Does Physical Housing Decay in Urban Areas Promote Crime?*

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Abstract

This paper investigates the nexus between physically decayed urban areas and crimes. We incorporate the existing arguments concerning the nexus in a model to offer systematic economic accounts of the direct effect of physical decay on crimes. We also explain the aggravating effect of physical decay interacting with other critical human or environmental factors known to increase crimes such as lowered self-control and increased exposure. We introduce two proxies for urban physical housing decay. Using a panel of 52 South Korean cities for 11 years from 2005, we find that not only is the direct effect of physical housing decay significant but its aggravating effect is also fairly persistent.

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*. (Acknowledgements to be completed later)

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1. Introduction

According to biennial surveys conducted by Statistics Korea, crime was the most threatening factor in South Korea among all risks considered in 2016 and 2018. The percentage of female victims of violent crime reached a record high of 90% in 2017—a large increase from 73.0% in 1995. Also, many media reports have revealed concerning situations where children, the elderly, and the economically weak are the targets of violent and property crimes. The Korean National Police Agency (2016) made a critical observation that the incidence of these crimes has been disproportionately related to areas with deteriorated housing, confirming earlier warnings by Seoul City from 2010.

In this paper, we extensively investigate the nexus between urban physical decay and crimes.[1] The existing literature discusses this nexus in terms of at least three channels: reduced surveillance, weakened guardianship, increased presence of criminal dens. Thus, we first incorporate these channels in a standard model to provide systematic economic accounts in terms of the 'direct effect of physical decay' on crimes. We subsequently reflect the existing claims in our economic model. For example, sociology and criminology studies suggest that a group of human or environmental factors not only directly increases crimes *per se* but also interacts with physical decay, resulting in more crimes. In the model, we name this latter effect the 'aggravating effect of physical decay'.

We empirically test these hypotheses concerning physical housing decay by estimating the supply function of conventional crimes utilizing two proxies for physical decay in the housing stock: the percentage of housing with the terms of construction over 30 years and the percentage of unauthorized houses. We confirm the legitimacy of these proxies, considering the relevant

[1] Physical decay represents deterioration in the physical condition of residential structures (Wallace and Schalliol, 2015, p. 179) or physical problems with buildings (Ross and Mirowsky, 1999, p. 419). In particular, Ross and Mirowsky (1999) express that reports of abandoned or ill-maintained buildings indicate physical decay.

characteristics of South Korea such as the Korean War in the 1950s and the housing development policy thereafter. Utilizing panel date for 52 South Korean cities, from 2005 to 2015, we find that the magnitude of the nexus between physical housing decay and crimes is fairly significant. For example, conventional crimes will increase by 5% if our first proxy of physical decay, the sample mean of which is 40%, increases up to 50% as predicted by experts to be easily reached within 15 years, such as in the case of Seoul.

We also find evidence that physical decay tends to play a catalyst role in accelerating the effect of other human factors on crimes. We confirm that the crime-increasing effects of lowered self-control and greater exposure, in particular, are significantly aggravated by physical decay. With regard to the robust alcohol-crime relationship in our estimation, for example, an increase in the frequency of drinking by 10%-points directly causes more crimes by as much as about 3% of the crime incidences nationwide of the year 2015. For the aggravating effect, the same increase in the drinking frequency, through interacting with physical decay, would additionally increase crimes by 7%-points, leading us to conclude that the aggravating effect of physical decay is obviously strong.

The remainder of the paper proceeds as follows. Section 2 explains crimes in Korea and presents the motivations for physical decay and crimes. In Section 3, we conduct simple economic accounts of the nexus between physical decay and crimes and, for the first time in the economic literature, further scrutinize the effects of decay interacting with other human factors. In Section 4, we describe the data and the empirical methodology, define the variables to be used, and examine their descriptive statistics. The empirical results are presented in Section 5. In Section 6, we conclude the paper with a brief discussion of policy implications.

2. Motivations: Physical Housing Decay and Crimes

2.1. Triggering Effect of Physical Decay on the Surge of Crimes in Korea

According to the Supreme Prosecutors' Office of Korea in their *Annual Crime Reports*, a steady increase in the reported number of total crimes (i.e., 'conventional crimes' and 'regulatory crimes') has been observed over the last four decades.[2] Over the years from 2000 to 2015, the average number of crimes per year was almost 2 million. This average is about three times higher than that over the previous three decades. In particular, since 2000, the number of conventional crimes has increased relatively more rapidly, on average, at 1.9% compared to a rather stagnant increase of regulatory crimes. Their average growth rate even reached 2.5% per year after 2005, as shown in Figure 1.

In particular, the two most serious sub-categories of conventional crimes, 'violent crimes' and 'property crimes',[3] have shown a significantly increasing trend, with the annual growth rate of 4.9% and 3.7% over the post-2000 period, respectively. Moreover, the increase in the sum of these two crimes accelerated after the mid-2000s. Similar accelerating trends are observed for the two crime rates controlled for population size, which are measured as the number of crimes per 100,000 population (i.e., 4.3% and 3.1%, respectively). Therefore, in Korea, conventional crimes present a particularly troubling picture in terms of magnitude and quality after 2000.

[2] The 'regulatory crimes' category includes violations of numerous administrative regulations that have been declared to be crimes through *political processes*. Thus, they are differentiated from 'conventional crimes', which include homicide, robbery, arson, rape and sexual assaults, theft, aggravated assault, and so on, based on traditional definitions under *criminal law*.

[3] The crimes in these sub-categories are generally perceived by citizens to be the most threatening to society, when considering, for example, their per-unit social costs, as confirmed by McCollister et al. (2010).

Although the increasing trend of conventional crimes in Korea can be explained in several ways, in the context of economics of crime literature, reduced deterrence may be the key reason.[4] In that regard, the existing studies in criminology or sociology concerning physical decay in areas can shed an important insight. While concern with the relationship between crime and place is not new,[5] their findings reveal that higher rates of crime are disproportionately concentrated in areas with significant physical decay, such as a large number of vacant or deteriorated houses and poorly lit streets (or areas with low visibility) (Skogan, 1990).

Many such areas can be found in Korea. The Korean National Police Agency identified the physically deteriorated environment as a major reason for the increase in conventional crimes, emphasizing that regions with serious crime problems are generally characterized with old buildings, neglected houses, and improper maintenance. Central or local governments and public research institutes also suggest that recent increases in crimes appear to be related to specific regions or spaces that involve deteriorated housing, urban housing renewal projects, or declining areas in cities (Korean Institute of Criminology, 2016; Seoul Institute, 2016). Moreover, Kang (2013) and Seoul Institute (2017) explicitly argue that such decayed areas tend to increase the incidence of homicide, robbery, rape, theft, assault, etc.

For potential criminals, physically decayed areas may indicate reduced surveillance and thus a reduced level of deterrence. If the property ultimately becomes vacant, the reduced surveillance

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[4] For instance, Kim and Kim (2015) claimed that this weakened deterrence was largely caused by disproportionate prosecuting focus on regulatory crimes. Given the stringent constraints of prosecuting resources, an unintended consequence of the increasing gap in the prosecution rates between these two crimes, via spillover effects, led to greater increases in the incidence of conventional crimes. In a similar vein, Byeon et al. (2018) found that the reallocation of police resources toward the control of political protest reduced arrest rates for crime and resulting reduction in arrest rate significantly increased the incidence of crime.

[5] As early as the first half of the 19th century, French scholars such as André-Michel Guerry and Adolphe Quetelet began to analyze the distribution of crime across regions with differing ecological and social characteristics (MacDonald, 2015, pp. 333-334).

will become more apparent. Deteriorated buildings are also valued as better spaces to engage in criminal activity since they provide weakened guardianship. Also, decayed buildings often become criminal dens, providing suitable hangouts for thieves, drug dealers, and prostitutes.[6]

In other countries, the nexus between physical decay and crimes has been explained in terms of both violent crimes, property crimes, and other crimes such as kidnapping (Spelman, 1993; Cui and Walsh, 2015). Note that in Korea these crimes correspond to conventional crimes (rather than regulatory crimes).[7]

[Figure 1 here]

2.2. Physical Housing Decay in South Korea

Many studies concerning the decay-crimes nexus have utilized litter, vandalism, vacant housing, abandoned buildings or cars, and unkempt lots as proxies of physical decay (Ross and Mirowsky, 1999; Skogan, 2015).[8] Recently, Hipp et al. (2019) measured the age of housing as a proxy for physical deterioration and disorder, however. The authors explained that older housing will exhibit more deterioration based on filtering theory, which should result in more crime.[9] In Korea, likewise, the 'term of construction' (i.e., the age of building) has dominantly been used as the primary index of decay in announcing official statistics by Statistics Korea and the Ministry of Land, Infrastructure and Transport (MOLIT). More specifically, they have frequently used the

[6] Refer to Section 3 for more details on the nexus between physical decay and crimes.

[7] Also, Ellen et al. (2013) and Chamberlain et al. (2016) focused on Part I offenses for the United States. According to our own detailed comparisons, Part I offenses constitute approximately 85% of the crimes that are categorized as conventional crimes in Korea.

[8] International organizations have also used the number of bedrooms, provision of electricity, water supply, or indoor toilets for indexes measuring housing quality (OECD, http://www.oecdbetterlifeindex.org/topics/housing/; UN, https://unhabitat.org/urban-themes/housing-slum-upgrading/).

[9] According to Rosenthal (2014), filtering theory proposes that housing slowly deteriorates as it ages, which reduces its value and results in a transfer of the housing to lower income residents over time. Hipp et al. (2018) would expect that older housing will exhibit more deterioration, compared with newer housing.

‘percentage of housing with the terms of construction over 30 years (Decay)’ to refer to areas with physical decay. This Decay index is sometimes supplemented by deterioration indices of facilities such as water supply, density of occupancy, and sewerage systems.

MOLIT’s *Data for Taxation of (Detached) Single-family Houses* (unpublished) is the only source that provides annual series of Decay across regions in Korea. According to *Data*, the Decay index for detached single-family houses was 47.8% nationwide over the 11 years from 2005 to 2015. This increased steadily with a growth rate of 2.6%, and reached the highest level at 52.3% in 2015.[10] Also, although its estimation was based on the data announced every 5 years by Statistics Korea, Seoul Institute (2016) predicted that physical housing decay would become an increasingly serious problem in the near future.

While housing ages alone cannot accurately reflect the physical housing decay, longer terms are likely to be associated with worse dwelling conditions.[11] Furthermore, our specific definition of Decay is expected to adequately reflect physical deterioration in Korea for the reasons described below.

First, a large number of buildings were destroyed during the Korean War from 1950 to 1953. With the initiation of economic development in full force, vast numbers of housing projects were

[10] Total housing in Korea comprises detached single-family houses, apartments, and multiplex (or multi-family) houses. Published data by Statistics Korea and MOLIT have limitations for application in the current paper; the decay data for the total housing in *Population and Housing Census* by Statistics Korea is only collected by every 5 years and the units of survey are households rather than physical structures. Also, since *Statistics of Buildings* reported by MOLIT strictly follow the characteristics of a building at the time of completion, the data does not reflect any later changes in use. In particular, this data was available only from 2012. The MOLIT data in the text is known to have an additional merit in reflecting accurately the level of physical deterioration as officers in charge actually visit and measure the terms of construction.

[11] While adverse neighboring conditions, neglected maintenance, designing errors, and defective materials can contribute to physical decay, malfunctioning due to the passage of time after construction is generally known to be the most dominant factor (Hwang et al., 2016). In particular, since detached single-family houses inherently have shorter terms of construction than apartments, it costs much more to maintain the quality of the former after 30 years (Seoul Institute, 2016).

constructed rapidly from the 1970s. However, construction technologies 50 years ago were inferior to those of today and the supply of fine quality construction materials fell significantly short of the enormous demand. Also, the government's price ceiling policy for new housing further reduced the housing quality. Therefore, the service life (or persistent period) of the houses built during the 20 years from the 1970s is generally known to be shorter than the normal duration, and physical housing decay already progressed during the late 1990s and the early 2000s.

Second, the government, faced with problems of rapid decay, started undertaking significant housing redevelopment in urban areas mainly by 'tearing down old housing and reconstruction'.[12] The 2002 FIFA World Cup to be held in Korea was an additional motivation for this massive redevelopment during this period. 'Remodeling' is another option used in other countries. However, the old housing developments were mostly built using construction methods that did not consider this remodeling option (Seoul Institute, 2016).[13] Therefore, if old housing was not reconstructed during this period, it can be assumed that the buildings had become seriously deteriorated by 2005, the first year of the sample used in the later empirical analysis. These observations suggest that our index of $Decay$ with a 30-year threshold accurately reflects the physical deterioration of housing in Korea.

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[12] As a consequence, numerous housing developments in Korea were effectively replaced before their terms of construction reached 30 years. This phenomenon was then naturally reflected into the relevant building laws. The baseline law concerning housing redevelopment in Korea (i.e., Act on the Maintenance and Improvement of Urban Areas and Dwelling Conditions) explicitly stipulates that municipal ordinances shall designate a figure ranging from 20 to 30 years as the minimum term of construction within which developers must apply to municipalities for reconstruction approval. This stipulation is believed to be an outcome of the legislative consideration of the construction technologies used in the 1970s and the 1980s (National Assembly, *The Assembly Plenary Session Minutes*, 2002). For example, in the case of Seoul, the municipal ordinance designates 30 years for housing developments built after 1986 and fewer years otherwise (e.g., 20 years for those built before 1982) in order to account for the lower quality of housing built during the earlier stages of economic development.

[13] On the contrary, remodeling was frequently used in other countries including France, the United Kingdom, and the United States. Also, the average life of apartments in Korea, for example, is shorter (i.e., approximately 27 years) than that in Japan (54 years), the United States (72 years), and France (80 years) (MOLIT, *The Long-Life Housing Certification*, 2013). The remodeling option started after 2010, but its use has yet to prevail (Hwang et al., 2016).

In the case of the United States, a frequently used measure of physical decay is the vacancy rate, which is defined as the percentage of houses that are vacant within each region. As the number of vacant houses increases, the level of surveillance will clearly be reduced. Thus, crime supply will increase in those areas (Ellen et al., 2013; Cui and Walsh, 2015; Chen and Rafail, 2019), which is the finding consistent with the economic reasoning to be explained below.

The number of vacant houses is in an increasing trend in Korea. *Population and Housing Census* by Statistics Korea provides only aggregate vacancy rates for the 16 metropolitan areas. While the vacancy rate was 3.8% in 1995, it doubled in 2015. We intended to examine the approximate relationship between the vacancy rate and Decay through the correlation coefficient. We used the Decay statistics also provided by Statistics Korea to maintain the consistency of sampling units. The correlation calculated by 48 observations was 0.82 as depicted in Figure 2.[14]

In conclusion, terms of construction (i.e., housing ages) may be a reasonable proxy for physical decay. Our index of Decay seems to be particularly appealing, since its 30-year threshold has significant relevance to the physical deterioration of housing in Korea in terms of specific factors such as the economic development plan, housing supply policies, and construction technologies of the past.[15] Based on the above background, in Section 3, we provide a simple economic account of the nexus between physical decay and crimes. In addition, for the first time in the economic literature, we further scrutinize the interaction effects of decay with other human factors. We then test these empirically in Sections 4 and 5.

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[14] According to *Population and Housing Census*, housing is classified as being vacant if unoccupied and if the damage ratio is below 50%. We used 3 census years (2005, 2010, and 2015) for the 16 metropolitan areas in Korea.

[15] In other words, housing with terms of construction over 30 years can be regarded as significantly deteriorated, as reinforced in related laws. As previously mentioned, municipal ordinances generally designate a maximum term of construction up to 30 years for obtaining reconstruction approval from cities. It is well known that owners show little tendency to invest in improving their property as the housing age approaches closer to 30 years, which tends to accelerate physical decay.

[Figure 2 here]

3. Nexus between Physical Decay and Crimes

3.1. A Simple Model of Physical Decay and Crimes: The Basic Nexus

Our own examination as well as literature surveys can be summarized to suggest that at least three explanations are plausible for the nexus between physical decay and crimes. First, the existing literature often pointed out *reduced surveillance* as a cause of crime in the decayed areas (Harcourt and Ludwig, 2006; Cui and Walsh, 2015). Increased blind spots make it more difficult to witness crime scenes. Second, areas of physical decay have been regarded as hot spots for crime since they provide *weakened guardianship* (Spelman, 1993; Raleigh and Galster, 2015). Deteriorated buildings often lack security systems (e.g., security grille or windows locks), or they are easily burglarized, such as with the help of gas pipes. As a result, larceny, theft, robbery, and other conventional crimes increase. Third, abandoned buildings often become criminal dens, which can become suitable hangouts for thieves, drug dealers, and prostitutes. Thus, this third explanation indicates an *increased supply of potential criminals* (Spelman, 1993; Cui and Walsh, 2015).

We present the aforementioned nexus between physical decay (D) and crimes (C^S), using the model of criminal behavior derived in Kim et al. (2017). Consider an individual i who earns income, w_i, in the legal labor market and also receives monetary benefits or gratification, x, upon committing an offense. A potential offender incurs the total cost, c, associated with planning and executing the offense, which depends on many factors such as the capacity of a victim's self-protection. The offender is arrested (and convicted) with probability p, and pays a penalty f. The individual thus rationally supplies a crime if the expected net benefit (NB) of the crime is greater than μ_i, a pecuniary value that the offender assigns to his self-control or moral standard. Assuming a logarithmic utility function, we can write the individual i's decision as shown in (1).

$$NB_i = (1-p)\times \ln(w_i + x) + p \times \ln(w_i - f) - c - \ln w_i \geq \mu_i \,. \tag{1}$$

Let $\underline{w}$ denote a threshold level of income that distinguishes potential criminals ($w_i \leq \underline{w}$) from others—i.e., for all $w_i \leq \underline{w}$, $NB_i \geq \mu_i$. Noting that NB_i is decreasing in w_i for all levels of w_i, it can be shown that $\underline{w}$ is a function of key parameters as in (2). It is subsequently possible to show that individual i's supply of C^s can take the reduced form of $C^s = C^s(c, \mu, x, f, p)$, and also that C^s gives the comparative static derivatives, among others, with respect to p, c, and μ as expressed in (3).

$$\underline{w} = \underline{w}(\overset{-}{c},\ \overset{-}{\mu},\ \overset{+}{x},\ \overset{-}{f},\ \overset{-}{p}). \tag{2}$$

$$\partial C^s / \partial p < 0,\ \partial C^s / \partial c < 0,\ \partial C^s / \partial \mu < 0. \tag{3}$$

The basic nexus between D and C^s is thus readily incorporated into this model. First, *reduced surveillance* indicates a reduction in p. Second, *weakened guardianship* can be interpreted as a decline of c. Third, the *increased supply of potential criminals* induces a shift in the crime supply curve, resulting in more crimes in the region other things being constant. Thus, based on (3), the $D-C^s$ nexus can be expressed as in (4).

$$\partial C^s / \partial D > 0. \tag{4}$$

3.2. Aggravating Roles of Physical Decay in Increasing Crimes

3.2.1 Three Aggravating Effects Stemming from Human Behaviors

While the expression in (4) indicates direct effects of physical decay (D) on crimes (C^s), the literature in sociology and criminology suggests that physical decay, by the very nature of *human* or *environmental factors*, may also increase crime indirectly via other routes. We name these latter influences as the *aggravating effects* of the direct $D-C^s$ nexus in (4). Three aggravating effects are investigated and will be empirically tested in Sections 4 and 5.

First, 'social disorganization' generally refers to the inability of a community structure to realize its common values and to effectively maintain (informal) social controls (Kornhauser, 1978; Bursik, 1984).[16] Thus, weakened social control lowers μ in terms of our model. Also, the general consensus in the literature is that alcohol consumption (A) increases criminal propensity primarily because an increase in A causes a decline in the self-control of potential criminals. In our model, this positive $A-C^s$ relationship is explained via a reduction of μ, as shown in (3) (Cook and Moore, 1993; Piquero et al., 2002). In addition, it is important to note that informal social control is usually weakened in physically decayed regions as argued by researchers such as Cui and Walsh (2015, p. 72) and Wallace and Schalliol (2015, p. 178), indicating that D reduces μ in our model.

In particular, we focus on the observation by Gottfredson and Hirschi (1990, pp. 121-122) and Spelman (1993, pp. 481-482) that an individual's self-control of their specific behaviors tends to decrease, according to the *interaction* with the reduced informal social control caused by physical decay as explained above. Taken together, we hypothesize that, given the amount of alcohol consumption, an increase in D will further aggravate the aforementioned $A-C^s$ relationship *ceteris paribus*.

[16] Informal social controls such as friendship ties have particularly been recognized as critical in maintaining order and morality in neighborhoods (Sampson and Groves, 1989).

Second, the 'broken windows theory (BWT)' suggests that signs of neglect and disorder such as graffiti, derelict buildings, or aggressive panhandlers signal to potential criminals that crime may be more permissible (Wilson and Kelling, 1982). The extent to which BWT holds may thus be interpreted as affecting the level of μ in terms of our model. Minor offenses (M) (e.g., traffic offenses, public drunkenness, and drug offenses) have been utilized as proxies of BWT in the empirical literature such as Corman and Mocan (2005) and Braga et al. (2015) to determine whether M increases serious crimes including homicide, rape, or theft, i.e., a positive $M-C^s$ relationship. Also, Skogan (1990) and Johansen et al. (2015) argued that the effect of BWT tends to be reinforced in physically decayed areas. This again implies that D reduces μ in our model through the strengthened BWT.

We specifically note the observation by Johansen et al. (2015, pp. 3055-3057) that people tend to show less self-control, in terms of BWT, in physically deteriorated areas. Taking these explanations above into account, we hypothesize that, given the identical level of minor offenses, an increase in D, as an *interaction* phenomenon, will aggravate the aforementioned $M-C^s$ relationship.

Third, in their routine activity theory (RAT), Cohen and Felson (1979) discuss the circumstances under which offenders commit criminal acts. They argue that a crime requires the convergence of motivated offenders, suitable targets, and the absence of capable guardians against crime. In this paper, we focus on guardianship (i.e., capacity to prevent crime incidences), which has close relevance to c in (1). Various measures of exposure (E) such as female workers have been used as a representative proxy of RAT: i.e., the positive $E-C^s$ relationship has been established as E reduces c. Recall also the earlier argument in (4) that D decreases c because of *weakened guardianship*.

Interesting enough, residents in physically decayed areas tend to have adverse employment conditions, whereby they need to work during the night or very early morning (Skogan, 1990, pp. 46-50; Hipp, 2007, p. 918). It suggests that, as an *interaction* of exposure and environment, D will further decrease c, given the same level of E. In conclusion, we hypothesize that an increase in D will accelerate the aforementioned positive $\mathrm{E}-\mathrm{C}^{\mathrm{s}}$ relationship *ceteris paribus*.

3.2.2 Modeling the Aggravating Effects into the Crime Supply Function

First, let us examine the aggravating effect in the alcohol-crimes relationship. The positive $\mathrm{A}-\mathrm{C}^{\mathrm{s}}$ relationship is expressed, in terms of (3), as in (5).

$$\frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mathrm{A}} = \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu} \times \frac{\partial \mu}{\partial \mathrm{A}} > 0. \tag{5}$$

For illustrative convenience, assume that μ in (1) consists only of D and A; i.e., $\mu(\mathrm{A}, \mathrm{D}) = \tau_0 + \tau_1 \mathrm{A} + \tau_2 \mathrm{D} + \tau_3 (\mathrm{D} \cdot \mathrm{A})$. Based on the above discussions, τ_1 and τ_2 have negative signs. Also, τ_3 should be negative if the interactive effect of D, given A, on μ holds. Hence, (5) can be rearranged to (6).

$$\frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mathrm{A}} = \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu} \times (\tau_1 + \tau_3 \mathrm{D}) = \tau_1 \times \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu} + \tau_3 \times \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu} \times \mathrm{D}. \tag{6}$$

Since $\frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu} < 0$ according to (3), the first term in (6), $\tau_1 \times \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu}$, is positive. The sign of $\tau_3 \times \frac{\partial \mathrm{C}^{\mathrm{s}}}{\partial \mu}$ is of primary interest, and it is positive because of the negativity of τ_3. Therefore, equation (6) is positive. In particular, note that, from the second term in (6), the coefficient of the interaction term $(\mathrm{D} \cdot \mathrm{A})$ in the crime supply function will be positive. This reflects the aggravating effect of D on the $\mathrm{A}-\mathrm{C}^{\mathrm{s}}$ relationship, which will be tested in Section 5.

Second, let us examine the aggravating effect in the minor offenses-crimes relationship. The positive $M—C^s$ relationship can be equally expressed as $\frac{\partial C^s}{\partial M} > 0$. Similarly, assume that μ in (1) consists only of D and M to facilitate our discussions in the previous subsection. It is then easy to show that the coefficient of the interaction term $(D \cdot M)$ in the crime supply function should be positive, which reflects the aggravating effect of D on the $M—C^s$ relationship.[17]

Finally, the third aggregating effect concerns the exposure-crimes relationship. The positive $E—C^s$ relationship is expressed in (7).

$$\frac{\partial C^s}{\partial E} = \frac{\partial C^s}{\partial c} \times \frac{\partial c}{\partial E} > 0. \tag{7}$$

Suppose again that c in (1) is a function of D and E: i.e., $c(E, D) = \omega_0 + \omega_1 E + \omega_2 D + \omega_3(D \cdot E)$. The preceding discussions imply that ω_1 and ω_2 are negative. Moreover, ω_3 should also be negative if the interactive effect of D, given E, on c occurs. Consequently, (7) can be rearranged to (8).

$$\frac{\partial C^s}{\partial E} = \frac{\partial C^s}{\partial c} \times (\omega_1 + \omega_3 D) = \omega_1 \times \frac{\partial C^s}{\partial c} + \omega_3 \times \frac{\partial C^s}{\partial c} \times D. \tag{8}$$

The first term in (8), $\omega_1 \times \frac{\partial C^s}{\partial c}$, is positive. The sign of $\omega_3 \times \frac{\partial C^s}{\partial c}$ is positive because both $\frac{\partial C^s}{\partial c} < 0$ and ω_3 are negative. Note particularly that, from the finding that $\omega_3 \times \frac{\partial C^s}{\partial c} > 0$, the coefficient of the interaction term $(D \cdot E)$ in the crime supply function will be positive. This reflects the

[17] Specifically, assume $\mu(M, D) = \xi_0 + \xi_1 M + \xi_2 D + \xi_3(D \cdot M)$. Previous discussions suggest that ξ_1 and ξ_2 have negative signs. ξ_3 should be negative if the interactive effect of D, given M, on μ holds. Incorporating these into the expression for $\frac{\partial C^s}{\partial M}$, we obtain the positive sign of the interaction term's coefficient.

hypothesis concerning the aggravating effect of D on the $E-C^s$ relationship, which is also tested below.

4. Data and Empirical Design

We use a panel of 52 South Korean cities from 2005 to 2015. We refer to *Annual Crime Reports* for the incidence of crimes and deterrence variables.[18] We also use the Korean Statistical Information Service (http://kosis.kr) and *Statistics Yearbook* published by the government of each city for demographic and socioeconomic variables.[19] Particularly, we used MOLIT's *Data for Taxation of (Detached) Single-family Houses* to calculate the 'physical decay' across the 52 cities, as explained in Section 2.

The baseline equation for the supply function of conventional crimes is given by:

$$CR_{it} = \beta_0 + \beta_1 P_{a_{it}} + \beta_2 P_{p_{it}} + X'_{it}\beta_3 + D'_{it}\beta_4 + \mu_i + \lambda_t + \varepsilon_{it} \,. \quad (9)$$

Subscripts i and t in (9) represent the 52 cities and 11 years, respectively. In order to reflect the discussion in Section 2, the dependent variable is the conventional crimes rate (CR), defined as the annual number of conventional crimes per 100,000 residents. The explanatory variables include the probability of arrest (P_a), the probability of prosecution (P_p), proxies for physical decay

[18] The Supreme Prosecutors' Office of Korea publishes *Annual Crime Reports* that include basic crime statistics such as the numbers of crimes, arrests, dispositions, and prosecutions across 18 District Offices that can be adequately reclassified into 13 jurisdictions nationwide considering population size. Also the *Reports* provide the number of crimes across these 52 cities with population size over 100,000. In Korea, 77 cities are distributed in 16 metropolitan areas nationwide.

[19] We use metropolitan-level data for a few socioeconomic variables, due to the data limitations with respect to city-level data as given in Levitt (2002). Also, for the same reason, jurisdiction-level statistics are used for two deterrence variables (i.e., probability of arrest and probability of prosecution). These deterrence variables have generally been omitted in the economics of crime literature focusing on the decay-crimes nexus.

($\mathbf{D}$), and other control variables ($\mathbf{X}$). Parameter u_i and λ_t are the city- and year-fixed effects, respectively, and ε_{it} represents the error term.

Table 1 presents the definitions and descriptive statistics of the variables employed in the current paper. We first consider the two deterrence variables, P_a and P_p, which are expected to have negative impacts on CR. For demographic and socioeconomic variables, Male Population measures the proportion of the male population between the ages of 35 to 49. This variable is expected to be positively related to CR. Economic variables include the unemployment rate and regional income. Since the 2000s, the unemployment rate among a certain group has been extensively explored in order to find a variable representing a more crime-prone group. In this regard, we use the unemployment rate of people aged between 15 and 29 ($\text{Youth Unemployment}$). We also use the growth regional domestic product (GRDP) to capture the regional income, or to reflect the business cycle hypothesis that CR tends to increase during recessionary periods (Laspa, 2015; Byeon et al., 2018).

Three further socioeconomic variables are considered. First, single-parent families may indicate family disruption, resulting in positive impacts on CR (Sampson, 1986). We measure the ratio of single-parent households to the total number of households ($\text{Single-Parent Household}$). Second, criminological studies such as that by Meier and Miethe (1993) revealed that living alone leads to an increase in victimization. We use the share of one-person households (Single Household).[20] Third, the elderly population has less capacity to protect themselves against crime for the same level of exposure (Cook, 1986). We use the proportion of population aged 65 years and over (Elder Population).

[20] According to *Population and Housing Census* by Statistics Korea, the number of one-person households has rapidly increased since 2000. One-person households constituted 27.1% of the total households in 2015, an increase by 11.6%-points from 2000.

The independent variable of primary interest in the current paper is the control for physical housing decay. In Section 2, we hypothesized that the percentage of housing with the terms of construction over 30 years (Decay1) might be a reasonable proxy for physical deterioration pertinent to the housing development policy in Korea. According to our own calculation for the 52 cities for each year, Decay1 increased steadily up to a very high level of 46.6% in 2015, with a sample average of 37.5%.

Furthermore, we found that, in the urban or architecture studies concerning physical decay in South Korea such as that by Kim et al. (2009), the percentage of unauthorized buildings in such an area was used. Because an unauthorized building is defined as a construction outcome with no valid approval, it may be regarded as a reasonable proxy for physical decay from an economic perspective. Owners know that the illegal buildings in question are usually forcefully demolished or removed if detected. They would then tend to complete construction extremely rapidly, possibly using low-quality or faulty materials, in order to minimize the probability of detection. Even after completion of the buildings, the owners hardly have incentive to maintain their property because the buildings could be demolished or seized at any time by law. They can also be subject to severe penalties proportional to the assessed values of the property.

Therefore, we conjecture that physical decay of unauthorized houses progresses more rapidly than that of legal ones *ceteris paribus*. Thus, we define Decay2 as the proportion of unauthorized houses across regions and use the same data as that for calculating Decay1. In fact, this conjecture appears to be legitimate to a degree, although it is based on a rather limited statistical examination.[21] Hence, to the extent that Decay2 performs successfully in the following estimation, we might be able to suggest a useful proxy for future studies of a similar nature.

Finally, in the third group of Table 1, we include six variables as human (or societal) factors to capture our theoretical conjecture that the three *aggravating effects* of physical decay interact with human or environmental factors, as explained in Section 3. First, social disorganization theory suggests, as expressed in (5) of Section 3, that a decrease in informal social control increases the incidence of crime because it causes a decline in the self-control of potential offenders. We use two proxies for self-control that often appear in the economics or sociology literature. Alcohol drinking has been frequently used in the studies that estimate the crime supply function because the consequently weakened self-control is claimed to increase CR (Cook and Moore, 1993; Piquero et al., 2002).[22] Thus, we use the frequency of drinking as a proxy for alcohol use, i.e., the percentage of people aged from 19 years who drink alcohol at least once a month (Alcohol), which is the only available alcohol-related data at the city level. Divorce can also lead to increased instability through family conflicts and economic hardship as verified in Sampson (1986) and Cáceres-Delpiano and Giolito (2012). Family disruption such as divorce may interfere with the realization of community goals by indirectly decreasing self-control or social control (Sampson, 1986). We use the number of divorces per 100,000 residents (Divorce).

Second, as measures in testing the broken windows hypothesis, existing studies generally use misdemeanor, drug use, or motor vehicle fatality rates (Corman and Mocan, 2005; Braga et al.,

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[21] We were fortunately able to obtain more disaggregated data for Decay2 along with our main proxy (Decay1), i.e., for 25 districts in Seoul for 10 years from 2006. The correlation coefficient between Decay1 and Decay2 was calculated as 0.68 indicating a positive relationship. Data for Decay2 was also available from 2006 for the 52 cities in our main estimation.

[22] According to *Police Statistical Yearbook* by the Korean National Police Agency, in 2016 approximately 40% of homicides were committed by offenders during or after drinking alcohol.

2015). If this hypothesis holds, minor offenses are claimed to increase the number of more serious crimes including homicide, rape, or theft. Similarly, we adopt two conventional proxies used in the literature to test the hypothesis. One proxy, Traffic Offenses, refers to per-100,000 traffic offenses such as driving under the influence or without a license, and the other proxy, Drug Offenses, indicates the per-100,000 drug crimes.

Third, as shown in (7), an increase in exposure raises crime as it reduces the potential offender's crime cost (c) based on the routine activity theory. Particularly, representative proxies for the level of guardianship closely related to c include the percentage of non-regular workers and the share of female population of a certain age group. Non-regular workers have a higher likelihood of being victimized, as their type of employment tends to require evening or very early morning work (Cohen and Felson, 1979). We use Non-Regular Worker, which is defined as the percentage of non-regular workers to all labor force participants. Meier and Miethe (1993) claimed that females are more vulnerable when they are very young or elderly. Thus, we adopt the proxy, Young-Old Female, which is the female population rate aged under 20 years and over 60 years, as an alternative proxy for the routine activity theory.

[Table 1 here]

5. Empirical Results

5.1. Estimation of the Crime Supply Function

We now empirically investigate our main conjecture on the nexus between physical decay and conventional crimes in equation (4). The baseline estimation results for equation (9) are presented in Table 2. **BASE1** simply includes the probability of arrest (P_a) and the probability of prosecution (P_p). As expected, the coefficient estimate of P_a is negative and significant at the 1% level. The coefficient of P_p has the expected sign but is insignificant.

Traditional demographic and socioeconomic variables are added in **BASE2**. Overall, coefficient estimates are significant. For the economic variables, Youth Unemployment and GRDP are significantly associated with conventional crimes rate (CR) as confirmed in the literature. Social variables such as Single Household and Elder Population have expected signs with statistical significance. In addition, the coefficient estimate of P_p becomes statistically significant. Hereafter, the coefficients of P_a and P_p are fairly robust.

As the main task in the paper, we test for the effect of physical decay on CR. Our economic model in Section 3 suggested that physical decay increases the incidence of crimes at least via three channels. **BASE3** and **BASE4** show the results of Decay1 and Decay2 on CR, respectively.

In **BASE3**, the coefficient estimate of Decay1 has a positive sign with statistical significance. **BASE4** shows the results of using Decay2 as an new proxy. Its positive coefficient is significant at the 5% level, supporting our theoretical account of the nexus between physical decay and crimes. Therefore, the results so far with Decay1 and Decay2 appear to be consistent with Raleigh and Galster (2015) and Hipp et al. (2019).

Seoul Institute (2016) predicted that physical decay in Seoul would rapidly worsen.[23] The range of the predicted values varied according to assumptions, but the middle point in the range of Decay1 reached 60% in Seoul by 2040, a significant increase from the current sample mean by 20%-points. Thus, evaluated at the mean, the 20%-points would be associated with an increase in

[23] The essential implication should be legitimate although the future values of Decay1 were estimated based on the total housing survey reported in *Population and Housing Census* discussed in Section 2.

conventional crimes by about 25,450, which would correspond to 11% of the 2015 crime incidences of Seoul. Predicted values of Decay2 are yet to be made publically available, but its increase by one standard deviation, evaluated at the mean again, is calculated to increase crimes by 8% of the 2015 crime incidences of Seoul.

Before proceeding further, we examined potential endogeneity problems associated with Decay. First, areas with a greater number of crimes could cause physical decay. This conjecture is theoretically possible, and we indeed admit that residents in an area will reduce, or even cease, the maintenance of their property when the area is increasingly and widely recognized as a crime zone. Residents rationally cease to improve their houses, since the capital cost of the improvement would not be recuperated.

However, we believe that physical decay, at least in our empirical specification (9), is dominantly exogenous. Discussions in Section 2 persuasively suggest that the deepening of physical decay over time in Korea was predetermined largely by the construction technologies adopted along with the economic development plan and various housing supply policies that were rapidly implemented nationwide from the 1970s.[24] In addition, while it should take relatively longer time for the potential problem of reverse causality, if it exits, to be actually realized, the effect of physical decay on crime may take place immediately. Thus, our empirical analyses are expected to be free from this type of endogeneity problem. This expectation is reinforced by the use of data at a highly aggregated level.

Secondly, apart from the reverse causality above, unobserved factors that affect the crime regression and also are correlated with Decay, if it exists, can cause the omitted variable problem.

[24] While the variations in physical decay across regions were determined by economic or political priorities of the past administrations, the essential sources of the deepening of physical decay were identical. We greatly appreciate very constructive suggestions and encouragement by several commentators with regard to the issue of reverse causality.

Thus, we investigated these two-fold problems of endogeneity using the instrumental variable method. The Durbin–Wu–Hausman test confirmed the exogeneity of our two Decay variables in the two baseline specifications (i.e., $\mathbf{BASE3}$ and $\mathbf{BASE4}$).[25]

[Table 2 here]

5.2. Three Aggravating Effects of Physical Decay in Increasing Crimes

In this subsection, we test the hypothesis regarding the three *aggravating effects* in association with the nexus between physical decay and crimes. As explained in Section 3, the existing literature in sociology and criminology suggests that physical decay, due to the *interaction* with human (or societal) factors, may also raise crime indirectly via other routes than those expressed in equation (4). Therefore, as explained in equations (5) to (8) in Section 3, we intend to estimate the direct effects of additional human factors on crimes and their indirect effects interacting with physical decay. Note that, in this paper, the latter indirect effects have also been termed as the 'aggravating effects of physical decay interacting with such human factors'.

In order to estimate the aggravating effects, we use specifications $\mathbf{BASE3}$ and $\mathbf{BASE4}$ in Table 2. While Panel A of Table 3 reports the direct effects of six relevant factors on crimes and also the aggravating effects of Decay1 interacted with them, Panel B reports the identical analyses based on Decay2.[26]

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[25] For two instrumental variables for Decay, we first use the one-year lagged value. Also, we use the amount of damage due to natural disasters such as typhoon, heavy rain, or snow. Natural disasters would definitely affect physical decay, but there hardly exist relationship with crime rates as shown in Altindag (2012). We obtained relevant statistics from *Statistical Yearbook of Natural Disaster* published by the Ministry of Public Safety and Security. The DWH statistics ($\chi 2$) then ranged from 0.21 to 1.33, confirming the exogeneity of the two Decay variables.

[26] In order to focus on the aggravating effects, we do not report deterrence and other control variables in Table 3. As in $\mathbf{BASE3}$ and $\mathbf{BASE4}$ of Table 2, the coefficient estimates of the deterrence variables, along with other control variables, were overall significant. Detailed results are available upon request from the authors.

First, let us investigate the direct and indirect effects of human factors on crimes pertinent to the social disorganization theory. As explained in Section 3, weakened self-control or moral standard of people directly increases crimes, which can also be explained via a reduction of μ in our economic model, as expressed in (3). Further, this relationship is aggravated by the interaction with the reduced informal social control in the physically decayed areas, as expressed by $\tau_3 \times \frac{\partial C^s}{\partial \mu} > 0$ in (6).

We used $\mathrm{Alcohol}$ and $\mathrm{Divorce}$ as proxies for self-control. Columns 1 and 2 report the results concerning $\mathrm{Alcohol}$. The direct effect of $\mathrm{Alcohol}$ is positive with statistical significance as suggested by many studies including those by Raphael and Winter-Ember (2001) and Saridakis (2004). The coefficient estimate of the interactive term is also positive and significant, as concurring with Gottfredson and Hirschi (1990) and Spelman (1993). Therefore, we conclude that an increase in physical decay generally aggravates the crime-increasing effect of lowered self-control *ceteris paribus*.

Second, according to the broken windows theory, an increase in minor offenses tends to allow more serious crimes to be committed. Estimation results in association with $\mathrm{Traffic\ Offenses}$ in columns 5 and 6 robustly show the direct impact on crimes, which is consistent, for example, with results by Corman and Mocan (2005) and Braga et al. (2015). In column 6, the coefficient estimates of its interactive term with decay variables are also positive with statistical significance as Johansen et al. (2015) postulated. Thus, an increase in physical decay appears to aggravate the crime-increasing effect of $\mathrm{Traffic\ Offenses}$ *ceteris paribus*.[27]

[27] Nevertheless, our experimental use of $\mathrm{Drug\ Offenses}$ as another proxy does not provide as strong a result. Columns 7 and 8 indicate that both direct and indirect impacts are positive but statistically insignificant. This could be because Korea is designated a drug free country by the United Nations, so that drug use is not yet widely known to the public. As a consequence, unlike other countries, $\mathrm{Drug\ Offenses}$ was probably not playing the signaling role to potential criminals demanded by the broken windows theory.

Third, we explore the positive exposure-crimes relationship based on the routine activity theory. Columns 9 and 10 demonstrate the positive direct effects of our first proxy, $\mathrm{Non\text{-}Regular\ Worker}$. In particular, the interactive terms in Column 10 indicate that physical decay aggravates the crime-increasing effect given the same level of exposure. This aggravation takes place primarily because employment conditions tend to be more adverse in physically decayed areas, as observed by Skogan (1990) and Hipp (2007). Estimation results for $\mathrm{Young\text{-}Old\ Female}$ are reported in columns 11 and 12. Not only the direct effects of exposure, but also the indirect effects with physical decay are robustly confirmed. Therefore, from columns 9 to 12, we confirm that physical decay plays a catalyst role of accelerating the positive exposure-crimes relationship *ceteris paribus*, as expressed by $\omega_3 \times \frac{\partial C^s}{\partial c} > 0$ in (8).

As a final illustration in this empirical section, let us assess the actual scales of the above direct and aggregating effect, using the $\mathrm{Alcohol\text{-}CR}$ relationship that provided significantly robust estimates in Table 3. For the direct effect, an increase in $\mathrm{Alcohol}$ by 10%-points, evaluated at the mean, is calculated to increase crimes by a significant magnitude, which corresponds to as much as about 3% of the crime incidences nationwide (i.e., 29,830) for the year 2015. For the aggravating effect, the same increase in $\mathrm{Alcohol}$ interacting with the mean of $\mathrm{Decay1}$ would increase crimes by 7%-points, leading to an increase in the total effect by 10%-points. The scale of the aggravating effect of physical decay is fairly large. Calculation based on the specification related to $\mathrm{Decay2}$ provides a very similar result.[28]

To summarize, our analyses so far demonstrate that physical decay clearly increases crimes. Moreover, although experimental in nature, our work also suggests that physical decay is likely to

[28] An increase in $\mathrm{Alcohol}$ by 10%-points would be associated with increases in the crime incidences nationwide for the year 2015 by 2% and 9% for the direct effect and the aggregating effect, respectively.

play a catalyst role in accelerating the effect of other human and environmental factors on the incidence of crimes. Specifically, we confirmed that the crime-increasing effects of lowered self-control and greater exposure are significantly aggravated by physical decay. The aggravation phenomenon has also been at least partly confirmed for the crime-increasing effect based on the broken windows theory.

[Table 3 here]

6. Conclusion

The issue of physically deteriorated housing has become increasingly more serious in South Korea. In particular, the Korean National Police Agency diagnosed a physically deteriorated environment as a major reason for the increase in conventional crimes, observing that regions with old buildings, neglected houses, and improper maintenance are generally characterized as having serious crime problems. Similar views are shared by the central and local governments and their public research institutes.

Based on this background, this paper has explored the nexus between physical housing decay and crimes in terms of an economics of crime model. Furthermore, we investigated the aggravating effects of physical decay interacting with other human or environmental factors. Specifically, we examined the direct effects of these factors on crimes and their indirect effects interacting with physical decay via three major routes.

In order to empirically test our conjecture on the decay-crimes nexus, we employed two proxies for the physical housing decay: i.e., the percentage of housing with terms of construction over 30 years and the percentage of unauthorized houses. We also demonstrated that these two proxies might be reasonable proxies for physical deterioration in association with the housing development policy in Korea.

Using a panel of 52 cities including these two proxies of physical housing decay in Korea, we then found evidence that physical decay clearly increases crimes, controlling for two deterrence and various socioeconomic variables. Further, although this study is experimental in nature, we also provided evidence that physical decay is likely to play a catalyst role in accelerating the effect of other human and environmental factors on the incidence of crime. Particularly, we confirmed that the crime-increasing effects of lowered self-control and greater exposure across regions are significantly aggravated by physical decay.

Our estimation shows that conventional crimes of Seoul will increase by 11% in about 20 years *ceteris paribus* if the first proxy of physical decay above increases as predicted by Seoul Institute (2016). Assessment of the scales of the aggregating effects of physical decay interacting with other factors reveals more compelling consequences. For example, in the case of the alcohol-crime relationship that provided robust estimates, an increase in the frequency of drinking by 10%-points is calculated to directly increase crimes by a significant magnitude, which corresponds to as much as about 3% of the crime incidences nationwide for the year 2015. For the aggravating effect, the same increase interacting with the mean value of the first index of physical decay would increase crimes by 7%-points additionally. Thus, the aggravating effect of physical decay is literally accelerating.

While housing decay has worsened steadily, counter-measures are only at their inception. Nonetheless, the seriousness of physical decay will worsen more rapidly, especially considering that urban population is predicted to firmly decline in around 15 years. Although the suggestion of providing detailed policies is not the main concern of this paper, our findings have simple implications for reducing crimes in physically deteriorated areas.

First, as the basis of future relevant policies, it is important to carry out a thorough investigation of the current states of physical decay, across all regions and in a comprehensive manner. For example, while the data of terms of construction over 30 years has been used in this paper, it is only one indicator of physical deterioration. We suggest developing a composite index that reflects related factors including the ages of critical infrastructure and other socio-economic conditions.

Second, it seems an effective measure in the short run to extend the use of Crime Prevention through Environmental Design (CPTED) that has been implemented by some local governments. As claimed in the literature such as Katyal (2002) and Cozens (2008), CPTED effectively contributes to increasing an area's natural surveillance by private citizens, and contributes to introducing territoriality and reducing social isolation. In fact, CPTED's intended goals are generally consistent with the implications that can be drawn from our theoretical conjectures in Section 3.

Third, the stability and safety of the life of residents are apparently disrupted by physical decay. The conventional approach of reconstruction has been confined to only the physical replacement of the deteriorated housing. Nonetheless, such approach has revealed a limit to overcoming the disruption that already occurred in the region. The conventional policy should be accompanied by a package of revitalization and should include employment, public health and safety, education, the elderly living alone, etc. This extensive approach is ultimately expected to help reduce the occurrence of crimes.

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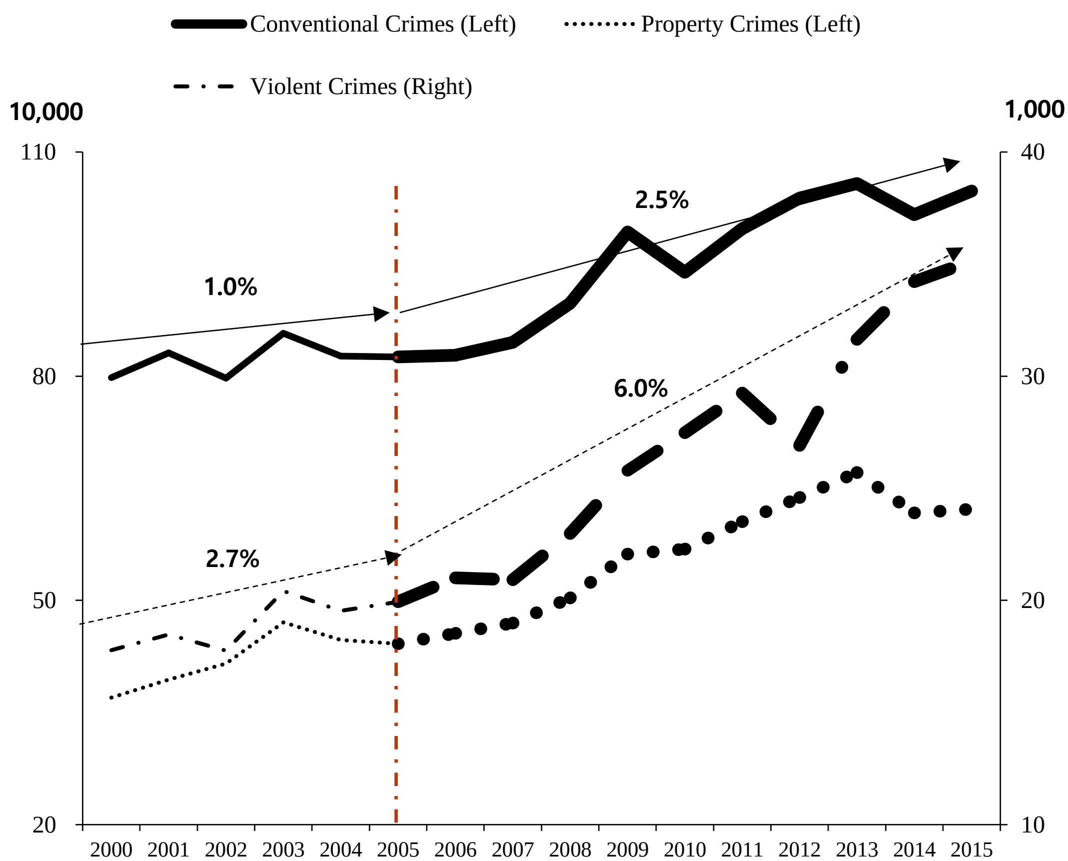
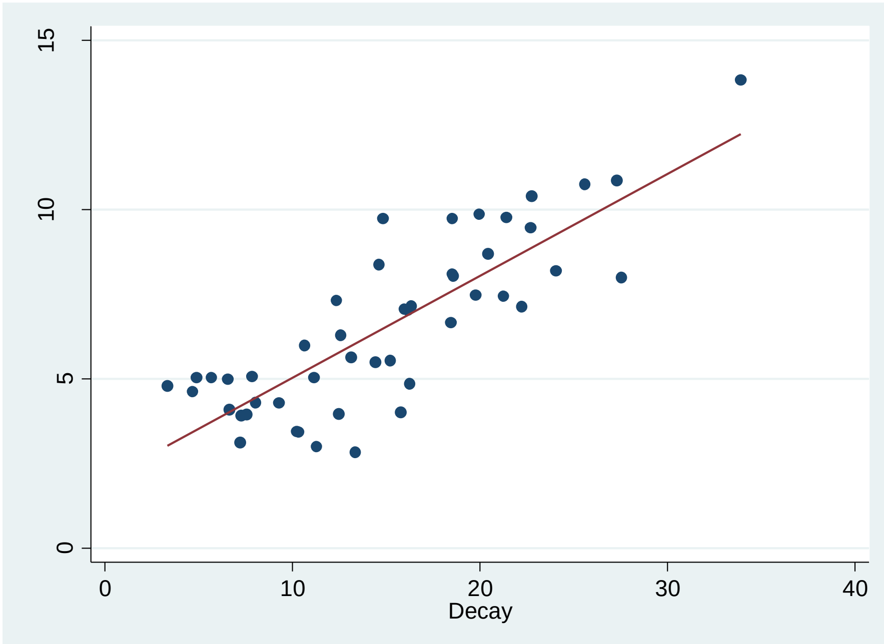
Figure 1. Frequency of Conventional, Property, and Violent Crimes: 2000-2015



Source: *Annual Crime Reports*, The Supreme Prosecutors' Office of Korea
Notes: Conventional crimes include violent crimes, property crimes, and others. Violent crimes include homicide, robbery, rape and sexual assaults, and arson. Property crimes include larceny-theft, burglary, motor-vehicle theft, vandalism, and others.

Figure 2. The Relationship between Degrees of Decay and Vacancy Rates in Korea



Source: *Population and Housing Census*, Statistics Korea.
Notes: Vacancy rate is the percentage of housing that is vacant within each metropolitan area. Housing is classified as being vacant if unoccupied and if the damage ratio is below 50%. The fitted line is estimated through a simple linear regression.

Table 1. Definition of Variables and Descriptive Statistics

Variables	Description	Mean (S.D.)	Data Unit
Crime and Deterrence Variables			
CR	Reported conventional crimes per 100,000 residents	1,891.9 (480.0)	52 Cities
P_a	Probability of arrest for conventional crimes (%)	73.5 (6.9)	13 Jurisdictions
P_p	Probability of prosecution for conventional crimes (%)	31.6 (2.2)	13 Jurisdictions
Control Variables and Physical Decay Proxies			
Male Population	Percentage of the male population aged 35 to 49 (%)	13.5 (1.3)	52 Cities
Youth Unempployment	Unemployment rate aged 15 to 29 (%)	7.5 (1.6)	16 Metropolitan areas
GRDP	Gross Regional Domestic Product (KRW)	1,450.6 (236.9)	16 Metropolitan areas
Single-Parent Household	Share of single-parent households (%)	8.9 (1.5)	16 Metropolitan areas
Single Household	Share of single households (%)	24.6 (3.7)	16 Metropolitan areas
Elder Population	Percentage of the population aged 65 years and over (%)	13.6 (4.6)	52 Cities
Decay1	Percentage of housing with the terms of construction over 30 years (%)	37.5 (10.2)	52 Cities
Decay2	Percentage of unauthorized houses (%)	11.5 (7.5)	52 Cities
Human and Environmental Factors Interacting with Physical Decay			
Alcohol	Percentage of people aged from 19 years who drink at least once for a month (%)	57.6 (4.9)	52 Cities
Divorce	Number of divorces per 100,000 residents	47.5 (9.2)	52 Cities
Traffic Offenses	Reported traffic crimes per 100,000 residents	1,082.5 (578.9)	52 Cities
Drug Offenses	Reported drug crimes per 100,000 residents	875.3 (236.5)	52 Cities
Non-Regular Worker	Percentage of non-regular workers to all labor force participants (%)	18.5 (5.6)	52 Cities
Young-Old Female	Female population rate aged under 20 years and over 60 years (%)	5.3 (1.8)	52 Cities

Table 2. Crime Supply Function with Physical Decay: Baseline Specifications

	BASE1	BASE2	BASE3	BASE4
P_a	-16.855*** (3.418)	-15.834*** (2.749)	-16.545*** (3.717)	-14.419*** (3.464)
P_p	-12.946 (10.665)	-13.102** (6.112)	-13.793* (7.896)	-12.553* (7.824)
Male Population		88.565* (47.578)	84.402 (74.591)	81.409** (39.519)
Youth Unempoyment		25.918** (12.279)	30.509* (13.787)	26.665* (14.450)
GRDP		-199.156** (98.106)	-200.215** (101.855)	-217.391** (104.015)
Single-Parent Household		5.412 (4.361)	5.289 (5.957)	4.501* (2.418)
Single Household		42.814* (23.143)	40.675* (29.253)	39.255 (33.894)
Elder Population		33.526** (16.524)	28.921 (22.636)	36.334* (19.747)
Decay1			12.697* (6.901)	
Decay2				25.557** (11.516)
Constant	3,288.6*** (465.0)	2,958.5*** (441.9)	3,240.1*** (591.9)	3,016.3*** (498.3)
R^2	31.2%	63.4%	64.1%	65.2%
No. of obs.	572	572	572	520
No. of cities	52	52	52	52

Notes: All columns include city and year dummies. Estimation methods are fixed effects. Cluster-robust standard errors are reported in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$). While the sample period of Decay1 was from 2005 to 2015, that for Decay2 was from 2006 to 2015.

Table 3. Aggravating Effects of Decay1 and Decay2 Interacted with Other Human and Environmental Factors

Specification from BASE3 and BASE4	1	2	3	4	5	6	7	8	9	10	11	12
Panel A: Decay1												
Decay1	13.634*	11.563*	14.699*	13.575*	15.207*	14.542*	15.572*	16.503*	15.755*	12.326*	13.755*	11.326*
	(7.304)	(8.984)	(7.989)	(7.089)	(8.310)	(7.903)	(9.250)	(9.992)	(10.037)	(9.065)	(7.395)	(6.257)
Alcohol	5.789**	4.806**										
	(2.810)	(2.369)										
Divorce			1.412*	0.994								
			(0.768)	(1.529)								
Traffic Offenses					0.058**	0.046*						
					(0.027)	(0.022)						
Drug Offenses							8.867	7.848				
							(5.673)	(5.661)				
Non-Regular Worker									5.180**	3.368**		
									(2.447)	(1.472)		
Young-Old Female											19.200***	17.283*
											(8.472)	(10.603)
Decay1 × Factor		0.446**		0.946*		2.426*		5.258		10.176**		7.877**
		(0.203)		(0.494)		(1.304)		(6.812)		(4.925)		(3.813)
Panel B: Decay2												
Decay2	24.036**	22.116*	23.797*	21.314*	24.094*	22.542*	24.876*	26.411*	25.121*	22.060*	21.159*	20.601*
	(11.782)	(10.841)	(13.004)	(11.647)	(13.166)	(12.318)	(13.598)	(14.432)	(13.727)	(11.860)	(11.376)	(11.076)
Alcohol	4.925**	4.001**										
	(2.414)	(1.898)										
Divorce			1.002*	0.888								
			(0.662)	(1.512)								
Traffic Offenses					0.053*	0.041*						
					(0.029)	(0.022)						
Drug Offenses							7.807	9.012				
							(7.573)	(10.659)				
Non-Regular Worker									6.082*	5.911**		
									(3.306)	(2.855)		
Young-Old Female											18.901*	16.253*
											(10.272)	(8.833)
Decay2 × Factor		0.541**		0.746*		2.726*		6.858		13.876**		16.911**
		(0.215)		(0.466)		(1.482)		(7.012)		(6.703)		(8.170)

Notes: Other independent variables are not reported. All columns include city and year dummies. Estimation methods are fixed effects. Cluster-robust standard errors are reported in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$). While the sample period of Decay1 was from 2005 to 2015, that for Decay2 was from 2006 to 2015.