경제학석사 학위논문

# Sustainable Social Housing and Land Use Policies for Ozone Concentration Abatement

## 유해 오존 저감을 위한 지속가능한 토지 이용 및 공공주택 정책

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지도 교수 Hong Sok(Brian) Kim

이 논문을 경제학석사 학위논문으로 제출함
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부위원장 Hong Sok(Brian) Kim

위 원 박 인 권

# Abstract

# Sustainable Social Housing and Land Use Policies for Ozone Concentration Abatement

Yun Yeong Choi
Major in Regional Information Studies
Dept. of Agricultural Economics and Rural Development
The Graduate School
Seoul National University

The Bogeumjari Social Housing Policy has released a greenbelt and built large social housing units to accommodate the increasing urban population in South Korea. Greenbelts prevent not only leapfrogging but also the further destruction of the environment. Thus, tradeoffs exist in releasing greenbelts for housing growth, which should be examined thoroughly to evaluate its future impact. Using difference–in–differences, this study aims to estimate changes in the ozone concentration after the implementation of the Bogeumjari social housing policies. The ozone concentration of the *gu* districts has increased after the implementation, which can be attributed to the loss of green infrastructure. It can be inferred that the loss of greenbelt due to the Bogeumjari Social Housing Policy increased the ozone concentration and may aggravate regional disparity in air quality. Moreover, an additional empirical analysis on *Bogeumjari* social housings' accessibility to urban infrastructure was conducted to assess its sustainability as a social housing policy. Compared to Haengbok Social Housing Policy, another prominent social housing policy in South Korea, *Bogeumjari* social housings had significantly fewer urban infrastructures in their1km radius. Thus, there is a need to introduce an eco-friendly approach to land use decisions, particularly for social housing constructions in greenbelt areas. Ultimately, improving policies and programs on housing and land use management can address the broader issue of sustainability and urbanization in which inequitable housing and environment are imbedded.

**Keyword:** Greenbelt Policy, Social Housing, Restricted Development Zones, Land Use, Green Growth, Sustainable Development
**Student Number:** 2020-25603

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# Chapter 1. Introduction

Around the world greenbelt and urban containment policies have been created to prevent the ever-increasing problems associated with urban sprawl and the protection of natural capital. The role of such policy is also expected to generate significant social and environmental benefits, including amenity and recreational value, bequest value, and protection of open space, agricultural land, natural resources, and life supporting ecosystem services. However, greenbelts have long been a controversial public policy instrument because of their purported negative consequences, including increased land and housing prices in the urban area contained by the greenbelt, decreased greenbelt land prices, loss or restriction of development rights for greenbelt landowners, increased urban congestion, and other undesirable consequences (Bengston and Youn, 2006).

In some cases, greenbelts have been blamed for increased sprawl and higher commuting costs as development goes beyond the greenbelt. In the case of Korea, urban containment and greenbelt policy were enacted for the purpose of preventing an overly disorderly expansion of cities while preserving the remaining green space for future development and preserving the existing natural environment (Jin, 2001). The greenbelt policy has been seen as a both positive and negative legislation decision.

In 2009, conversion of greenbelts to residential lands became a hot issue in Korea. Equitable access to housing remains as a major challenge in Korea as people are still getting less despite government has already provided much. Access to housing is steered side to side by economics and pressing urban sprawl, favoring those that are more financially able while depriving poor families who are really in need. President Myung-Bak Lee's administration vows to release greenbelts to give way to provide affordable social housing (called *bogeumjari*) in hope that government will level-off the playing field to favor of the low-income homeless families.

Common to every government project, criticisms on a new welfare project (*Bogeumjari* or Bogeumjari Social Housing Policy) have surfaced. Many environmentalists and private realty firms oppose this project recognizing that it will sabotage the environmental projects and private construction businesses. Even though the overall blueprint of the policy was to select a worthless greenbelt area to provide affordable apartments to low-income citizens and alleviate housing shortage problems simultaneously, the Bogeumjari Social Housing Policy (BSHP) was soon condemned by the public for its failure to offer affordable prices for low-income citizens and undesirable environmental consequences from the development. National government however remained rigid in its standby stressing that this direction will reap greater societal benefits.

Could the loss of greenbelts compensate the housing demand for poor population without significantly harming the environment? What are the tradeoffs therefore? This paper aims to answer these important questions by looking at the issues surrounding the policies and programs in social housing and greenbelts. Particularly, it will identify the tradeoffs between greenbelt preservation and social housing by investigating the relationship between the changes of greenbelt area and ozone concentration. To further consolidate the argument, it will compare tradeoffs associated with another social housing policy, called the Haengbok Social Housing Policy (HSHP) to define a sustainable social housing policy. In addition, Difference-in-differences (DID) method is applied to capture the environmental changes and regional disparities from two social housing policies.

# Chapter 2. Literature Review

The greenbelt, also known as the restricted development zone (RDZ), was adopted in 1971 as an urban containment policy that can prevent the maldevelopment and centralization of the Seoul Metropolitan Area (SMA). Since the 1970s, approximately 129.40 $km^2$ of greenbelt was initially allocated and 23.40 $km^2$ was added. However, greenbelts soon experienced extensive release for national urban development projects, and many studies began to investigate the history of greenbelts and their relationship with land use change to suggest directions for future land use decisions. For instance, Choi et al. (2010) found that the greenbelt area decreased from 166.82 $km^2$ to 156.50 $km^2$, urban space increased from 12.55 $km^2$ to 15.50 $km^2$, and green space decreased from 87.45 $km^2$ to 84.50 $km^2$ from 1999 to 2007. Kim and Park (2009) analysed the changes in land use of the released greenbelt area in Namyangju City and demonstrated that the areas that experienced the most changes in land use were greenbelt areas with ongoing social housing projects and district plans.

As mentioned earlier, there are some purported negative consequences of urban containment methods like greenbelt. However, some studies have found that releasing greenbelt can also bring adverse effects to our society. Kim and Kim (2019) reported a drastic decrease in the normalized difference vegetation index (NDVI) and a negative correlation between the NDVI and land surface temperature (LST) from 2007 to 2017 in all Bogeumjari housing districts in Seoul. Jo et al. (2003) estimated that the vegetation coverage in the Jung-gu district can absorb 1830 tons of carbon dioxide and decrease its temperature by 0.6 Celsius in summer. These results align with the recent study of Hong et al. (2021), which examined the social housing development districts in the SMA to analyse the effects of land cover change on summer urban heat island intensity and heat index. The results indicate that urbanization increases both the urban heat island intensity and heat index.

Meanwhile, fluctuating land, housing and greenbelt prices, conflicts on property rights, and others have long been recognized as associated costs of building social housing in greenbelt areas. On top of such criticisms, social exclusion has recently been introduced as a common tradeoff of social housing, which is yet to be completely resolved. Ha and Seo (2006) conducted a field-based survey on residents of public and non-public housing communities, which revealed a causal relationship between residential satisfaction and social exclusion. It was found that discrimination of residential areas directly influenced the satisfaction of public housing residents and low-income residents who are residing in the non-public housing neighbourhoods. Nevertheless, the social exclusion of social housing residents is a serious social phenomenon that can be further aggravated by geographic isolation.

Other studies have adopted different approaches to accentuate the preservation value of greenbelts. Park et al. (2019) assessed the economic value of the potential ecosystem services of urban green facilities in Seoul by quantifying their regulation, supporting, and cultural services. The results indicate that the value of the regulation service provided by urban green spaces and forests in Seoul was about 16.39 billion Korean Won (KRW), the value of the supporting service was about 5.8 billion KRW, and the cultural service value was about 7.78 billion KRW, yielding a total net value of 33.93 billion KRW. Similarly, Kim et al. (2012) evaluated the economic value of forest diversity in South Korea and estimated that the net annual benefit of maintaining forest biodiversity was about 6.5 trillion KRW.

In addition, some studies suggest that a greenbelt policy decision-whether to release or preserve-should be evaluated based on its ability to restrict leapfrogging. Some associated effects of preventing urban sprawl include the reduction of travel time from home to work, pollution mitigation from increased accessibility to public transportation, job opportunities, and so on (Baek 2016). Many researchers have applied this as an indicator to compare the effects of different land-use decisions, especially on greenbelts. For example, Jun (2001) measured the total vehicle kilometres travelled (VKT) and mobile emissions in two different scenarios (with and without greenbelt) and concluded that relaxing greenbelt will increase both commuting distance and air pollutants, which can increase transportation expenses and the risk of exposure to air pollution. Moreover, Kim (2007) also reported that releasing greenbelts for development increased traffic congestion and associated travel. Some recent studies include Lee (2018), who argued that preserved greenbelts produce a positive outcome in terms of population and job opportunities.

Overall, greenbelts have had a long history of use as a tool to control urban sprawl. Particularly, greenbelt policy in Korea has traditionally been created in order to fulfil number of other primary goals such as prevention of an over-concentration of the population in large urban centers, control of rampant land speculation and the protection of the natural environment. Based on the literature review, building social housings in greenbelt may offset environmental benefits provided by greenbelts. As a whole, destruction of greenbelt for housing growth takes away ecosystem services provided by trees and forests, which may lead to increased land surface temperature and greenhouse gases in the atmosphere. This adversely affect not only the whole country but also residents living in the area. Besides, individuals living in social housings on greenbelt are geographically isolated from others. Thus, they may experience more social exclusion and inconvenience from lack of urban infrastructure, especially public transportations. Therefore, many factors and perspectives are involved in making land use decisions on greenbelt and tradeoffs between greenbelt preservation and social housing is an important problem that needs to be addressed for South Korea’s sustainability.

# Chapter 3. Research Design

## 3.1. Research Objective

Land use and land use change can exert an impact on air quality in many ways. For instance, land use change for urbanization can increase air pollution level. In order to achieve economic development and accommodate explosive population, many countries promoted urbanization by building more factories, housings, buildings, recreational facilities and infrastructure for transportation. However, building these facilities can be challenging sometimes, especially for countries suffering from land shortage like South Korea. Therefore, massive land use change in exchange of urbanization was inevitable and existing land originally allocated for natural protection or other non-urban purposes were released for urbanization. Such decision eased the process of changing land use and not much follow-up measures were considered before its execution. Consequently, trees and vegetations were removed indiscreetly while large-scale constructions were emitting harmful chemicals and pollutants in the air.

Nevertheless, expansion of demographic and spatial urbanization through industrialization is one of the major sources of increased air pollution. This leads to the fact that people who live in urban regions are exposed to air pollution levels exceeding the WHO (World Health Organization) guidelines (Goossens et al., 2021). Besides, spatial urbanization can increase land surface temperature. In other words, it can expose people to extreme heatwaves. For example, Civerolo et al. (2007) suggested that extensive urban growth in the NYC metropolitan area has the potential to increase afternoon near-surface temperatures by more than 0.6 ° C, across the NYC metropolitan area, with the areal extent of all these changes generally coinciding with the area of increased urbanization.

As mentioned earlier in the literature review, the reduction of green infrastructure is critical to air quality because trees and vegetation can lower greenhouse gases (GHG) concentration and heat intensity. For example, trees play indirect role in protecting humans from air pollution by purifying harmful gases, but they also play direct roles such as physically protecting human skin from exposure to highly concentrated ozone and sunlight. Thus, trees and green canopies can protect us from not only greenhouse gases but also harmful ozone. Particularly, ozone is important because ozone is identified as one of the six air pollutants to measure air quality in South Korea and is highly associated with sunlight. Therefore, a reduction of green infrastructures after land use change for urbanization make us especially more vulnerable to harmful ozone.

While other ambient air pollutants such as particulate matter (PM) and nitrogen dioxide ($NO_2$) showed decreasing trends in mean annual concentrations worldwide, ozone concentrations have not declined in most countries (Kim et al., 2020). Similarly, annual ozone ($O_3$) concentration level is increasing in South Korea while trees that can mitigate its detrimental effect are decreasing. That being the case, issues associated with $O_3$ must be addressed and further destruction should be dissuaded.

Another reason why this study chooses to observe ozone as an environmental indicator of a social housing policy is because of its short and long-term health effect. For instance, short-term exposure to high concentrations of ozone has been associated with increased mortality and cardiovascular and respiratory morbidity internationally (Kim et al., 2020; Turner et al., 2016). Acute exposure or short-term exposure to ozone leads to acute disruption of the airway epithelium with desquamation of epithelial cells and leakage due to disrupted tight junctions.

Furthermore, chronic ozone exposure or long-term ozone exposure induces similar problems as acute exposure but is amplified (Goossens et al., 2021). The effects of long-term chronic exposure to $O_3$ are yet to be completely uncovered;

however, recent studies suggest that past ambient ozone levels are sufficient to cause premature aging of the lungs (Lippmann, 1989).

Altogether, $O_3$ can adversely affect human health by causing irritation on the ocular mucosa and respiratory system, which leads to higher risk of respiratory diseases and premature skin aging (Willey et al., 2004; Heal et al., 2013; Morales et al., 2014). Specifically, it is already known that being exposed to even a small amount of ozone, can cause an asthma exacerbation and further worsening of the symptoms of respiratory diseases, with even an increase in mortality (Liu et al., 2019). As a result, depending on the dose and the frequency, ozone is known to cause bronchial inflammation and airway hyper-responsiveness via oxidative injury and inflammation (Kim et al., 2020; Goossens et al., 2021).

Besides, some other generally known negative effects of ozone include the following. First, excessive $O_3$ can deteriorate leaves and fruits. This can ultimately generate negative consequence on ecosystems by increasing susceptibility of crops to diseases (Krupa et al., 2001; Morales et al., 2014). In addition, $O_3$ can deteriorate materials and accelerates the corrosion of metallic surfaces, which can lead to various losses (Conway, 2003; Morales et al., 2014).

Therefore, land use changes and pollutant emission changes can exert significant impacts on air quality, regional climate, and human health (Civerolo, 2007). Hence, we need to develop a more complete understanding on the potential effects and consequences of ozone pollution because: 1) the national average of ozone concentration is increasing in South Korea; 2) ozone is a secondary pollutant that its effects are greatly potentiated by the presence of other environmental variables; 3) the short and long-term health effects of ozone are associated with mortality rates. Thus, this study particularly examines $O_3$ to propose a way forward for sustainable development. By observing $O_3$' s relationship with other variables, this study aims to reconfirm an association between vegetation and $O_3$ and reveal how urbanization that deplete green vegetation affect $O_3$ level in the metropolitan city. Furthermore, this study is meaningful since studies in Korea have neither observed ozone’ s association with housing development nor used ozone to measure a housing policy impact to evaluate a housing policy’ s sustainability. Ultimately, it aims to pave ways forward to mitigate ozone while pursuing urban growth and identify methods that can environmentally and socioeconomically sustain us.

## 3.2. Research Area

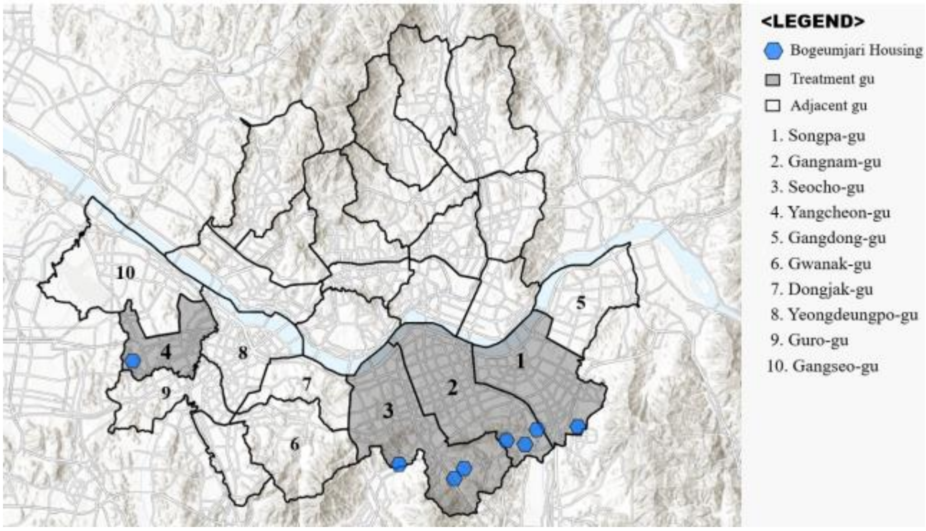


**Figure 1** Visualized map of BSHP Sites

The study areas are *gus* in Seoul that are directly subjected to the policy and *gus* in Seoul that are adjacent to subjected *gus*. First of all, subjected *gus* are defined as treatment group. *Gus* that are adjacent to the subjected *gus* are defined as control group and denoted as adjacent *gus* in this study. Adjacent *gus* are *gus* that share the administrative boundary with the subjected *gu* and its *Bogeumjari* housings in 3km distance. *Gus* that neither have Bogeumjari housings nor adjacent to treatment group are removed from the analysis. As a result, it analysed a total of 10 *gus*, all located in the southern part of Seoul.

Since greenbelts are mainly located at the periphery for natural connectivity -aloof from dense metropolitan area, their location enabled utilization of large amount of land for *Boguemjari* housing complexes. Thus, constructions took in massive scale and each *Bogeumjari* housing has multiple complexes. As a result, most *Bogeumjari* social housings share the feature of large complex size, which is large enough in both numbers sizes to justify that these housings can represent a single *gu* district as a whole. Information on apartment name, location, move-in date, and the total number of residential units of all *Bogeumjari* housings were collected from the Seoul Housing and Communities Corporation website, and information on those that were selected for this study can be found in Table 1 and Figure 1.

**Table 1** Research Design

| Category | Bogeumjari Housings |
|---|---|
| Treatment gu district (4) | Gangnam, Seocho, Songpa, Yangcheon |
| Adjacent gu district (6) | Dongjak, Gangdong, Gangseo, Guro, Gwanak, Yeongdeongpo |
| Earliest Move-in | 2011.06 |
| Move-in Period | 2011.06 -2015.09 |
| Observation Period | 2008.01-2019.12 |

## 3.3. Data

To capture the association of social housing policies with ongoing environmental issues in Korea, this study observed the monthly ozone concentration ($O_3$) as the key variable. The average difference in $O_3$ levels of treated and adjacent *gus* before and after the earliest residential move-ins was measured, with the speculation that disparities may exist in ozone concentration levels across provinces, cities, and towns. In estimating the policy effect, the data set is composed of environmental, geographic, meteorological and socioeconomic variables from 2008 to 2019. To control various factors that may deter accurate estimation of change in ozone concentration with respect to change in the number of social housing sites, the following variables are considered: monthly data of $PM_{10}$, $NO_2$, $SO_2$, CO; average precipitation; average temperature; proportion of forest area and greenbelt area; open green zone area; green buffer zone area; population density; and private car usage rate.

Most of the data were collected from national government institutions except for private car usage rate. Private car usage rate was collected from Seoul Survey, which surveys twenty thousand households on their perspectives on various factors related to their living. Private car usage rate was collected from a survey on methods of commuting. It indicates a percentage of people who use on-foot, bicycle, subway, bus, private car and etc to commute to work or school in each *gu*. There may exist a limitation from the innate nature of a survey that it cannot completely represent the whole population. However, due to data acquisition issue, this study selected 'private car usage rate' under the supposition that it is a valid national survey and can produce better outcome than other available transportation variables. Table 2 summarizes the variables used in the analysis and their corresponding sources.

Table 2 List of Variables

| Name | Description | Source |
|---|---|---|
| Dependent Variable | | Clean Air Korea |
| $O_3$ | ln (Monthly Average $O_3$) | |
| Independent Variable | | Seoul Housing and Communities Corporation |
| $D_g$ | Treatment Group=1<br>Control Group=0 | |
| $T_t$ | After move-in=1<br>Before move-in=0 | |
| $D_gT_t$ | Treatment group after move-in=1<br>Otherwise=0 | |
| Control Variable | | Clean Air Korea |
| *Air Pollutants* | | |
| $PM_{10}$ | ln (Monthly Average $PM_{10}$) | |
| $NO_2$ | ln (Monthly Average $NO_2$) | |
| $SO_2$ | ln (Monthly Average $SO_2$) | |
| CO | ln (Monthly Average CO) | |

| | | |
|---|---|---|
| *Green Infrastructure* | | Seoul City Department of Landscape and Architecture |
| GB proportion | ln (Annual Greenbelt Area / District Area) | |
| Forest Proportion | ln (Annual Forest area / District Area) | |
| Open Green Area | ln (Annual Open Green Area) | |
| Green Buffer Area | ln (Annual Green Buffer Area) | |
| *Climate* | | Korea Meteorological Administration |
| Temperature | Monthly Average Temperature | |
| Precipitation | ln (Monthly Average Precipitation) | |
| *Socioeconomic* | | Ministry of Interior Safety |
| Population Density | ln (Monthly Population Density) | |
| Private Car Usage Rate | ln (Annual Percentage of Private Car Usage) | Seoul Survey |
| Other | | Seoul Housing and Communities Corporation |
| Number of total residential units | ln (Number of Total Housing Units) | |

# Chapter 4. Analytical Methods

## 4.1. Difference-in-Differences

### 4.1.1. Difference-in-Differences

The Differences-in-Differences (DID) is used to verify the impact of an intervention by comparing the average change over time of the treatment group with that of the control group. In other words, DID investigates whether an intervention influences an outcome over time by comparing the observed differences in a sample that receives the intervention with a sample that does not (Heckert and Mennis, 2012). Ultimately, it estimates the change in the value of the applied variables before and after a policy to examine whether a difference in the two subgroups can be found. It is useful because it can isolate treatment effects above and beyond any difference, regardless of the treatment and control influences from time-invariant factors (Meyer, 1995). Moreover, it provides a more direct measure of the added value that is attributable to social housing construction than that provided by other methodologies, such as the hedonic price model.

### 4.1.2 Research Model and Methodology

While most studies on social housing and housing prices use a single hedonic modelling, this study uses the DID model which considers hedonic regression. This study is interested in determining whether there is a difference in ozone concentration levels from social housing constructions in the greenbelt area between the pre- and post-implementation periods. Acknowledging the limitations of single modelling in controlling various factors that may influence ozone concentration, this study used the design and formula below (Ko and Lee 2017) (Table 3, Table 4).

$$\ln(O_{3gt}) = \alpha_0 + \alpha_1 D_g + \alpha_2 T_t + \alpha_3 (D_g \times T_t) + \sum_{p=1}^{n} (\beta_{p,gt} lnX_{p,gt}) + e_{gt} \quad (1)$$

**Table 3** DID Design and estimated values

| | Before Move-in | After Move-in |
|---|---|---|
| Control Group (Adjacent) | a(=$\alpha_0$) | c(=$\alpha_0$+ $\alpha_2$) |
| Treatment Group (Treatment) | b(=$\alpha_0$+ $\alpha_1$) | d(=$\alpha_0$+ $\alpha_1$+ $\alpha_2$+ $\alpha_3$) |

**Table 4** Interpretations on estimated coefficients

| Description | Simplified formula | Coefficient |
|---|---|---|
| Difference in $O_3$ between treatment gus and adjacent gus before move-in | b-a | $\alpha_1$ |
| Difference in $O_3$ between treatment gus and adjacent gus after each move-in | d-c | $\alpha_1$ + $\alpha_3$ |
| Difference in $O_3$ between after each move-in and before move-in of treatment gus | d-b | $\alpha_2$ + $\alpha_3$ |
| Difference in $O_3$ between after each move-in and before move-in of adjacent gus | c-a | $\alpha_2$ |
| Double Difference in 'average change in $O_3$ between before and after of treatment gus' and 'average change in $O_3$ between before and after of adjacent gus' | (d-b)-(c-a) | $\alpha_3$ |

$\ln(O_{3gt})$ is the natural log of the average ozone concentration level in *gu* at time t. $D_g$ is a dummy variable that indicates information regarding the treatment *gu*. The treated and adjacent *gus* are denoted as $D_g=1$ and $D_g=0$, respectively. $T_t$ is a time dummy that indicates information regarding the time point. After the move-in is denoted by $T_t=1$, whereas before the move-in is denoted by $T_t=0$. $D_g \times T_t$ refers to the product of $D_g$ and $T_t$, an interaction term and a key element of this study. Therefore, $D_g \times T_t=1$ represents the case of treatment *gu* after the earliest move-in. Hence, $\alpha_3$ explains the average treatment effect, which describes the double difference, and indicates the significant effect of policy implementation on the dependent variable. In terms of other coefficients, $\alpha_0$ denotes a constant, $\alpha_1$ controls various inherent traits of each *gu*, while $\alpha_2$ controls the parallel trend that occurs based on time regardless of policy implementation. Finally, $\beta_{(p,gt)}$ is a regression coefficient of $X_{p,gt}$, which stands for a set of control variables in relation to the ozone concentration, and $e_{gt}$ refers to the error term (Ko and Lee, 2017; Votsis and Perrels, 2016).

### 4.1.3 Relevant Tests

This study used a panel data to estimate the environmental impact of BSHP across *gus* in Seoul. The panel data in this study is a data set that contains observation about selected *gus* from 2008 to 2019. Thus, the Wooldridge test was done to test the autocorrelation in the panel data. The null hypothesis of this test indicates no first-order autocorrelation and $P > 0.05$ is the probability that the null hypothesis is true. According to the test, the p-value was 0.0507, which confirms the nonexistence of first-order autocorrelation.

Overall, the Wooldridge test for autocorrelation in panel data indicated no first-order autocorrelation but the small p-value may question the validity of the analysis result. Therefore, this study decided to apply an alternative calculation for the standard error to correct potential heteroskedasticity. Formally known as the Huber/White/sandwich estimator, vce (robust) command was applied, which ultimately made the variance-covariance matrix of the estimators robust to heteroskedasticity of the errors. In addition, such application enhanced the overall result of the analysis.

## 4.2 Assumption and Solution

### 4.2.1. Parallel Trend Assumption

DID is a flexible method that can capture a causal effect from observational data if few basic assumptions are met. The parallel trend assumption is the most critical among them and hardest to fulfil. It states that the trends in outcomes between the treatment group and control group are the same prior to the intervention. In addition, it requires that the difference between the treatment group and control group is constant over time in the absence of treatment. In other words, parallel trend assumption is met and DID can be effective if ozone concentration trends of treatment *gus* and control *gus* are the same when BSHP is not implemented. Furthermore, DID procedures with multiple intervention periods and multiple groups rely on different types of parallel trend assumptions but no statistical test exists. Thus, this study chose to analyse the ozone concentration level of all treatment and control *gus* before and after 2011 to 2015. To do so, a visual inspection on the monthly ozone concentration levels of Gangnam-gu, Songpa-gu, Seocho-gu, Yangcheon-gu, Gangdong-gu, Gangseo-gu, Gwanak-gu, Guro-gu, Dongjak-gu and Yeongdeungpo-gu was deemed most appropriate. Therefore, the monthly ozone concentration data of 10 *gus* from 2008 to 2019 is converted into a graph as below (Figure 2).

Since ozone concentration itself is a small decimal number, this study chose to analyse its trend by visualization instead of a numerical comparison on average monthly ozone concentration from 2008 to 2019 or on average annual concentration between observed *gus*. Based on Figure 2, every *gu* showed a similar annual ozone concentration trend. Slight monthly variation existed between *gus* and between years but monthly ozone concentration was generally the highest in the summer time (May-July). Not much prominent variation could be found in annual ozone concentration trend; thus, a parallel trend in the ozone concentration of all *gus* can be assumed.

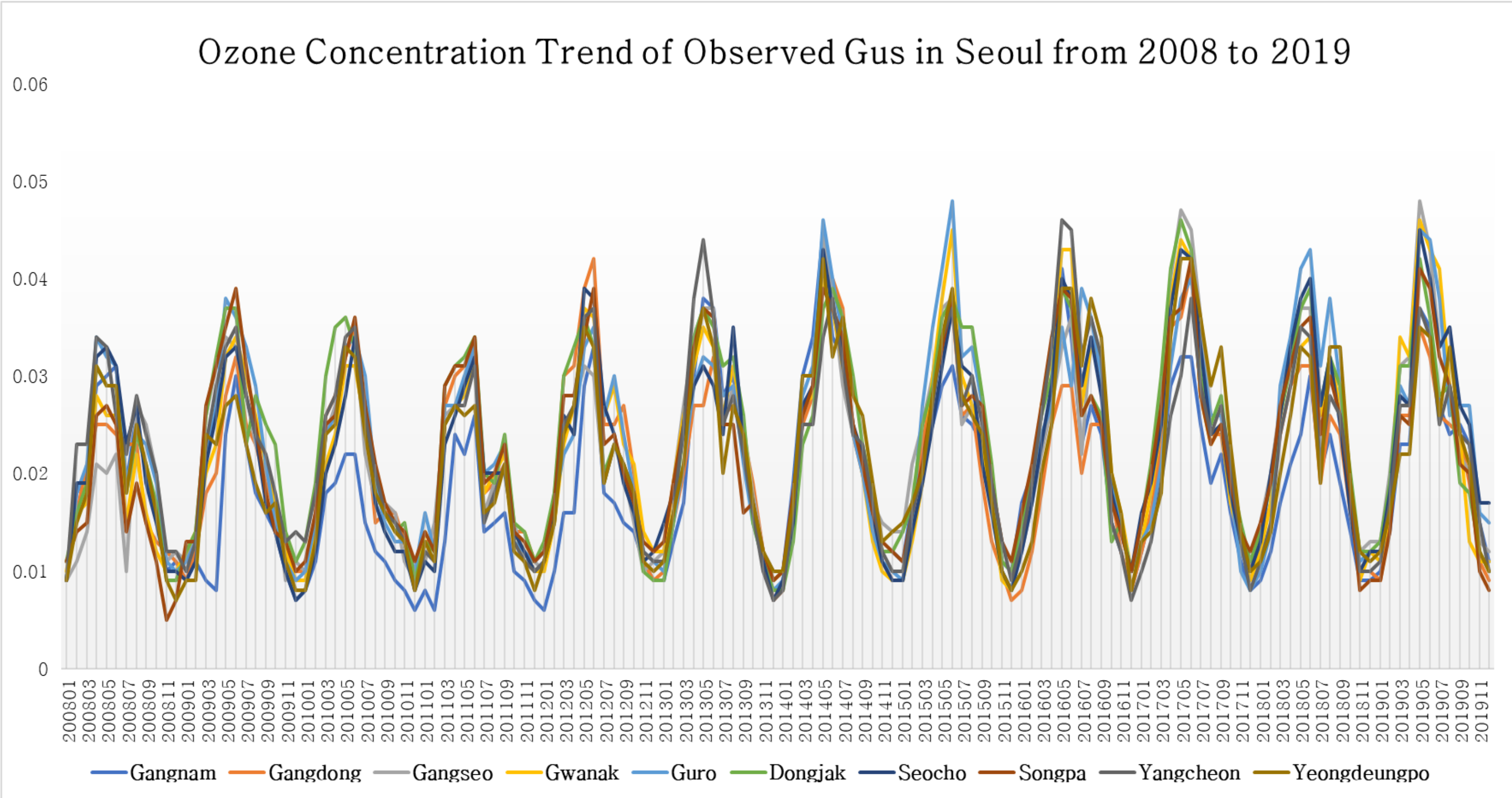


**Figure 2** Ozone Concentration Trend of Observed Gus in Seoul from 2008 to 2019

### 4.2.2. Solution

In order to address the limitation of using simple DID to capture multiple time interventions, total residential units per apartment was used as a control variable. When multiple social housings are built at different time points in the same treatment *gu*, binary property of $T_t$ impedes indication of numeric differentiation after each move-ins. This study observes all *Bogeumjari* housings in Seoul that had their earliest move-ins from 2011 to 2017, but their move-in date can only be expressed as 0 or 1. Since multiple additions of *Bogeumjari* housings imply more implementations in a *gu* and stronger influence of policy, a *gu* that experienced consecutive addition of housing throughout the years should be differentiated from a *gu* district that experienced a single move-in. Hence, number of total residential units was collected for *Bogeumjari* housings and a total residential unit in a treatment *gu* was calculated by accumulation of residential units per apartment based on move-in dates. Thus, the addition of housing is indicated by the accumulation of residential units, which ultimately explains the policy magnitude change over time in each *gu* district. Moreover, residential units also enable a distinction between the treatment and adjacent *gu* at the same time point because adjacent *gu* does not have residential units.

In summary, this study used DID hedonic regression controlled by total number of residential units instead of extended DID. Identifying different time shocks while being short on data is a difficult issue for DID methodology (Votsis and Perrels, 2016). Limitations are evident that collected data set are not highly sensitive because *gu* is a big administrative unit. However, DID hedonic regression was deemed more appropriate for this study and potential limitation of such decision was addressed by a control variable, each *gu*' s total number of residential units which can explain different time interventions and housing magnitude.

# Chapter 5. Result

## 5.1. Result

This study investigated the impact of housing growth on ozone concentration in the context of BHSP. Table 5 below shows the results.

**Table 5** BSHP Analysis Result

| Dependent variable: $O_3$ | |
|---|---|
| Variable | Coef. (St. Err.) |
| $D_g$ | −0.065 (0.040) |
| $T_t$ | 0.088 (0.022) *** |
| $D_g$ $T_t$ | 0.130 (0.070) ** |
| Number of units (UNITS) | −0.009 (0.007) |
| $PM_{10}$ concentration ($PM_{10}$) | 0.731 (0.031) *** |
| $NO_2$ concentration ($NO_2$) | −0.338 (0.046) *** |
| $SO_2$ concentration ($SO_2$) | 0.0339 (0.029) |
| CO concentration (CO) | −0.385 (0.040) *** |
| Forest proportion (FP) | −0.034 (0.011) *** |
| Greenbelt proportion (GP) | −0.257 (0.144) * |
| Open green area (OGA) | 0.084 (0.025) *** |
| Green buffer area (GBA) | −0.034 (0.018) * |
| Temperature (TEMP) | 0.036 (0.001) *** |
| Precipitation (PRECIP) | −0.023 (0.009) *** |
| Population Density (POP_DEN) | 0.052 (0.060) |
| Private car usage rate (PRIVATE_CAR) | 0.063 (0.036) * |
| Constant | −9.555 (0.714) *** |
| Number of obs | 1440 |
| Adj. $R^2$ | 0.65 |

Notes: ***$p<.001$; **$p<.01$ *$p<.01$

The results imply that the average ozone concentrations in Gangnam-gu, Seocho-gu, Songpa-gu, and Yangcheon-gu districts increased after all move-ins compared with those of the adjacent *gus*. Specifically, in the case of BSHP, $D_g$ is negative, which means that the ozone concentration of adjacent *gus* was higher than that of treatment *gus* before residential move-ins. The positive coefficient of $T_t$ can be interpreted as the ozone concentration of the adjacent *gus* increased after the move-ins took place. The positive coefficient of $D_gT_t$ with 0.130 indicates double difference before and after ozone concentration between the treatment *gus* and the adjacent *gus*. Therefore, the positive value implies that treatment group's increase in ozone concentration after all move-ins was higher than the control group's increase in ozone concentration after all move-ins. Altogether, the implementation of BSHP increased the overall ozone concentration of both treatment *gus* and adjacent *gus* but treatment *gus* experienced higher increase in ozone concentration. A detailed interpretation is presented in Table 6.

**Table 6** Interpretation Summary

| Coefficient interpretation | | Result interpretation | |
|---|---|---|---|
| Coef. | Definition | Coef.Sign | Result |
| $\alpha_1$ | (Before move-ins)<br>T -A | - | T<A |
| $\alpha_1 + \alpha_3$ | (After move-ins)<br>T-A | + | T>A |
| $\alpha_2 + \alpha_3$ | (T)<br>After move-ins-<br>Before move-ins | + | T increased |
| $\alpha_2$ | (A)<br>After move-ins-<br>Before move-ins | +<br>*** | A increased |
| $\alpha_3$ | (Double Difference)<br>Change in T-<br>Change in A | +<br>* | T↑>A↑ |

Notes: T= treatment gus' $O_3$ level, A=adjacent gus' $O_3$ level, upper arrow indicates the degree of increase in $O_3$ level

The result of GP (-0.257) indicates that the proportion of greenbelt has the largest negative effect on $O_3$ among all the geographic and green variables. Since the greenbelt area of Gangnam-gu district decreased from 8 km$^2$ to 6.48 km$^2$ and that of Seocho-gu district decreased from 24.87 km$^2$ to 23.88 km$^2$, this can be further interpreted in that a loss of greenbelts from BSHP influenced higher concentration of $O_3$. In addition, the results of FP and GBA have a negative association with $O_3$. It can be inferred that forest and green buffer areas may partially offset the negative impacts of concentrated ozone. These results align with previous literatures that examined the positive services of forests and importance of preserving its functions within urban areas. According to Park and Yoo (2004) and Song (2006), the forest and green buffer area in a densely urbanized city can prevent pollutions and promote ecological connectivity. Therefore, unsustainable land use can threaten the health of residents and may aggravate regional differences in residential welfare.

The positive coefficients of the OGA seem to contradict with the results in previous studies. The OGA is largely composed of open and street green areas, however an increase in street green zones may imply a simultaneous increase in both streets and street trees. An increase in streets may induce more pollution and heat waves, especially from an increase in car travels. Hong et al. (2018) stated that the extent of air pollution abatement may vary according to the type and structure of vegetation that is planted along the streets. This is because of several factors, such as the idiosyncratic features of different trees, wind speed and direction, and other potential geomorphic interactions. In other words, planting more street trees may not necessarily address all air pollution in the area. Hence, it can be inferred that no clear relationship can be established between open green areas and ozone concentration.

$PM_{10}$ and $SO_2$ exerted a positive influence, whereas $NO_2$ and CO exerted a negative influence on $O_3$. However, only $PM_{10}$, $NO_2$ and CO were found to be statistically significant. Such result may seem to be contradicting existing consensus on a relationship between $O_3$ and $NO_2$. Scientifically, $O_3$ is a secondary pollutant that is formed by interacting with other atmospheric chemical and nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) are two primary pollutants that react in sunlight. In other words, the formation of ozone is promoted by the presence of VOC, NO, $NO_2$ and $NO_x$ (Jacob 1999; Morales 2014; Seinfeld and Pandis, 2012). Based on this previous scientific finding, $NO_2$ and $O_3$ must have positive proportional relationship whereas the analysis result showed a negative association. Hence, more concrete empirical evidence seemed necessary to verify such result.

To confirm the validity of the analysis result, this study examined the National Annual Air Quality Report to compare whether the national trend aligns with the scientific finding that $NO_2$ and $O_3$ have positive association. The report summarizes and provides a visualized graph of annual national trend of $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, $O_3$, CO from 1989 to 2020. According to the 2020 National Annual Air Quality Report by Air Korea, $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, $O_3$, CO displayed different trends from 1989 to 2020. The national annual concentration level of $PM_{10}$, $PM_{2.5}$, $SO_2$ and CO exhibited a steady decreasing trend with a minor variation. On the other hand, $O_3$ was steadily increasing whereas. Besides, $NO_2$ concentration levels were not constant rather somewhat fluctuating until 2014 and gradually decreased afterwards (Figure 3,4,5).

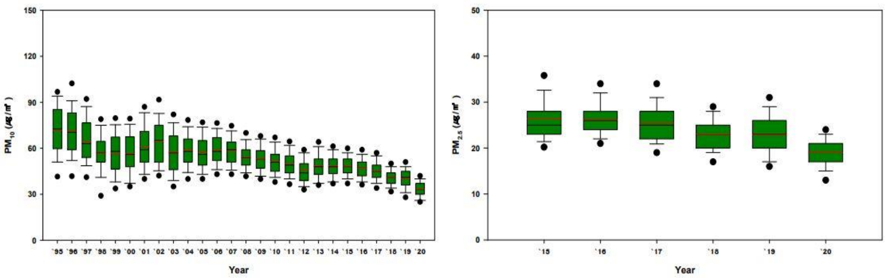


**Figure 3** 1995−2020 $PM_{10}$ Annual Average Concentration (left)
2015−2020 $PM_{2.5}$ Annual Average Concentration (right)

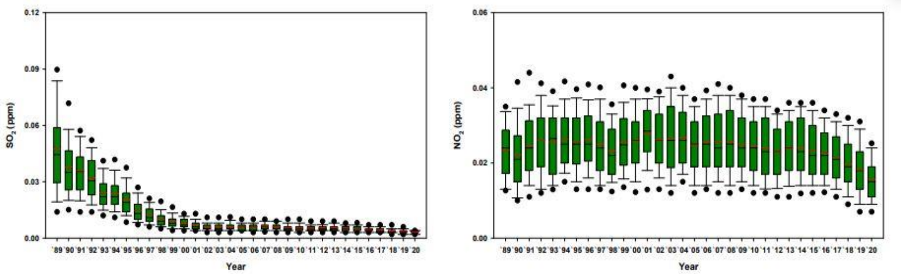


**Figure 4** 1989−2020 $SO_2$ Annual Average Concentration (left)
1989−2020 $NO_2$ Annual Average Concentration (right)

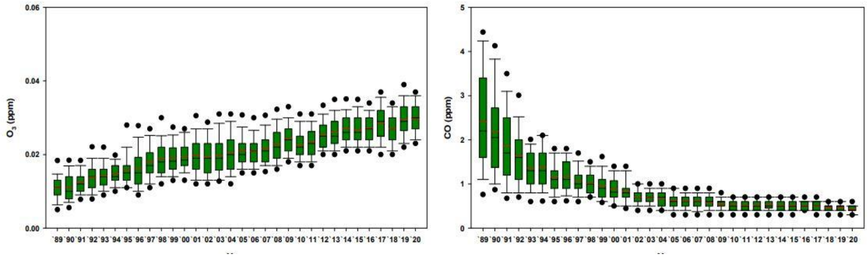

**Figure 5** 1989−2020 $O_3$ Annual Average Concentration (left)
1989−2020 CO Annual Average Concentration (right)

Based on above statistics, it is clear that national $O_3$ concentration level is annually increasing while all other pollutants are gradually decreasing. Therefore, this can explain the strong negative coefficient of $NO_2$ in association with $O_3$. But it should be acknowledged that more research on why actual values of measured $O_3$ and $NO_2$ show contrasting behaviour is needed, which can later assist in devising a more fitting strategy for air pollution mitigation. Overall, the negative association between $O_3$ and $NO_2$ was a valid result and an accurate representation of South Korea's current air pollutants trend.

For a more precise comparison, this study took an additional step to compare whether observed *gus* also exhibited similar air pollutants trend to that of South Korea. Since the statistics provided by Air Korea were national average values, it cannot be assumed that all observed *gus* from this study have the same trend. Therefore, this study chose treatment *gus* (Gangnam-gu, Yangcheon-gu, Seocho-gu and Songpa-gu) and graphed each *gu*'s $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, $O_3$, CO concentration level during their observation period (2008-2019) to check whether they align with the general national trends.

Likewise, while annual average $O_3$ concentration levels of all four *gus* are increasing, annual $PM_{10}$, $SO_2$, $NO_2$ and CO concentration levels are decreasing in all *gus* on average. However, $PM_{10}$ of treatment *gus* increased from 2012-2016 and those of $SO_2$ started decreasing from 2014 (Figure 6-10). Though the national $PM_{10}$ and $SO_2$ level was decreasing, those of treatment *gus* showed a slightly different behaviour. More interestingly, this is a time frame when move-ins took place. Perhaps, the temporary regional divergence may infer that housing constructions and move-ins can partially affect $PM_{10}$ and $SO_2$ level. Thus, even though the overall average concentration levels are decreasing, a positive association is formed between $O_3$ and $PM_{10}$ and between $O_3$ and $SO_2$. Moreover, a number of small fluctuations can be found in $SO_2$ values, and this may explain why the coefficient value of $SO_2$ is not statistically significant. Lastly, $NO_2$ and CO have more prominent decreasing trends and annual variations are not as big as other air pollutants; hence, their association with $O_3$ came out to be negative and statistically significant.

Though it should be acknowledged that a single set of numerical data and statistical analysis cannot perfectly represent laws and formulas established in the scientific world, it is clear that both nationally and regionally $O_3$ is increasing while $NO_2$ is decreasing. This does not necessarily mean $O_3$ and $NO_2$ are negatively associated but it is proven that they are showing an opposite trend. Perhaps, further research on identifying potential players involved in such result and understanding complex relationship between air pollutants may later promote simultaneous mitigation of all air pollutants.

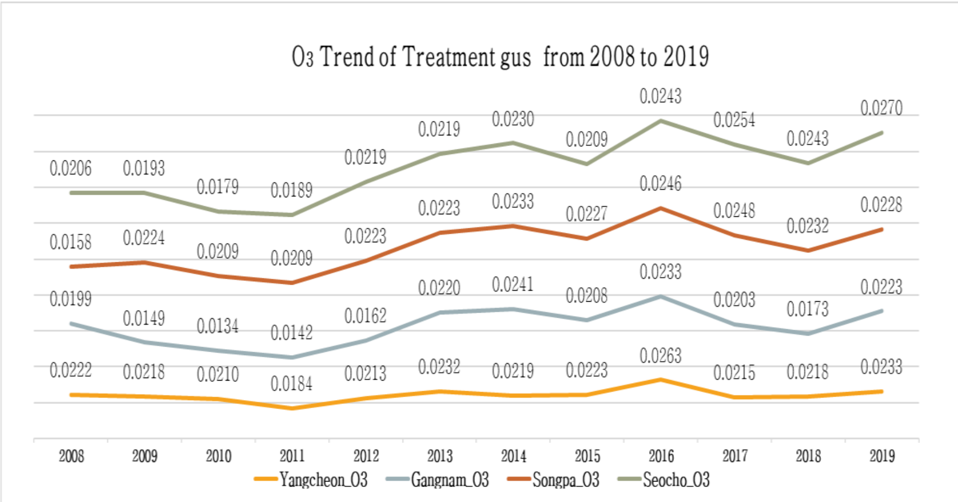


**Figure 6** Annual Average $O_3$ in subjected gus from 2008-2019

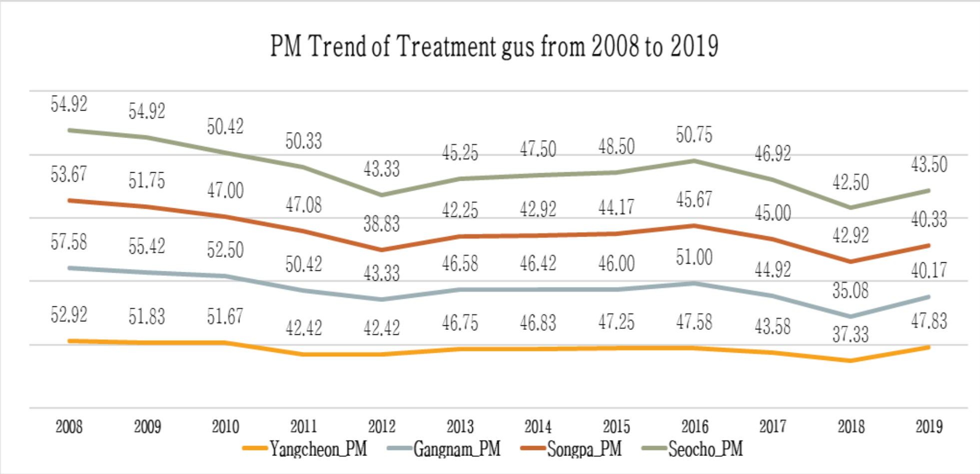


**Figure 7** Annual Average $PM_{10}$ in subjected gus from 2008−2019

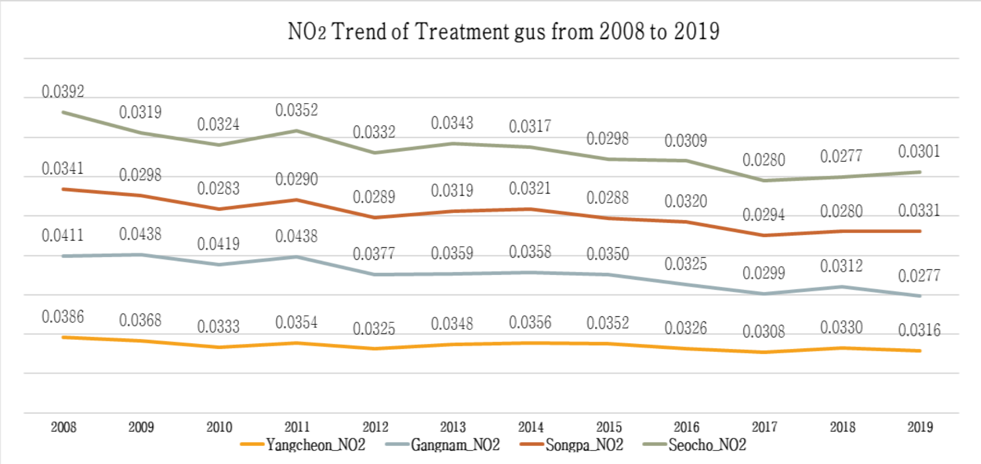


**Figure 8** Annual Average $NO_2$ in subjected gus from 2008−2019

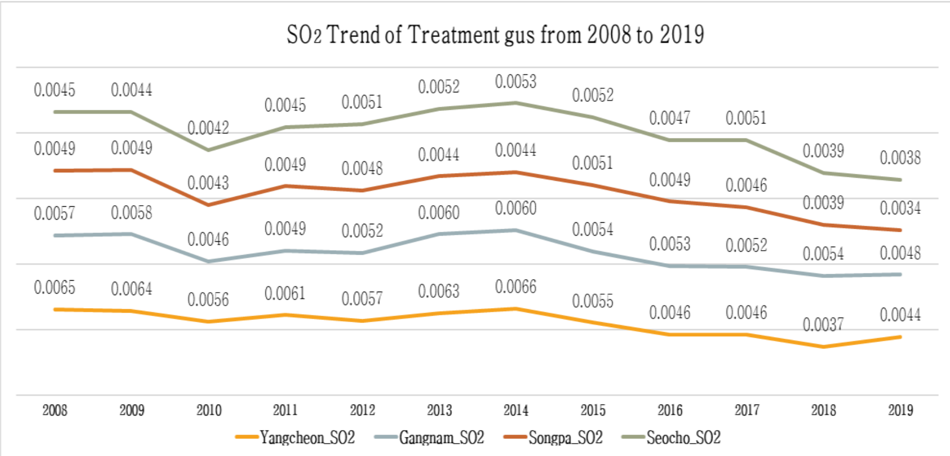


**Figure 9** Annual Average $SO_2$ in subjected gus from 2008−2019

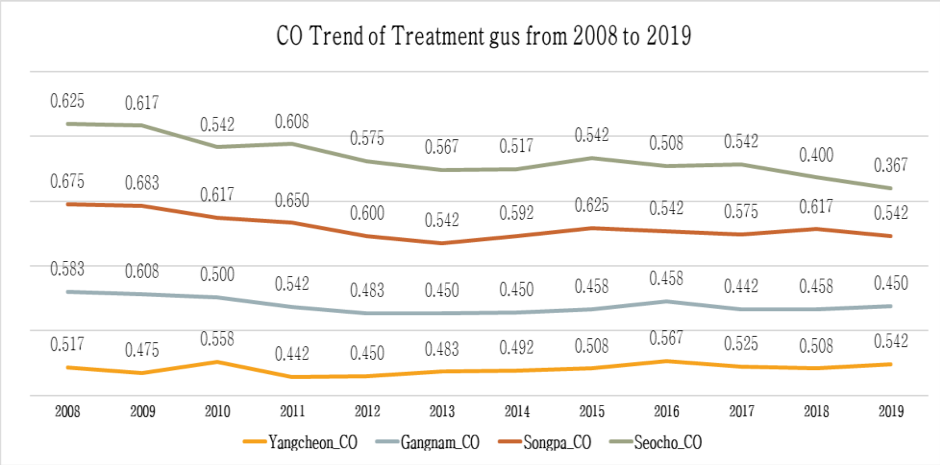


**Figure 10** Annual Average CO in subjected gus from 2008–2019

Moreover, the coefficient of TEMP had a positive value, whereas the coefficient of PRECIP had a negative value. The relationship between $O_3$, air pollution, TEMP and PRECIP is clear and widely accepted these factors can influence the level of $O_3$. Chung and Chung (1991) found that the surface ozone concentration index in SMA were low with decreasing solar radiation and increasing days of cloudiness and precipitation. Ghim (1996) also found that frequent precipitation prevented a further rise in the daily maximum concentration of ozone in July and August.

The result of UNITS has a negative coefficient but statistically insignificant. To overcome the limitation of the binary nature of DID analysis when there was multiple policy implementation in the regions throughout the observation period, number of total residential units per housing was used in the analysis. Hence, the UNIT data are composed of the accumulation of each apartment's residential units in each *gu* district. In other words, these data do not show fluctuations in the number of residents in *Bogeumjari* housing since they do not reflect the actual residents' move-ins and move-outs. Therefore, the number of residential units in treatment *gus* only increase in number throughout the observation period whereas that of the adjacent *gus* remain zero. Since this variable is intended to control multiple policy implementation periods in an extended format of DID, the negative coefficient does not hold significance in establishing a negative association between the UNITS and $O_3$.

Socioeconomic factors produced an outcome that aligned with the study's expectations. The result showed a positive coefficient of POP_DEN, whereas opposite coefficient signs of PRIVATE_CAR. The positive coefficient of PRIVATE_CAR in BSHP is due to increasing in time and distance for commuting that may depends on higher private car usage. This portrays the criticism of the BSHP for building housing that is geographically isolated and aggravates existing social exclusion due to less infrastructures and increasing commuting expenses. Lack of transportation infrastructure encourages use of private car and additional commuting expenses is inevitable. To low-income social housing residents, such additional cost may serve as a heavy financial burden.

Therefore, it suggests that BSHP has increased the ozone concentration level of not only Gangnam-gu, Seocho-gu, Songpa-gu and Yangcheon-gu but also Dongjak–gu, Gangdong–gu, Gangseo–gu, Guro–gu, Gwanak–gu and Yeongdeongpo–gu. However, the magnitude of change in ozone concentration was bigger in Gangnam-gu, Seocho-gu, Songpa-gu and Yangcheon-gu, *gus* directly subjected to BSHP. Consequently, this implies that BSHP did not provide a follow-up measure to prevent air pollution, which ultimately resulted in regional disparity in ozone quality. Perhaps, more in-depth comparison between observed *gus* and *gus* that are neither in treatment group nor in control group may be helpful to accurately evaluate BSHP's contribution to air quality disparity. But it is clear that BSHP has been implemented in an indiscreet manner and it adversely influenced the air quality.

Most importantly, such result can be explained by ozone concentration's negative association with green infrastructure, especially greenbelt and forest proportion. The negative association between greenbelt and ozone concentration is meaningful because greenbelt proportion had significantly decreased due to BSHP and other development purposes and many previous studies have already proven the positive ecosystem services of green infrastructure. In other words, this confirms that BSHP failed to build eco-friendly housing by destroying green space and increasing ozone concentration level. Furthermore, it reconfirms that the greenbelt and forest mitigate air pollution. Green space was lost after release of greenbelt and the adverse environmental effects of losing them are evident in the analysis result.

Moreover, ozone concentration's positive association with private car usage rate also suggests a meaningful implication. *Bogeumjari* housings are located in greenbelt area. Greenbelt areas are depopulated areas that are located far away from the main city; thus, not much urban infrastructure exists. Therefore, it suggests that people who will be living in *Bogeumjari* housings may not be able to enjoy facilities and services needed for living. Among those facilities and services, transportation is one of the biggest factors that may influence one's residential quality. Since transportation infrastructure around *Bogeumjari* housings is lacking, their residents must inevitably have to choose from buying a personal vehicle or traveling longer distance and time. Considering that people who live in *Bogeumjari* housings are citizens of low-income, indirectly forcing them to buy a private car seems unreasonable. Regardless, private car usage for commuting would increase and accordingly to the analysis, increased private car usage would increase ozone concentration level.

Altogether, BSHP destroyed green space and encouraged private car usage to provide affordable housings to low-income citizens. Though the policy would provide cheap housings, it is evident that decrease in greenbelt has led to increase in ozone concentration level in subjected areas. This is because *Bogeumjari* housings were built right on the greenbelt so they are directly under the influence of greenbelt's existence. On the other hand, it is somewhat difficult to conclude that increase in private car usage has contributed to increase in ozone concentration because the data used for private car usage includes all residents living in a *gu,* not just *Bogeumjari* residents. Therefore, an additional analysis is needed to confirm whether BSHP's location has encouraged private car usage rate.

The main objective of this study is to identify tradeoffs of BSHP: greenbelt preservation rand affordable social housings. This study believes that greenbelt preservation brings more benefits, especially environmental benefits. Hence, this study speculates that there are purported environmental costs in releasing greenbelt for social housings. The initial analysis aimed to show benefits of greenbelt preservation by measuring the costs from implementing BHSP, which were increased ozone concentration and regional disparity in air quality. Based on this result, BSHP can only be successful when it serves more benefits as a social housing than what greenbelt preservation can provide. The main purpose of social housing is to protect residential rights of low-income citizens and that of BSHP was to provide inexpensive housing. In other words, *Bogeumjari* housings should be cheap and equitable as a social housing to an extent that no compensation would be needed for their loss in enjoying good air quality. Hence, a second analysis on benefits and costs of social housing is needed for more accurate evaluation.

For more effective evaluation, this study selects another social housing policy called Haengbok Social Housing Policy (HSHP) for a comparison. In order to evaluate BSHP' s residential equitability and affordability as a social housing policy, the next section will first compare and contrast BSHP and HSHP. Then, it will measure each policy' s accessibility to urban infrastructure by analysing average area percentage of different land use zone in the 1km radius of each housing to identify whether equal residential conditions are given to both *Bogeumjari* and *Haengbok* residents. In addition, it will measure the number bus stations and subway stations in the 1km radius to examine whether private car usage was encouraged or not under the assumption that accessibility of public transportation may inversely influence private car usage. Lastly, it will examine the change in average transaction price (ATP) of *Bogeumjari* housings throughout today to evaluate its affordability. At the end, probing into benefits and costs associated with social housing policies will ultimately provide us a need to devise a new paradigm for sustainable social housing and offer a guideline for future land-use decisions, especially on housing development.

## 5.2. Comparison between BSHP and HSHP

### 5.2.1 Haengbok Social Housing Policy (HSHP)

After President Lee finished his term in the office in 2013, President Geun-hye Park suggested a different approach to tackle housing market issue in Korea: Haengbok Social Housing Policy (HSHP). HSHP utilizes public land and small parts of land within the city to improve housing and job proximity; thereby, attracting the youth population to invigorate local economy. This social housing policy was designed to minimize commuting distance and hours of young students and workers by building social housing units near subway or bus stations. The ultimate goal of this policy was to reduce young people's social cost from traffic congestion and financial burden on housing, as well as to vitalize the local economy. HSHP exhibits a different trend from BSHP in that it assigned housing sites on public transit district, redevelopment towns, or existing residential complex. However, several pilot projects of HSHP were opposed by local communities because they were concerned about traffic congestion that may arouse from increased population density. There was a strong opposition for social housing apartments in certain areas because some were concerned about a potential drop in housing prices and a depreciation of the residential environment. For example, Yangcheon-gu's Mok-dong district construction was postponed until 2019 and housing supplies were cut into half in Nowon-gu, Gongreong-dong district. Like every other social housing policy, it can be inferred that HSHP was not welcomed by all interest group.

Despite these criticisms on social housing policies, HSHP is exceptional because it attempts to utilize various types of abandoned land without damaging green areas. Until now, *Haengbok* housings have been built in 22 out of 25 *gu* districts in Seoul. More information on apartment location, apartment name, move-in dates and etc can be found in Appendix 1 (Table A1-A3). The types of housing, scale, size varies across transportation hubs of diverse districts and regions. This was possible because *Haengbok* housings are not built on a greenbelt or any other types of green area. As a result, *Haengbok* housing development sites are widely scattered across Seoul. Furthermore, HSHP was established to bolster the local economy by forming a compact community near transportation hubs. In achieving this objective, *Haengbok* housings do not destroy any preserved green area and their constructions are smaller in size because they are not built on open green fields. In this sense, HSHP can be re-evaluated as it seems to be incorporating environmental social welfare for future residents. Considering that HSHP is still on-going, a thorough comparison between BSHP and HSHP can assess their policy effect and will highlight the necessity of including environmental social welfare as an indicator of successful social housing.

To sum up, the BSHP is one of the first housing policies that enforced the massive release of greenbelts for social housing. On the other hand, HSHP, which was carried out under President Park in 2014, has adopted a different land-use approach to meet the housing needs of low-income citizens. Each social housing policy was implemented during different presidential eras, but their main difference lies in the locational conditions of their sites. Unlike *Bogeumjari* housing, which is located in the greenbelt area of highly urbanized and populated 'Gangnam' area (Southern part of Seoul), *Haengbok* housing is relatively widespread and located at station influence areas, varying in complex size. Hence, *Haengbok* housing is located in almost every single district, but the majority of large housing complexes are concentrated in the Gangbuk area (Northern part of Seoul). Further comparison between BSHP and HSHP can be found in Table 7.

**Table 7** Traits of BSHP and HSHP

| Category | Bogeumjari Housing | Haengbok Housing |
|---|---|---|
| Definition | An affordable housing constructed or purchased by the public funding that are redistributed in forms | An Affordable rental housing in downtown city that provides proximity to work for college students, |

| | | |
|---|---|---|
| | of sale or lease | newlyweds and |
| Objective | Enhancing level of residential stability of working-class | Stabilizing and enhancing residential welfare for the Youth |
| Locational Condition | Greenbelt area of low preservation level | Station districts where transportation is accessible for short commuting distance |
| Qualification of residents | Low-income citizens whose income is below the category of $4^{th}$ quantile | Youth population such as college students, newlyweds (80%) and elderly with Disability (20%) |
| Housing sites in Seoul | Gangnam-gu, Seocho-gu, Yangcheon-gu, Songpa-gu, Guro-gu and Nowon-gu | 22 gu districts out of 25 total gu districts in Seoul |
| Duration of policy implementation | 2012-2018 | 2015-present |

### 5.2.2 Comparing BSHP and HSHP

Haengbok Social Housing Policy (HSHP) aimed to solve such issues from BSHP by conducting a transit-oriented development, which was to build and designate social housings near bus or subway stations. HSHP used a different land use approach from that of BSHP that it utilized small areas around bus stations or subway stations. Thus, comparing these two policies may draw out a meaningful conclusion on whether each location actually affected the infrastructure accessibility level. Moreover, the result from comparison between two disparate social housing policies will enable more accurate evaluation of BSHP. Land use zone around 1 km radius of all *Bogeumjari* and *Haengbok* housings was observed and each land use zone was calculated into percentage to empirically assess average accessibility level of various infrastructure around *Bogeumjari* and *Haengbok* housings in each *gu* district.

Land use zones are largely divided into four zones of different purposes: Residential, Commercial, Industrial and Green. Each land use zone is designated with certain types of buildings that can be built in the area which are mainly differentiated by floor area ratio and building-to-land ratio and their purposes Detailed definition of each land use can be found in Table 8. Here, residential land use zone is the main area of interest, which refers to an area designated to guarantee pleasant residential environment. Residential land use includes areas specifically for apartments, public and cultural assembly, grocery stores, elementary school, middle school, high school, medical facilities and etc.

**Table 8** Types of land use zone

| Type | Classification | Description |
|---|---|---|
| Residential | Type 1 Residential Only-Area | Areas designated to guarantee good residential environment for individual houses |
| | Type 2 Residential Only-Area | Areas designated to guarantee good residential environment for town houses |
| | Type 1 Residential Area | Areas designated to provide convenient residential environment around low-floor houses |
| | Type 2 Residential Area | Areas designated to provide convenient residential environment for mid-floor housings |
| | Type 3 Residential Area | Areas designated to provide convenient residential environment for high-floor housings |

| | | |
|---|---|---|
| | Semi-Residential Area | Areas designated to commercially support various residential services |
| Industrial | Industrial Only-Area | Areas to accommodate chemical industries, light industries and other types of industry |
| | Industrial Area | Areas needed for locational arrangement for industries that do not produce hazardous waste |
| | Semi-Industrial Area | Areas that can accommodate light industries but can also support residential and commercial services |
| Commercial | | Areas designated for various commercial purposes which includes educational, medical, sports, office, recreational, religious assembly, apartment housing, storage facilities and services |
| Green | | Areas designated for<br>1) environmental protection,<br>2) agricultural production,<br>3) prevention of urban sprawl,<br>4) limited development |

According to the analysis, *Haengbok* housings overall have more accessibility to infrastructure needed for living (Figure 11). On average, *Haengbok* housings showed higher percentage of land use zone for residential purposes in each *gu* district. The average percentage of residential-use land of all *Bogeumjari* housings was 33.52% whereas that of Haengbok housings was 65.6%. Particularly, the biggest difference in areas for residential purposes could be found between *Bogeumjari* housings and *Haengbok* housings in Seocho-gu and Gangnam-gu, two of the most urbanized *gu* districts in Seoul.

Moreover, the average percentages of commercial-use land around *Bogeumjari* and *Haengbok* housings were 1.75% and 4.77% respectively. Considering this type of land are designated for store buildings, office buildings and facilities that provide various types of services, residents of Haengbok housings clearly have more access to infrastructures and related services. Though *Bogeumjari* residents get to enjoy more green space, their basic needs for living are lacking compared to those living in *Haengbok* housings.

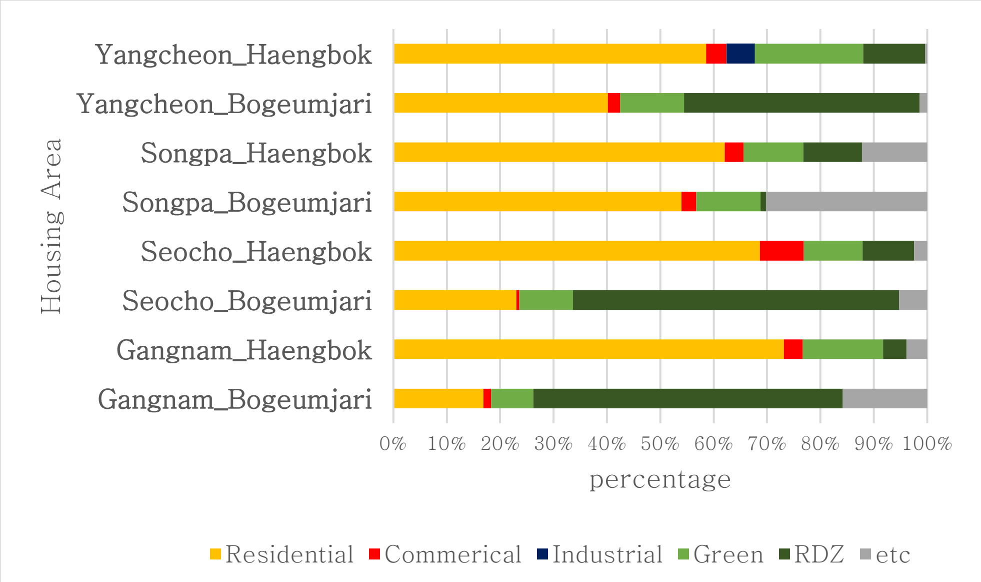


**Figure 11** Average Percentage of Land Use Zone Area near Bogeumjari and Haengbok housings

Furthermore, average number of bus stations and subway stations in the radius of 1km was calculated based on 2019 data from Seoul Open Data Plaza and Korea Transport Database (KTDB). On average, there was 0 (0.11) subway stations and 37(37.19) bus stations per a *Bogeumjari* housing per a *gu* district whereas there were 2.46 subway stations and 59 (59.305) bus stations per a *Haengbok* housing per a *gu* district. Figure 12 juxtaposes the number of bus stations per gu district for each policy. HSHP targeted the younger population including college students and newlyweds and public transit availability would lift their financial burden from commuting distance and associated expenses. On the other hand, BSHP targeted low-income population but took away their access to public transportation. All residents have a right to enjoy pleasant residential environment and such rights can be heavily restricted by wanting road infrastructures and public transportation. To *Bogeumjari* residents, whom are mainly composed of people who cannot financially afford themselves, restrictions on mobility may be a crucial defect. Hence, BSHP failed to not fulfil the needs of its target population but also provide equitable and sustainable housings to all residents.

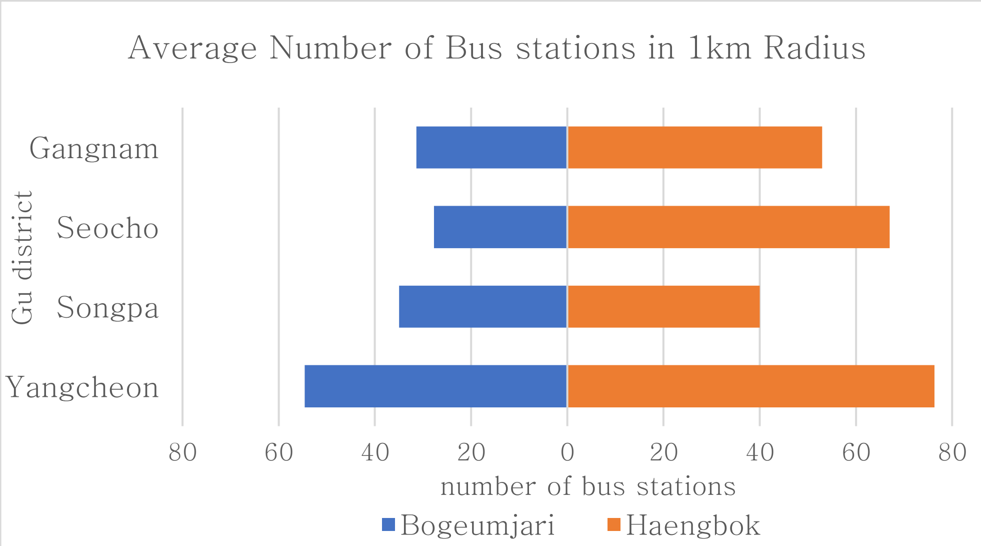


**Figure 12** Bogeumjari and Haengbok housings' accessibility to public transit

Besides, BSHP also failed to meet its initial objective to provide affordable housings to increase housing ownership of low-income citizens. On a similar note, the National Assembly Budget Office evaluated that BSHP failed to meet its initial objective because its candidate nomination was not consistent with its original target population (NABO, 2012). Since its challenging to accurately measure each individual resident' s income level and housing ownership rate may not necessarily represent the housing ownership of low-income citizens, this study examined the overall actual transaction price (ATP) of all *Bogeumjari* housings used in the analysis. An increasing trend of ATP was detected in all four gus. Specifically, average ATP of *Bogeumjari* housings in Seocho-gu increased by 190.75% in six years.

Nevertheless, an exponential increase in ATP questions BSHP's success in providing affordable housing to citizens in desperate need. Table 9 and Figure 13 provide information on average annual ATP of *Bogeumjari* housings in each *gu*.

**Table 9** ATP of Bogeumajari housings (2012–2020)

| *Gu* district | Bogeumajari housing ATP (unit:10K KRW/m$^2$) | | | | | | | | year |
|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| Yangcheon | 414.35 (22.21) | 464.85 (11.94) | 473.54 (22.86) | 490.26 (12.06) | 516.47 (12.99) | 534.78 (13.78) | 579.34 (23.51) | 704.84 (50.10) | 776.43 (35.27) |
| Songpa | | | 579.19 (72.40) | 796.46 (N/A) | 1009.35 (66.04) | 1082.59 (42.85) | 1318.39 (119.27) | 1360.95 (123.52) | 1670.52 (143.07) |
| Gangnam | | | 740.73 (68.62) | 854.90 (57.35) | 899.24 (136.52) | 1029.47 (112.86) | 1315.42 (139.97) | 1418.84 (134.62) | 1569.00 (128.53) |
| Seocho | | | 610.00 (164.13) | 836.25 (133.44) | 959.20 (87.97) | 1071.69 (183.06) | 1390.22 (148.32) | 1515.47 (148.32) | 1773.60 (154.75) |

Note: Each *gu* district has different number of apartment complex that varies in price and number of transactions. Number in parenthesis indicate the annual standard deviation between apartments in a *gu* district

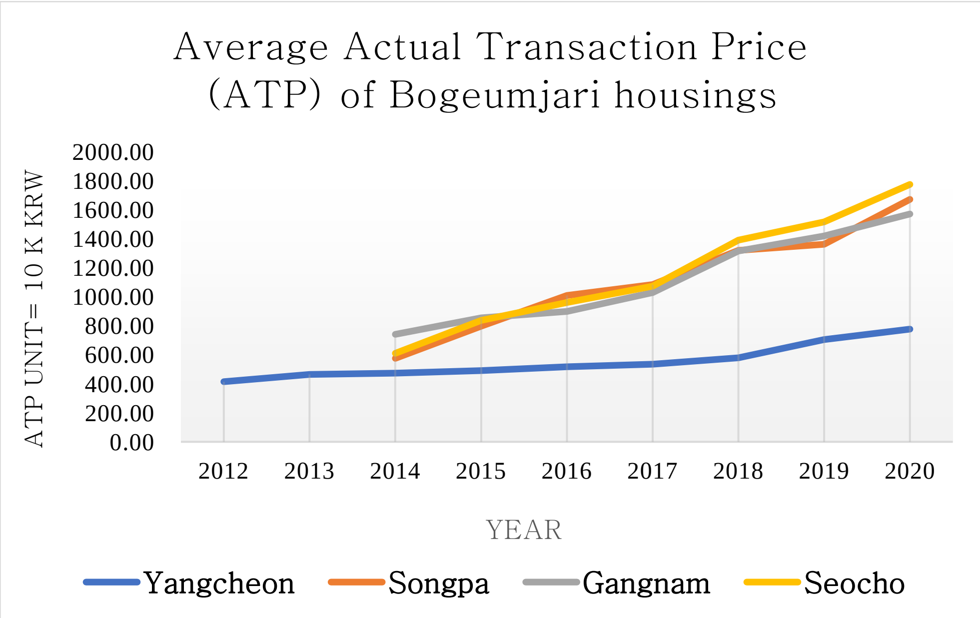


**Figure 13** Average ATP of Bogeumjari housings

## 5.3 Sustainable Social Housing

### 5.3.1 Social Housing Policy in South Korea

Conventionally, social housing is defined as any rental housing that may be owned and managed by the state, by non-profit organizations, or by a combination of the two, usually with the aim of providing affordable housing. Social housing is generally rationed by a government through some form of means-testing or through administrative measures of housing need. Some can regard social housing as a potential remedy for housing inequality. In South Korea, Social Housing Special Law was established to assist in citizens' residential life by stabilizing housing price and enhancing residential environment. Here, a social housing or a public housing follows the conventional definition and further specification includes all housings that has a supply area under 914 $ft^2$ and rental period over 5 years. To visualize how social housing laws have evolved, Table 10 shows housing policies and main social housing policy of several presidential era. This table demonstrates common housing issues that South Korea has been confronting by examining trends of housing policy in South Korea. In addition, this partially explains motives behind establishment of each social housing policy.

**Table 10** Housing Policy in each Presidential Era

| Year | Presidency | Housing Policy Goal | Example |
|---|---|---|---|
| 2003-2007 | President Roh | Stabilization of Real Estate Market and Expansion of Residential Welfare | National Social Housing Law |
| 2008-2012 | President Lee | Promotion of Home Ownership and Residential stability of Working-class | Bogeumjari Social Housing Policy |

| | | | |
|---|---|---|---|
| 2013-2017 | President Park | Mitigation of Housing Shortage by revitalizing housing market and Provision of Youth Housing by revitalizing local economy | Haengbok Social Housing Policy |
| 2017-Present | President Moon | Stabilizing Housing Market by Actual Demand Protection and Short-term Property Speculation Control | Residential Welfare Roadmap |

Social housing polices in Korea were oriented towards stabilizing housing market and providing housing assistance to low-income citizens. Nevertheless, the most common strategy used to achieve these goals is adjusting the price. However, each government uses different approach to decrease the housing price or rental price. For instance, President Lee built social housings on greenbelt area that has relatively cheap land price to provide cheap housings. On the other hand, President Park utilized various types of abandoned area and supplied housings for single-person households (net leasable area smaller than $45m^2$) (Kim and Kang, 2020). Yet, trade-offs were inevitable in order to cut the housing price and social housing policies are sometimes criticized for low physical quality, social exclusion and etc. In other words, residential quality and social equity were usually neglected to achieve affordability.

As a result, some scholars suggested a set of indicators that can measure various residential qualities, which is more known as Resident' s Satisfaction Index. Many studies used this index to evaluate social housings and identify factors associated with resident' s decision-making and satisfaction level before and after moving-in. Series of literature review on determinants of resident satisfaction confirmed that physical quality of housing unit and residential environment are key constituents of residential satisfaction, which are also problems traded for cheap price. Kown and Kim (2012) presented that physical environmental factors and community environmental factors were statistically significant in residential satisfaction of national sales and rental housing residents. Moreover, Kim (2016) reported that daily security environment has been newly introduced as the most important factor in one's satisfaction on residential environment by specifying factors included in daily security environment.

Thus, social housing polices in Korea were initially designed to enhance stability of housing market and to extend residential welfare. In achieving these goals, price was used as a major instrument; however, residential environment and housing quality were often overlooked. Since residents discern residential environment and housing quality as important components of residency, they should be addressed promptly to promote equitable housing and effective land use.

### 5.3.2 BSHP and Sustainable Land Use

As mentioned earlier, each government has selected different location for social housing sites. Locational condition is crucial not only because it determines the price of a housing but also because it decides the residential environment, particularly, accessibility to urban infrastructure. For instance, previous studies have found that South Korean social housing residents identified accessibility to infrastructure such as transportation, educational institutions and outdoor or indoor recreational facilities as one of the most influential factors of residential satisfaction (Kim and Park, 2012; Kown and Kim, 2012; Nam and Choi, 2007). Hence, based on the findings of this study, BSHP's decision to build social housings in greenbelt area is a questionable path to achieve economically and environmentally successful social housing.

To summarize, the result of DID analysis implies that BSHP may further aggravate residents' exposure to harmful ozone. Implementation of BSHP has worsened the overall air quality across

Seoul but it particularly affected the ozone concentration of *Bogeumjari* sites. It is important to note that this study specifically aimed to identify loss of green infrastructure as a principal factor that influence ozone concentration level. Releasing greenbelt for housing growth led to destruction of green space and implementation of BSHP increased ozone concentration. This can also be interpreted as no further measure was taken to offset losses from greenbelt release. If the release of greenbelt was an unavoidable step to supply cheap housings, some actions must have been carried out to retain services given by green space that are beneficial to our health like mitigation of air pollution and heatwaves. Eventually, continuing such housing development practices may put residents' health in jeopardy. More precisely, it will threaten certain resident's health, particularly that of *Bogeumjari* social housing residents.

Moreover, loss of greenbelt not only led to destruction of nature but also inaccessibility to urban infrastructure. Such loss in green infrastructure and urban infrastructure is not even financially compensated to *Bogeumjari* residents as it can be inferred from its increasing housing price. Thus, these make *Bogeumjari* housings an inequitable housing and raise doubts on its ability to be maintained as a social housing. Therefore, this study believes BSHP failed to fulfil its objectives. It has increased the ozone concentration level. It has decreased accessibility to services and facilities needed for pleasant living. Besides, it has increased the housing price. Altogether, the overall result suggests that its failure to adhere to its initial objectives is attributed to its decision to release greenbelt.

### 5.3.3 Sustainable Social Housing Policy

Sustainability is the ability to be maintained at a certain level over time and meeting our own needs without compromising the ability of future generations to meet their own needs. Though sustainability is more heavily emphasized in describing environmental problems, it can be used in various context. In the context of social housing, sustainability means the ability to fulfil its objectives without violating adequate standard of living and depleting natural resources. In other words, social housings should also integrate sustainability and establish polices that can economically and environmentally sustain low-income residents. Thus, wiser land use that incorporates both development and preservation purposes can sustain social housings more economically and environmentally. In the long run, it will enhance residential welfare program by introducing sustainability in housing development.

In conclusion, the result proposes two suggestions for future social housing polices and land use regulations. First, it suggests a need for a new paradigm in land use decisions for sustainable social housings. Second, it recommends devising a green indicator that can assist in sustainable planning and executing land development plan. For instance, the current government should incorporate an eco-friendly approach in land development and review ongoing development plans. In addition, the government should first evaluate a land in an environmental perspective and design a specific ecological planning. Execution of land development follows afterwards. Overall, land use regulation should ultimately embrace both preservation purpose and development purpose and application of such new ecological structure should not be limited to housing development but should go beyond different types of urbanization development.

# Chapter 6. Conclusion

This study examined the change in ozone concentration after releasing greenbelt for Bogeumjari housing constructions to identify trade-offs associated with BSHP. The major takeaways are as follows. Largely, the ozone concentration of all treatment *gus* and adjacent *gus* increased after move-ins. Additional Bogeumjari housing development sites increased the overall ozone concentration of both treatment *gus* and adjacent *gus*; however, *gus* with Bogeumjari housings experienced a higher degree of increase in ozone concentration than adjacent *gus* without Bogeumjari housings. Altogether, the overall increase in ozone concentration was found after implementation of BSHP, particularly in regions that were subjected to build housings on released greenbelt. Such finding can be partially explained by the negative coefficients of green infrastructures, confirming the greenbelt and forest’s role in mitigating air pollution and the adverse environmental effects of losing them.

Future studies could also address several limitations of this study. Lack of data was the biggest issue of this research. For instance, not much data could be found on dong (a smaller administrative unit of Korea) level or weekly level from 2009 to 2018. It was only recent that environmental data was provided in a smaller regional and temporal scale. Thus, some assumptions had to be made and the data was collected on *gu* and monthly level. Therefore, the data set itself may be inaccurate since it cannot capture variations of all dongs in one gu. Moreover, this study used DID hedonic regression controlled by the number of residential units instead of extended DID. Perhaps, a more sensitive data set with extended DID could have enhanced the result. Since recent data are available in various scale, same analysis can be done on HSHP and other social housing policies in the future, using extended DID.

Though faced with data limitation, this study is meaningful because it introduces a new paradigm in evaluating a social housing policy’s residential welfare and defining a sustainable social housing policy. Compared to Haengbok housings, Bogeumjari housings are no longer affordable and lack infrastructures, placing additional financial burden of traveling expenses while taking away the rights to enjoy equal residential welfare. Altogether, loss of greenbelts may further favor urban sprawl and residential welfare disparity and aggravate exposure to highly concentrated ozone. Clearly, BSHP has failed to compensate trade-offs derived from releasing greenbelt for social housings. This defeats the social housing’s initiative as a residential welfare policy and questions BSHP’s role as a social housing policy. Therefore, devising a green indicator that can assist in sustainable planning and executing land development plans is pivotal; ultimately, incorporating both preservation and development purposes in land use regulations. Thus, improving policies and programs on housing and land use management can help address the broader issue of sustainability and urbanization in which inequitable housing and the environment are imbedded.

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# Appendices

## Appendix 1. List of *Bogeumjari* and *Haengbok* housings

| Gu District | Apartment Name (in Korean) | Earliest Move-in | Number of Total Residential Units |
|---|---|---|---|
| Gangnam-gu | 세곡푸르지오아파트(A2) | 2012.09 | 912 |
| | 강남e편한세상(A1) | 2013.06 | 809 |
| | LH강남8단지 | 2013.11 | 96 |
| | 강남LH3단지아파트(A3) | 2013.11 | 1065 |
| | 세곡2보금자리지구3단지 래미안포레 | 2014.03 | 1070 |
| | 세곡2보금자리지구4단지 강남한양수자인 | 2014.03 | 1304 |
| | 래미안강남힐즈(A6) | 2014.06 | 1020 |
| | 강남힐스테이트(A5) | 2014.10 | 1339 |
| | 강남아이파크(A7) | 2014.10 | 716 |
| | 강남브리즈힐아파트(A4) | 2014.11 | 402 |
| | 세곡2보금자리지구8단지 강남한신휴플러스 | 2015.09 | 169 |
| | 세곡2보금자리지구6단지 강남한신휴플러스 | 2015.09 | 378 |
| | 서초힐스(A2) | 2012.12 | 1082 |
| | 서초호반써밋(A1) | 2013.10 | 550 |

| | | | |
|---|---|---|---|
| Seocho-gu | LH 서초3단지 아파트(A3) | 2013.10 | 790 |
| | 서울내곡 보금자리 포레스타 7단지 | 2013.10 | 310 |
| | LH 서초5단지 아파트(A5) | 2013.12 | 358 |
| | LH 서초4단지 아파트(A4) | 2013.12 | 424 |
| | 서울내곡 보금자리 포레스타 5단지 | 2014.05 | 547 |
| | 서울내곡 보금자리 3단지 서초포레스타 | 2014.06 | 482 |
| | 서울내곡 보금자리 1단지 서초더샵포레아파트 | 2014.08 | 1264 |
| | 서울내곡 보금자리 4단지 힐스테이트 서초젠트리스 | 2015.01 | 256 |
| | 서울내곡 보금자리 포레스타 6단지 | 2015.04 | 585 |
| | 서울내곡 보금자리 2단지 서초포레스타 | 2015.06 | 1077 |
| Songpa-gu | 위례22단지비발디(A1-8) | 2013.12 | 1139 |
| | 위례24단지꿈에그린(A1-11) | 2013.12 | 1810 |
| | 오금지구 보금자리주택 1단지 | 2017.11 | 575 |
| | 오금공공주택지구 2단지 | 2018.06 | 818 |
| Guro-gu | 항동 8단지 하버라인 | 2018.11 | 384 |
| | 항동 1단지 중흥 s 클래스 베르데카운티 | 2019.12 | 419 |
| | 항동 2단지 하버라인 | 2019.07 | 646 |
| | 항동 3단지 하버라인 | 2019.03 | 1170 |
| | 항동 4단지 하버라인 | 2019.07 | 297 |
| | 항동 5단지 한양수자인 에듀힐즈 | 2019.09 | 634 |

| | | | |
|---|---|---|---|
| | 항동 6단지 우남퍼스트빌 더센트럴 | 2020.06 | 337 |
| | 항동 7단지 제일풍경채 포레스트 | 2020.03 | 345 |
| Yangcheon-gu | 신정이펜하우스 신정3지구(1-5단지) | 2011.06 | 3060 |

Table A1 List of analyzed Bogeumjari housings (2011−2015)

| Gu District | Apartment Name (in Korean) | Earliest Move-in (YEAR.MONTH) | Accumulated Number of Total Residential Unit |
|---|---|---|---|
| Gangnam-gu | 세곡푸르지오아파트(A2) | 2012.09 | 912 |
| | 강남e편한세상(A1) | 2013.06 | 1721 |
| | LH강남8단지 | 2013.11 | 1817 |
| | 강남LH3단지아파트(A3) | 2013.11 | 2882 |
| | 세곡2보금자리지구3단지 래미안포레 | 2014.03 | 3952 |
| | 세곡2보금자리지구4단지 강남한양수자인 | 2014.03 | 5256 |
| | 래미안강남힐즈(A6) | 2104.06 | 6276 |
| | 강남힐스테이트(A5) | 2014.01 | 7615 |
| | 강남아이파크(A7) | 2014.01 | 8331 |
| | 강남브리즈힐아파트(A4) | 2014.11 | 8733 |
| | 세곡2보금자리지구8단지 강남한신휴플러스 | 2015.09 | 8902 |
| | 세곡2보금자리지구6단지 강남한신휴플러스 | 2015.09 | 9280 |
| | 서초힐스(A2) | 2012.12 | 1082 |
| | 서초호반써밋(A1) | 2013.10 | 1632 |
| | LH 서초3단지 아파트(A3) | 2013.10 | 2422 |
| | 서울내곡 보금자리 포레스타 7단지 | 2013.10 | 2732 |

| | | | |
|---|---|---|---|
| Seocho-gu | LH 서초5단지 아파트(A5) | 2013.12 | 3090 |
| | LH 서초4단지 아파트(A4) | 2013.12 | 3514 |
| | 서울내곡 보금자리 포레스타 5단지 | 2014.05 | 4061 |
| | 서울내곡 보금자리 3단지 서초포레스타 | 2014.06 | 4543 |
| | 서울내곡 보금자리 1단지 서초더샵포레아파트 | 2014.08 | 5807 |
| | 서울내곡 보금자리 4단지 힐스테이트 서초젠트리스 | 2015.01 | 6063 |
| | 서울내곡 보금자리 포레스타 6단지 | 2014.04 | 6648 |
| | 서울내곡 보금자리 2단지 서초포레스타 | 2015.06 | 7725 |
| | 위례22단지비발디(A1-8) | 2013.12 | 1139 |
| | 위례24단지꿈에그린(A1-11) | 2013.12 | 2949 |
| Yangcheon-gu | 신정이펜하우스 신정3지구(1-5단지) | 2011.06 | 3060 |

Table A2 List of Haengbok housings 2015-2020

| Gu District | Apartment Name (in Korean) | Earliest Move-in | Number of Total Residential Units |
|---|---|---|---|
| Gangnam-gu | 삼성동 센트럴 아이파크 | 2018.09 | 57 |
| | 래미안개포루체하임(일원동현대) | 2019.03 | 50 |
| | 래미안블레스티지(개포주공2단지) | 2019.03 | 112 |
| | 디에이치 아너힐즈(개포주공3) | 2019.1 | 85 |
| | 개포래미안포레스트 | 2020.12 | 120 |
| Gangdong-gu | 강일리버파크11단지 | 2015.12 | 346 |
| | 고덕 그라시움(고독2) | 2019.1 | 140 |
| | 래미안 명일역 솔베뉴(삼악그린) | 2019.1 | 156 |
| | 푸르내 | 2020.02 | 119 |
| | 고덕센트럴아이파크(고덕5) | 2020.04 | 96 |
| | 롯데캐슬베네루체(고덕 7) | 2020.04 | 97 |
| | 이편한세상강동에코포레 | 2020.12 | 38 |
| | 고덕아르테온 | 2020.12 | 108 |
| | 고덕센트럴푸르지오 | 2020.12 | 142 |
| Gangbuk-gu | 꿈의숲 롯데캐슬 | 2017.09 | 35 |
| | 꿈의 숲 효성해링턴플레이스(미아 9-1) | 2019.1 | 88 |
| | 미아동 159-29 다가구 | 2021.01 | 4 |

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|---|---|---|---|
| | 미아동 791-1614 다가구 | 2021.01 | 5 |
| Gangseo-gu | 가양모듈러 | 2017.12 | 30 |
| | 이편한세상 염창(염창1) | 2019.10 | 56 |
| Gwanak-gu | 이편한세상 서울대입구(봉천 12-2) | 2019.10 | 47 |
| | 이편한세상서울대입구 | 2020.01 | 23 |
| | 이편한세상 서울대입구2차 | 2020.10 | 27 |
| Guro-gu | 천왕이펜하우스(천왕7단지) | 2015.10 | 374 |
| | 천왕연지마을1- 천왕지구2지구 도시형생활주택 | 2017.09 | 181 |
| | 천왕연지마을2 | 2017.09 | 138 |
| | 천왕지구 8단지 | 2018.09 | 298 |
| | 고척동 156 | 2018.10 | 28 |
| | 항동하버라인 9,10,11단지 | 2019.02 | 871 |
| | 숲에리움 | 2020.11 | 180 |
| Nowon-gu | 수락리버타운(상계장암5) | 2016.12 | 48 |
| | 상계역센트럴푸르지오(상계 4) | 2020.04 | 17 |
| | 인덕아이파크(월계 2) | 2020.04 | 69 |
| | 상계역센트럴 푸르지오 | 2020.05 | 8 |
| | 포레나노원 | 2020.12 | 141 |
| Dongdaemun-gu | 힐스테이트 청계 | 2018.09 | 114 |
| | 휘경 sk뷰(휘경2) | 2019.10 | 16 |

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| | 답십리파크자이 | 2019.10 | 32 |
| | 휘경 sk뷰 | 2020.01 | 9 |
| | 동대문더퍼스트데시앙(장안동) | 2020.04 | 23 |
| | 휘경해모로 프레스티지 | 2020.05 | 20 |
| Donjak-gu | 래미안 로이파크 사당 1구역 | 2018.09 | 58 |
| | 이편한세상 상도 노빌리티(상도대림) | 2019.10 | 5 |
| | 아크로리버하임 | 2019.10 | 7 |
| | 롯대캐슬에듀포레 | 2019.10 | 7 |
| | 학수복합 | 2020.02 | 7 |
| Mapo-gu | 마포 웨스트리버 태영데시앙(마포창전 1) | 2019.10 | 9 |
| | 신촌숲 아이파크(신수 1) | 2019.10 | 98 |
| | 마포자이3차 | 2019.10 | 28 |
| | 신촌그랑자이 | 2020.10 | 69 |
| | 공덕 sk리더스뷰 | 2020.12 | 61 |
| Seodaemun-gu | 이편한세상신촌 | 2017.08 | 130 |
| | DMC 센트럴 아이파크(남가좌1) | 2019.10 | 47 |
| | 연희파크 푸르지오(연희 1) | 2019.10 | 35 |
| | 홍제센트럴아이파크 | 2019.10 | 52 |
| | 북한산두산위브 | 2020.05 | 31 |
| | 래미안루센티아 | 2020.05 | 58 |

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| | DMC에코자이 | 2020.05 | 53 |
| | 연희동 136-21 다가구 | 2020.12 | 4 |
| | 힐스테이트신촌 | 2020.12 | 25 |
| Seocho-gu | 서초선포레(내곡지구) | 2015.10 | 87 |
| | 반포 래미안 아이파크(서초한양) | 2018.09 | 116 |
| | 래미안 서초 에스티지 S(서초 우성 2차) | 2018.09 | 91 |
| | 반포센트럴 푸르지오 써밋(삼호가든 4차) | 2018.10 | 130 |
| | 신반포자이(반포한양) | 2019.03 | 71 |
| | 래미안 신반포 리오센토(신반포 18,24차) | 2019.10 | 71 |
| | 방배아트자이(방배 3) | 2019.10 | 41 |
| | 반포센트럴자이 | 2020.12 | 53 |
| | 래미안디더스원 | 2020.12 | 166 |
| Seongdong-gu | 왕십리자이 | 2017.11 | 50 |
| | 금호파크힐스이편한세상 | 2018.09 | 59 |
| | 힐스테이트 서울숲리버 | 2018.09 | 40 |
| | 서울숲리버뷰자이 | 2018.09 | 33 |
| Seongbuk-gu | 보문파크뷰자이 | 2017.08 | 75 |
| | 꿈의숲 코오롱하늘채 | 2017.12 | 30 |
| | 롯데캐슬 골든힐스(길음3) | 2019.10 | 40 |
| | 래미안 아트리치 | 2019.10 | 48 |

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| | 래미안길음센터피스 | 2019.10 | 25 |
| | 래미안 장위퍼스트하이 | 2020.01 | 95 |
| | 포레카운티 | 2020.01 | 59 |
| | 정릉 하늘마루(청신호)- 정릉 공공주택 건설사업 | 2020.04 | 166 |
| | 동소문동 다가구 | 2021.01 | 8 |
| Songpa-gu | 송파파크데일(마천3) | 2017.03 | 148 |
| | 거여리본타운 | 2018.09 | 128 |
| | 송파헬리오시티(가락시영) | 2019.03 | 1401 |
| | 잠실올림픽공원아이파크(풍납우성) | 2020.04 | 95 |
| | 이편한세상 송파파크센트럴 | 2020.12 | 20 |
| Yangcheon-gu | 이든채 | 2019.03 | 499 |
| | 목동센트럴아이파크위브 | 2020.10 | 187 |
| | 신정동 행복주택 | 2020.11 | 101 |
| Yeongdeungpo-gu | 대림아크로타워스퀘어 | 2017.12 | 48 |
| | 신길아이파크 | 2019.10 | 31 |
| | 보라매 sk뷰 | 2020.10 | 34 |
| | 신길센트럴자이 | 2020.10 | 24 |
| | 당산센트럴아이파크(상아현대) | 2020.06 | 87 |
| | 이편한세상보라매2차(대림3) | 2020.08 | 55 |
| Yongsan-gu | 용산롯데캐슬센터포레 | 2019.10 | 25 |

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| | 용산센트럴파크 해링턴스퀘어 | 2020.10 | 97 |
| Eunpyeong-gu | 힐스테이트 녹번 | 2018.10 | 106 |
| | 신사효성해링턴플레이스(신사 19) | 2019.03 | 22 |
| | 은뜨락 | 2019.03 | 350 |
| | 이룸채 | 2019.03 | 630 |
| | 백련산파크 자이(응암 3) | 2019.10 | 4 |
| | 래미안 베라힐즈 | 2019.10 | 100 |
| | 백련산 sk뷰 아이파크 | 2020.01 | 48 |
| | 백련산해모로 | 2020.10 | 48 |
| | 녹번역이편한세상캐슬 | 2020.10 | 163 |
| | DMC 롯데캐슬더퍼스트 | 2020.10 | 77 |
| | 역촌헤르미온 | 2020.12 | 10 |
| Jungnang-gu | 신내 3 도시형생활주택 | 2017.09 | 50 |
| | 신내 3지구 4단지 도시형생활주택 | 2018.09 | 289 |
| | 신내글로리움 | 2019.10 | 229 |
| | 한양수자인 사가정 파크(면목1) | 2019.12 | 36 |
| | 사가정센트럴아이파크(면목3) | 2020.08 | 163 |
| | 면목라이온프라이빗 | 2020.12 | 60 |
| Jongno-gu | 경희궁자이 | 2017.08 | 188 |
| Jung-gu | 서울역 센트럴자이 | 2018.09 | 36 |

# 국문초록

## 유해 오존 저감을 위한 지속가능한 토지 이용 및 공공주택 정책


최 윤 영

농경제사회학부 지역정보학전공

서울대학교 대학원


본 연구는 보금자리주택 정책의 환경적 효과를 파악하기 위해 이중차분법(Difference-in-Differences)을 사용하여 보금자리주택 이행 전후 서울의 오존 농도의 변화를 분석한다. 보금자리주택정책은 시중 시세 대비 저렴한 가격으로 저소득층의 자가소유율을 높이고자 그린벨트를 해제하여 다양한 공공주택을 공급을 목표로 한 이명박 정권의 대표적인 주택정책이다. 특히 수도권에서 그린벨트는 자연환경 보전 외에도 서울의 스프롤 현상을 막고 도시 연담화를 방지하는 완충 목적을 가지고 있다. 따라서, 무분별한 그린벨트 해제를 통한 택지개발사업에는 트레이드오프가 발생하고 이는 면밀히 평가할 당위성이 존재한다.

그린벨트 보전과 공공주택 건설을 통한 택지개발의 트레이드오프를 분석하기 위해 본 연구는 두가지 관점을 적용한다. 우선, 환경적인 관점에서 그린벨트 해제를 통한 공공주택 건설을 평가하기 위해 보금자리주택 정책 이행 전후 오존 농도 변화를 측정한다. 또한 주거복지 관점에서 그린벨트 내 보금자리주택의 위치선정성을 평가하기 위해, 다음 정권에서 추진한 행복주택의

위치와 인프라 접근성을 실증적으로 비교하고자 한다. 분석 결과, 서울의 보금자리주택 지구가 늘어날수록 해당 자치구와 인접 자치구의 오존농도가 증가하고 보금자리주택들은 평균적으로 교통시설, 교육시설, 문화시설 등의 인프라와 접근성이 행복주택보다 현저히 낮은 것으로 나타났다. 이를 미루어 보아, 토지개발과 환경보전에 있어 보금자리주택이 본래 취지와 공공주택의 목적을 달성했는지 의문이 제기되는 바이다. 따라서 토지 개발에 있어 친환경적인 접근 혹은 이의 지속가능성을 평가할 수 있는 지표가 도입되어야 하며, 특히 그린벨트와 같은 그린 인프라를 개발할 경우 신중한 결정과 후속조치가 필요하다. 이러한 개선은 토지이용과 공공주택이라는 도시화의 지속가능성과 관련한 많은 문제들을 해결하고, 보전과 개발을 모두 고려한 지속가능한 주택정책을 설립할 수 있을 것으로 보인다.

**주요어: 보금자리주택, 공공주택정책, 그린벨트, 토지이용, 지속가능한 개발,**
**학번:** 2020-2560