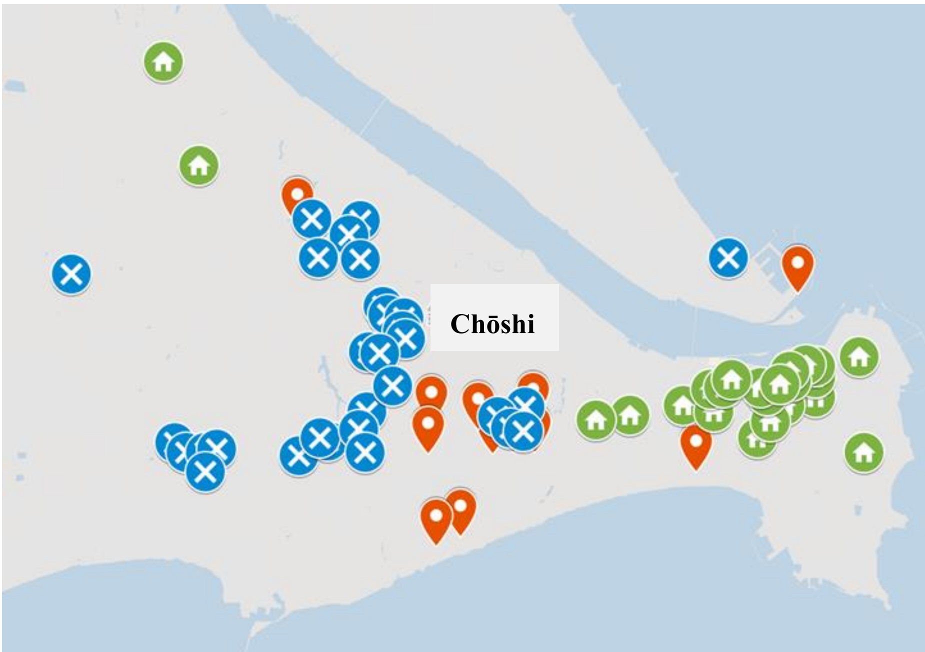

Figure 2. Map of Chōshi Area and Positional Information of Wind Turbines

Note 1: We map the positional information of wind turbines on Google Maps using the address information from Nedo (2017) and basic residence register in Chōshi city.

Note 2: The home markers indicate the residential locations of our sample, x markers indicate wind turbines that were not targeted, and other markers represent the targeted wind turbines.

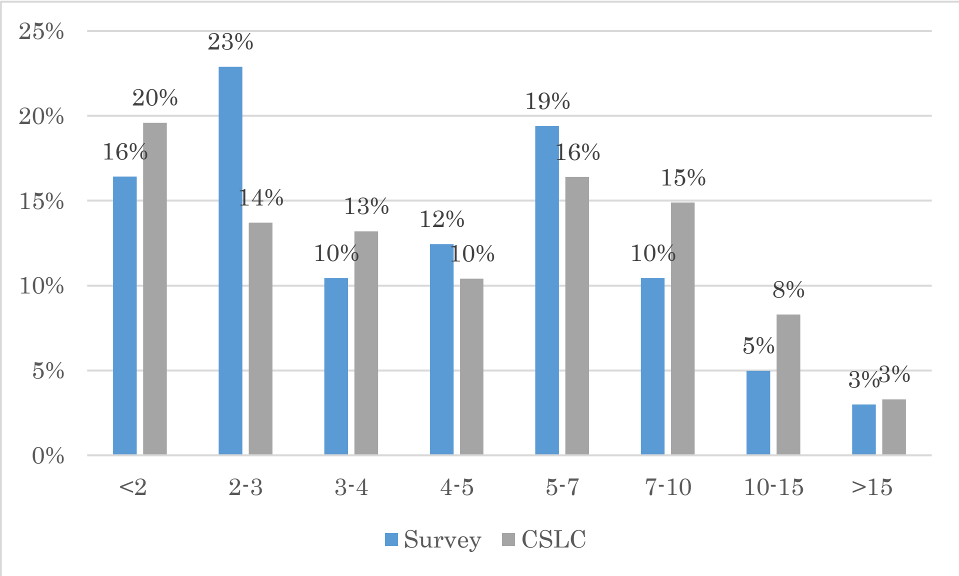

Figure 3. Distribution by Income Class

Note: Survey refers to the survey results of our study and CSLC refers to the results of Comprehensive Survey of Living Conditions 2016 (Ministry of Health, Labor and Welfare, 2016). Unit: Annual income in million JPY.

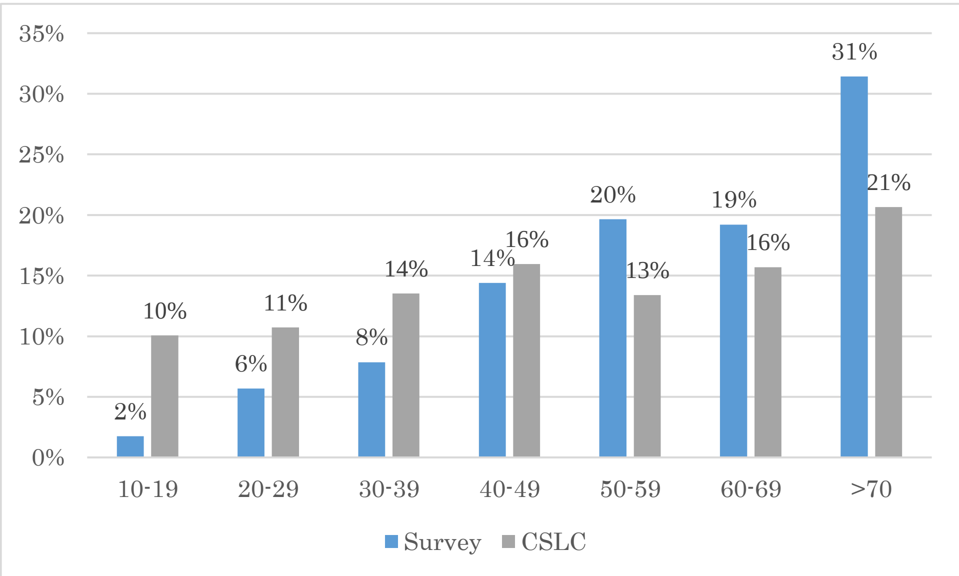

Figure 4. Distribution by Age

Note: Survey refers to our survey results and CSLC refers to the results of Comprehensive Survey of Living Conditions (2016).

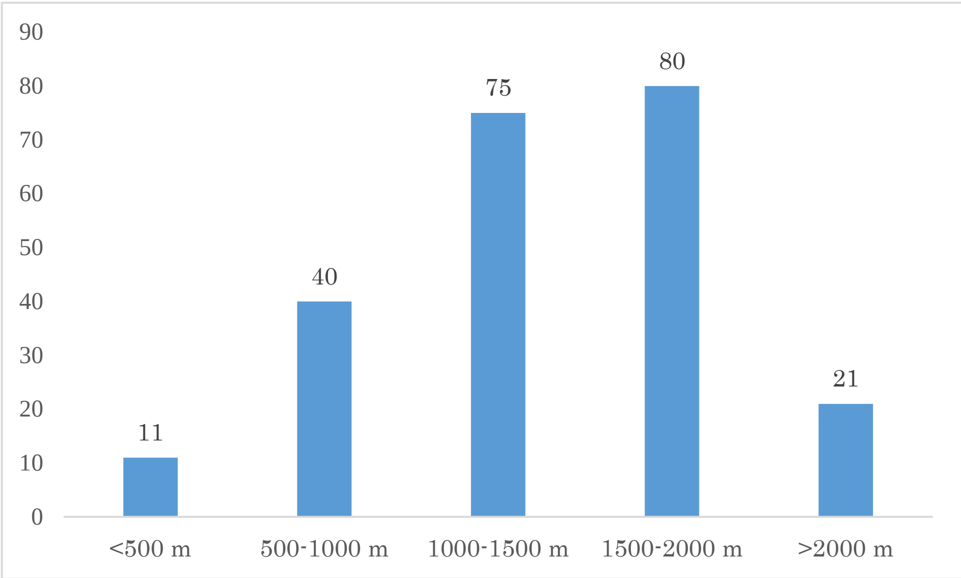

Figure 5. Distribution of Distance from Wind Turbines to Residence

Note: The vertical axis represents the number of observations.

Unit: Meter.

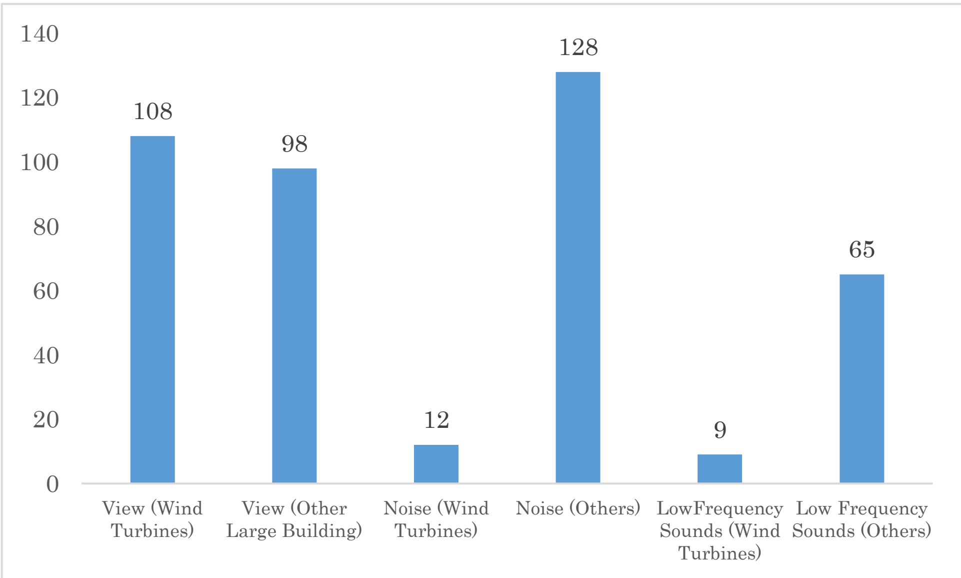

Figure 6. Environmental Context of the Place of Residence

Note: The vertical axis represents the number of observations.

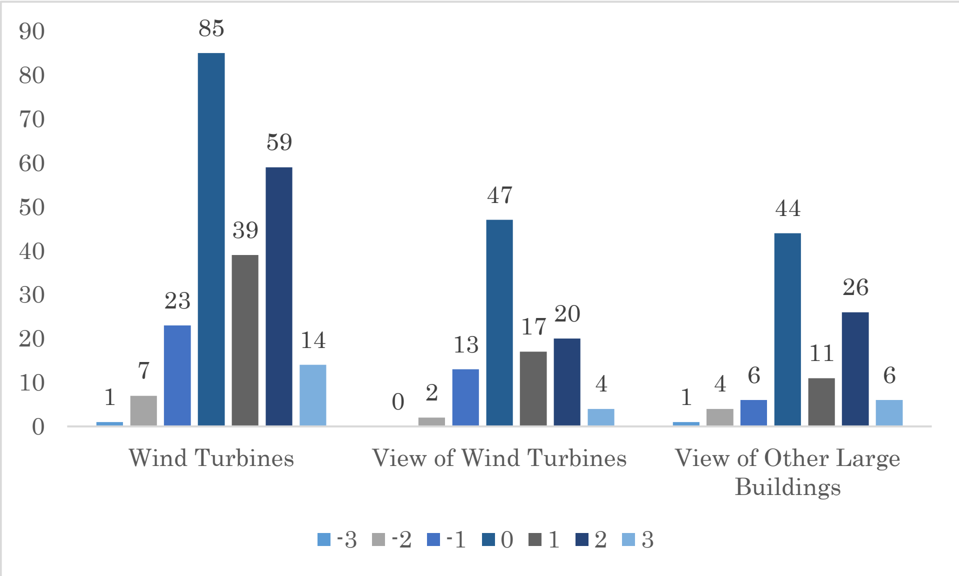

Figure 7. Evaluation of Wind Turbines and Other Large Buildings

Note: A negative number represents a negative evaluation, 0 represents a neutral evaluation, and a positive number represents a positive evaluation. The vertical axis represents the number of observations.

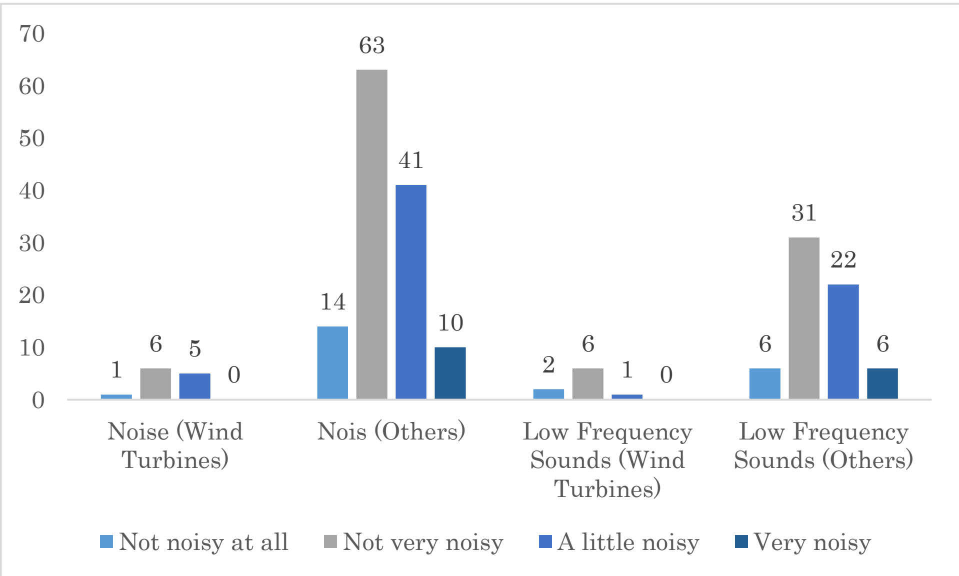

Figure 8. Evaluation of Sounds around the Place of Residence

Note: The vertical axis represents the number of observations.

Table 1. Descriptive Statistics

Variable	Mean	Std.Dev.	Min	Max
Well-being	6.56	1.85	1	10
View	0.49	0.50	0	1
View × Distance (≦1,500 m)	0.35	0.48	0	1
View × Distance (>1,500 m)	0.13	0.34	0	1
Distance (＜500 m)	0.05	0.22	0	1
Distance (500-1,000 m)	0.18	0.39	0	1
Distance (1,000-1,500 m)	0.32	0.47	0	1
Distance (1,500-2,000 m)	0.36	0.48	0	1
Distance (>2,000 m)	0.08	0.28	0	1
Noise	0.58	0.49	0	1
Income (＜2 million JPY)	0.16	0.37	0	1
Income (2-3 million JPY)	0.23	0.42	0	1
Income (3-4 million JPY)	0.10	0.31	0	1
Income (4-5 million JPY)	0.12	0.33	0	1
Income (5-7 million JPY)	0.19	0.40	0	1
Income (7-10 million JPY)	0.10	0.31	0	1
Income (10-15 million JPY)	0.05	0.22	0	1
Income (＞15 million JPY)	0.03	0.17	0	1
Male	0.51	0.50	0	1
Employment	0.60	0.49	0	1
Ln Age	4.00	0.35	2.9	4.5
Ln Age Squared	16.12	2.70	8.4	20.1
Education (≧High school)	0.27	0.45	0	1
Marriage	0.63	0.48	0	1
Duration of Residence (＜10 year)	0.11	0.31	0	1
Duration of Residence (10-20 year)	0.18	0.39	0	1
Duration of Residence (20-30 year)	0.24	0.43	0	1
Duration of Residence (＞30 year)	0.46	0.50	0	1

Note: Number of observations (N) = 201.

Table 2. Results of Regression Analysis

	Model 1			Model 2			Model 3			Model 4			Model 5		
Variable	Coef.	Std Error		Coef.	Std Error		Coef.	Std Error		Coef.	Std Error		Coef.	Std Error	
View	0.49	[0.28]	*	0.46	[0.29]										
View × Distance (≦1,500 m)							0.83	[0.34]	**	0.79	[0.35]	**			
View × Distance (>1,500 m)							0.08	[0.46]		0.08	[0.46]				
Distance (500-1,000 m)	0.66	[0.67]		0.71	[0.68]		0.70	[0.68]		0.74	[0.69]				
Distance (1,000-1,500 m)	1.18	[0.63]	*	1.25	[0.64]	*	1.33	[0.64]	**	1.38	[0.65]	**			
Distance (1,500-2,000 m)	0.88	[0.67]		0.90	[0.67]		1.32	[0.74]	*	1.32	[0.74]	*			
Distance (>2,000 m)	1.24	[0.83]		1.29	[0.84]		1.64	[0.84]	*	1.67	[0.85]	*			
Noise				0.19	[0.26]					0.16	[0.25]				
Male	-0.97	[0.26]	***	-0.96	[0.26]	***	-0.92	[0.26]	***	-0.91	[0.26]	***	-0.89	[0.25]	***
Employment	0.64	[0.32]	**	0.67	[0.32]	**	0.67	[0.32]	**	0.69	[0.31]	**	0.59	[0.31]	*
Ln Age	-13.08	[7.99]		-13.94	[7.78]	*	-13.12	[7.78]	*	-13.82	[7.65]	*	-11.13	[7.66]	
Ln Age Squared	1.83	[1.06]	*	1.95	[1.03]	*	1.82	[1.04]	*	1.92	[1.02]	*	1.57	[1.02]	
Education (≧High school)	0.32	[0.26]		0.32	[0.26]		0.32	[0.26]		0.32	[0.26]		0.43	[0.27]	
Marriage	0.67	[0.26]	***	0.68	[0.26]	***	0.64	[0.26]	**	0.65	[0.26]	**	0.75	[0.26]	***
Income (2-3 million JPY)	0.40	[0.39]		0.43	[0.39]		0.43	[0.38]		0.45	[0.39]		0.39	[0.41]	
Income (3-4 million JPY)	0.19	[0.47]		0.22	[0.47]		0.17	[0.47]		0.20	[0.47]		0.19	[0.46]	
Income (4-5 million JPY)	1.19	[0.45]	***	1.22	[0.45]	***	1.10	[0.45]	**	1.13	[0.45]	**	1.22	[0.44]	***
Income (5-7 million JPY)	1.03	[0.44]	**	1.04	[0.44]	**	1.03	[0.44]	**	1.05	[0.44]	**	0.99	[0.45]	**
Income (7-10 million JPY)	1.97	[0.48]	***	2.01	[0.49]	***	1.96	[0.48]	***	1.99	[0.48]	***	1.91	[0.47]	***
Income (10-15 million JPY)	0.85	[0.54]		0.93	[0.55]	*	0.85	[0.52]		0.92	[0.54]	*	0.89	[0.6]	
Income (＞15 million JPY)	0.67	[0.96]		0.64	[0.96]		0.65	[0.92]		0.63	[0.92]		0.65	[0.83]	
Duration of Residence (10-20 year)	-0.82	[0.44]	*	-0.85	[0.44]	*	-0.74	[0.45]		-0.77	[0.45]	*	-0.80	[0.43]	*
Duration of Residence (20-30 year)	-1.04	[0.39]	***	-1.06	[0.39]	***	-1.08	[0.39]	***	-1.09	[0.39]	***	-1.03	[0.39]	***
Duration of Residence (＞30 year)	-0.46	[0.4]		-0.48	[0.4]		-0.41	[0.41]		-0.42	[0.4]		-0.43	[0.4]	
Cons	27.78	[14.71]	*	29.09	[14.33]	**	27.59	[14.37]	*	28.69	[14.12]	**	25.08	[14.18]	*
Observations	201			201			201			201			201		
R Square	0.25			0.25			0.26			0.26			0.22		

Note: *** p<0.01, ** p<0.05, and * p<0.1.

All model estimations are robust.