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Research Report

Environmental Benefits of Green Space: Focusing on the Seoul Metropolitan Area

KDI Policy Study, No. 2015-02

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Environmental Benefits of Green Space:

Focusing on the Seoul Metropolitan Area

Hyungtai Kim
John I. Carruthers

A large, stylized grey L-shaped graphic element located on the left side of the cover.

KOREA DEVELOPMENT INSTITUTE



Environmental Benefits of Green Space: Focusing on the Seoul Metropolitan Area

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| Preface |

This paper is set in the Seoul metropolitan area (SMA) and attempted to analyze the Korean population's behavior vis-à-vis to open space and other factors that determine housing prices. Using the spatial econometric method and the comprehensive real transaction price data and other geocoded socio-economic data of the entire SMA apartment market between 2012 and 2014, the analysis reveals that marginal implicit prices can be monetized by using estimates from the revealed preference method of hedonic price analysis and shows the SMA residents are willing to pay higher premiums for green and open spaces and other favorable unit and location attributes. The present analysis also suggests that, having marginal implicit prices in hand, a global demand curve can be derived – which can be then used as an important tool to estimate economic benefits of environmental attributes of the project. It is important that economic benefits of environmental projects – public goods for which there is no entrance fee and therefore economic benefits cannot be estimated with a conventional economic analysis – can be estimated with revealed preference methods which are considered theoretically and empirically more sound than stated preference methods such as contingent valuation method that has been heavily used for estimating environmental benefits for practical reasons although it often produces inconsistent results.

Joon-Kyung Kim
President of KDI

| Contents |

Preface	
Summary	1
Chapter 1	
Introduction	3
Chapter 2	
Research Methodology and Data Requirements	7
Chapter 3	
Research Setting and Dataset	12
Chapter 4	
Independent Variables	20
Chapter 5	
Model and Estimation Results	28
Chapter 6	
Policy Implications and Future Research	37
Chapter 7	
Summary and Conclusion	40
References	42
Appendix	48

| List of Tables |

Table 3-1	Nation-wide Proportion of Apartment over Time	13
Table 3-2	Proportion of Apartment over Time in the SMA	13
Table 3-3	Average Transaction Prices in the SMA by Size	14
Table 3-4	Average Transaction Prices within Seoul	16
Table 3-5	Average Transaction Prices in the SMA by Year	16
Table 4-1	Definition of Explanatory Variables	20
Table 4-2	Descriptive Statistics	22
Table 4-3	Proportion of above-average students in the NPT by Region	24
Table 4-4	Household Income Level by Region	25
Table 4-5	Average Commuting Time by Region	26
Table 5-1	S2SLS Estimates of Hedonic Price Function	29
Table 5-2	Marginal Implicit Prices Monetized for the SMA	31
Table 5-3	Marginal Implicit Monetized for Gangnam Area	32
Table 5-4	Demand Estimation of Park	34
Table 5-5	Demand Estimation of River	34

| List of Figures |

Figure 3-1	The Seoul Metropolitan Area	12
Figure 3-2	Frequency of Transactions in the SMA	15
Figure 3-3	Transaction Price in the SMA	15
Figure 5-1	Consumer Surplus	35

Summary

The current empirical analysis is set in the Seoul metropolitan area and attempted to analyze the Korean population's behavior vis-à-vis to open space and other factors that determine housing prices. Using the comprehensive real transaction price data and other geocoded socio-economic data, the analysis reveals that marginal implicit prices can be monetized by using estimates from the revealed preference method of hedonic price analysis and shows the SMA residents are willing to pay higher premiums for green and open spaces and other favorable unit and location characteristics. For example, the present analysis shows that homes decrease in value at rates of 14,614 KRW and 9,958 KRW per meter of distance: homes located closer to these amenities are worth more than those located at a distance. It implies that the government needs to pay a great deal of attention in a location decision of green and open spaces since new investment in green and open spaces would be likely to entail positive externalities or pitfalls in general.

The present analysis also suggests that, having marginal implicit prices in hand, a global demand curve can be derived – which can be then used as an important tool to estimate economic benefits of both environmental and non-environmental attributes of the project of our interests. It is important that economic benefits of environmental projects – public goods for which there is no entrance fee and therefore economic benefits cannot be estimated with a conventional economic analysis - can be estimated with revealed preference methods (i.e. hedonic price model) which are considered theoretically and empirically more sound than

stated preference methods such as contingent valuation method because revealed preference methods analyze the behavior of actual market participants with advanced statistical methods.

Nevertheless, we should be cautious when applying hedonic price models to estimate economic benefits of environmental projects when the size and scale of the investment projects are large. This is because the scale and size of public goods investment projects that PIMAC analyzes are often so large that the spatially influenced area is also often large, which implies that it is likely that non-use values – which revealed preference methods cannot capture by nature - are in play. A vast size of area set in the present analysis helps to estimate economic benefits of large-scale projects. If non-use values are in play, however, socio-economic benefits will be, in theory, smaller than benefits predicted by contingent valuation methods. In such cases, we need to be cautious for applying revealed preference methods. Nevertheless, contingent valuation methods are subject to various types of biases arisen from diverse sources inherent in surveys and the well-known fact that free riders consuming public goods are less likely to state their WTP accurately. This often entails political conflicts in an investment decision making, which gives lights to consideration of revealed preference methods such as hedonic price models given that a more robust structural model is developed by the research followed.

CHAPTER 1

Introduction

This report describes the results of a revealed preference analysis of the economic value of open – “green” – space and other neighborhood amenities in the Seoul metropolitan area (SMA), South Korea. It focuses specifically on how households value two forms of green space: access, measured as proximity, to parks and water. The analysis involves two components, both of which are in line with the Korea Development Institute’s (KDI’s) mission of delivering scientifically based benefit cost analyses (BCAs) of public investments. The first component is positive, or scientific: its objective is to monetize the value the Korean population values open space – specifically, given Koreans’ psychological attachment to nature and, then, which types of open space are valued and how. The second component is normative, or policy-oriented: its objective is to inform decision-making processes related to the creation and/or preservation of open space. It is a well-known fact that people value nature and open space related amenities, so this is not in question. Rather, the research delivers new findings – specific to Korea and the Korean culture – about quantifying the benefits of open space and suggests avenues for deeper research that can inform the implementation and evaluation of public policies related to open space.

KDI is the Korea’s leading research institute focused on economic development and public policy analysis. In particular, the Public and Private Infrastructure Investment Management Center (PIMAC) is tasked

with carrying out BCAs of public investment throughout Korea. However, PIMAC's capacity for evaluating the social benefits of open space and other amenities is presently under-developed. For various reasons, PIMAC relies heavily on *stated preference (SP)* methods of valuation. Such reasons include that SP is more practical to use because it surveys the WTP (willingness to pay) directly and because it can take non-use values into account. However, it is subject to various biases that arise from the fact that it is based on surveys in hypothetical market settings while revealed preference (RP) methods analyze the actual behavior of market participants. So from the practical point of view, it is not uncommon that different WTPs are derived from SP when repeated surveys are conducted on basically the same project. In this respect, results of the current analysis are expected to expand PIMAC's capacity for environmental valuation by helping establish a *revealed preference* modeling framework for valuing open space. Specifically, it employs a hedonic price analysis (Rosen, 1974) of the apartment market of the Seoul metropolitan area (SMA) to begin probing households' WTP for open space. The model, presented in this report, is well developed and is designed to be used to explore not only the value of open space – but also the value Koreans place on other quality-of-life enhancements.

The tradeoff between stated preference methods and revealed preference methods is not as concrete as it is often portrayed to be. In particular, revealed preference methods – especially the hedonic price approach, which is used here – is exceptionally data and time intensive. Therefore, revealed preference approaches are often impractical for the pressing and time sensitive day-to-day valuation work that PIMAC is tasked with doing. The advantage of stated preference – indeed, its whole reason for being – is that it is a sound and practical approach to estimating WTP with a minimum of data and time. Research comparing the two approaches generally finds that they converge on the same solution when done properly (see, for example, Champ *et al.*, 2003; Freeman *et al.*, 2014), especially when non-use values are expected minimal. As a matter of *science* the revealed preference method is very important – however, as a *practical* matter, the costs of using it generally (far) outweigh the benefits, so it is often confined to scientific research applications like the present report. That having been said, an important contribution of this

work is that it provides PIMAC with a working hedonic price model that, with some more efforts, can be applied to practical valuation problems throughout the SMA. A worthwhile extension of the project would be to apply the model to selected PIMAC projects in order to compare results obtained via stated and revealed preference approaches.

The analysis itself – which engages more than 148 trillion KRW, or about 129 billion USD, in housing transactions – reveals, among other things, that open space and other amenities exert considerable force within the SMA’s real estate market: households pay substantially for access to parks, water, and other neighborhood attractions. Specifically, home values are estimated to decrease by 14,614 KRW (12.7 USD) per meter of distance from parks and by 9,958 KRW (8.66 USD) per meter of distance from water. Other locational factors that matter include school quality; neighborhood income; proximity to the center of Seoul; access to the metro system; commuting time; and distance from arterial roads – which produce noise pollution and other environmental contaminants. A particularly interesting finding is that, all else being equal, residents of Seoul’s prestigious Gangnam district pay an average premium of 278,000,000 KRW (241,740 USD) for the privilege of living there. This general finding is a measure of a cultural zeitgeist that has recently swept the globe and a manifestation of Seoul’s primacy as a world city – it is also an important discovery that merits detailed exploration via further research.

Before moving on, it is important to be clear about objectives. This report develops a hedonic price model of the Seoul Metropolitan Area (SMA) apartment market. The model is a revealed preference tool that is used to estimate the marginal implicit price of numerous neighborhood amenities and that, eventually, can be used to estimate the consumer surplus associated with those amenities. The project is policy-oriented in the sense that it models the SMA real estate market in a manner that reflects existing public policies and opens the door to policy evaluation. However, this report is not prescriptive: it stops short of saying what government *should do* as a matter of policy. It stops short because what it delivers is a tool for evaluating this – not the policy scenarios that can (and should) eventually be evaluated. For example, the focus of the analysis is on green space - proximity to parks and water - and it

illustrates that these amenities are important to the Korean population. The report also sketches out what the demand curves for these amenities might look like. What the report does not do is to propose actionable policy scenarios wherein estimated benefits can be weighed against estimated (or known) costs. As explained in Chapter 6, that work is left for future research.

The next chapter elaborates methodology and data requirements, followed by elaboration of research setting and dataset, explanatory variable, and model and estimation results. The current report ends with summary and conclusion.

CHAPTER 2

Research Methodology and Data Requirements

Hedonic price analysis is a revealed preference¹ method of disaggregating the value of differentiated commodities – those, like housing, having multiple attributes that collectively account for total value – into their component parts. The name, derived from hedonism, and initial application are generally attributed to Court (1939) – who used the method to study the automobile industry – but there is evidence that something resembling it was used to evaluate farmland as early as the 1920s (see Colwell and Dilmore, 1999).² Whatever its inception, hedonic analysis was first applied to housing by Ridker and Henning (1967) before being formalized by Rosen (1974) in his famous paper, *Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition*. Since then, it has evolved into what is perhaps the best econometric method of valuing environmental quality and other non-market goods via housing markets (see, for example, Palmquist, 2005). The method has also been applied to labor markets for interregional quality of life analysis – beginning with Rosen (1979) and Roback (1982)³ – but the present focus is squarely on an intraregional application to the apartment market

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- ¹ Revealed preference approaches, such as hedonic pricing, differ from stated preference approaches, such as contingent valuation, in that they rely on actual, observed preferences rather than hypothetical expressions of preferences (see Freeman, 2014 for overviews of the full spectrum of methods available for getting at the value of non-market goods and services).
 - ² Palmquist (2005) notes that Griliches (1971) – who like Court (1939) applied hedonic price analysis to the automobile industry – also helped popularize the approach.
 - ³ For a review, see Gyourko *et al.* (1999).

of the SMA.

Hedonic analysis casts housing as a bundle of k separable attributes, z , so that the total selling price, p , is a function of the prices of those attributes: $p(z) = p(z_1, z_2, \dots, z_k)$. Within this framework, the demand for any particular attribute can be estimated via the two-step process. In the first step, the price of housing is regressed on all of the things that influence it – structural characteristics, location, neighborhood features, environmental factors, and more:

$$\tilde{p}_i = \alpha_0 + \lambda \cdot W_{ij} \cdot \tilde{p}_j + \alpha_1 \cdot z_{i1} + \alpha_2 \cdot z_{i2} \dots + \alpha_k \cdot z_{ik} + \epsilon_i \quad (1)$$

This equation is the first-step hedonic price function and, in it: \tilde{p}_i represents the natural logarithm of the sales price of home i ; the z s represent measures of housing attributes; the α s represent estimable parameters; and ϵ_i represents a stochastic error term. If the function were linear, the α s themselves would register the implicit price schedule, but, in semi-log form, the prices are calculated as: $\hat{\pi}_{ik} = \hat{\alpha}_k \cdot p_i$.⁴

The specification of hedonic price models of housing markets is well established (see, for example, Baranzini *et al.*, 2008). In particular, the vector of housing attributes must characterize the home itself; its location within the region vis-à-vis major destinations and other attractions; the demographic makeup of the neighborhood it is located in; and location-specific amenities that shape the housing market. While the specific variables included depend upon data availability and the nature of the individual market being investigated, the overall specification is general – with the basic set of features being applicable across most housing markets in advanced economies. There is, however, reason to believe that, because of how quality-of-life of felt, different cultures value the same amenities differently – and, likewise, altogether different amenities (see Inoguchi and Fujii, 2013; Glatzer *et al.*, 2015). For this reason, a very important contribution of the present research is that it delivers the core

⁴ When both variables are logged, the marginal implicit price is calculated as: $\hat{\pi}_{ik} = \hat{\alpha}_k \cdot p_i / z_i$. There is no “one way” to estimate the first-step function, but it should *not* be linear: it should be either log-linear, as done here, or log-log. The latter results in a multiplicative model wherein the parameters are interpreted as elasticities – the more conservative (and parsimonious) approach is the log-linear model.

tool – namely: a fully specified hedonic price model of the housing market of the SMA – that can be used to explore any number of factors beyond those of immediate concern.

Turning back to equation (1) note that the hedonic price function contains a spatial lag of the dependent variable, expressed as $W_{ij} \cdot \tilde{p}_j$, and a corresponding spatial autoregressive parameter, λ . The lag – where W_{ij} ($j \neq i$) is a row-standardized $n \times n$ weights matrix describing the arrangement of homes – is included in order to account for spatial interaction among market participants. In particular, on the supply side, proximate homes are usually similar to each other, and, on the demand side, homebuyers generally emulate one another’s behavior, especially within submarkets. Further, financing typically involves the use of “comparable sales,” where an underwriter looks at nearby transactions in order to establish value before a loan is issued. In short, both theory and practice make a good case for the inclusion of a spatial lag (Kim *et al.*, 2003; Theebe, 2004; Brasington and Hite, 2005; Palquist, 2005; Anselin and LeGallo, 2006; Anselin and Lozano-Gracia, 2008; Cohen and Coughlin, 2008; Carruthers and Clark, 2010; Bin *et al.*, 2011; Nappi-Choulet and Maury, 2011; Small and Stemetz, 2012). But, because the behavioral rationale for the lag is that the sales prices of nearby homes influence each other, including it adds an endogeneity problem to the hedonic price function that must be resolved via an appropriate estimator. There exists an array of competing ideas about how (and, indeed, if) to handle the problem – see: Anselin, 2010; McMillen, 2010 – but a reasonably mild treatment is a spatial two-stage least squares (S2SLS) estimator developed by Kelejian and Prucha, (1998). The solution involves first regressing the spatially lagged dependent variable on all explanatory variables plus spatial lags of those same variables in order to produce predicted values (say, $\widehat{W_{ij} \cdot \tilde{p}_j}$) and then using those predicted values in place of the actual values in a second-stage equation; like other, more elaborate remedies – often designed for more nuanced econometric circumstances – S2SLS yields efficient, unbiased estimates, even in the case of spatial error dependence (Das *et al.*, 2003).

Next, in the second step of hedonic analysis, observed quantities of individual housing attributes are regressed on the implicit prices estimated via the first step, plus other factors relevant to demand:

$$\tilde{q}_i = \beta_0 + \gamma_{ik} \cdot \hat{\pi}_{ik} + \beta_1 \cdot x_{i1} + \beta_2 \cdot x_{i2} \dots + \beta_{s2} \cdot x_{is} + u_i. \quad (2)$$

This equation is the second-step implicit demand function and, in it: \tilde{q}_i represents the natural logarithm of the quantity of attribute z_k consumed by household i ; $\hat{\pi}_{ik}$, which is endogenous, represents the estimated price paid; the x s represent demand shifters, including income and other demographic factors that influence preferences; the γ and β s represent estimable parameters; and u_i represents a stochastic error term. Like the hedonic price function, the implicit demand function contains an endogenous variable and, so, cannot be estimated via ordinary least squares (OLS). Whereas the problem in the former arises from spatial interaction among market participants, the problem in the latter arises from interaction between supply and demand – which is what led Rosen (1974, page 50) to characterize it as a “garden variety” problem, easily resolved via a commonplace two-stage least squares (2SLS) estimator.

Variations on the first step of hedonic price analysis have been productively used to examine many general forms of environmental quality (Boyle and Kiel, 2001; Carruthers and Mundy, 2006; and Kiel, 2006 provide in-depth reviews). It has also been used to examine a number of specific environmental hazards (for example, Kohlhase, 1991; Kiel and McClain, 1995; Clark *et al.*, 1997; Hite, 1998; Clark and Allison, 1999; Dale *et al.*, 1999; Hite *et al.*, 2001; Bae *et al.*, 2007; Brasington and Hite, 2008). And, recently, there has been a revived interest in the second stage of hedonic price analysis, which has been used to evaluate the demand for air quality (Chattopadhyay, 1999; Zabel and Kiel, 2000), neighborhood and school quality (Cheshire and Sheppard, 1995; 1998; 2004; Black, 1999; Brasington, 2000; 2003), and distance from environmental hazards (Brasington and Hite, 2005; Carruthers and Clark, 2010). Along with the growing commitment to second-stage analysis, there have been important advances in sharpening first-stage analysis, including the improvements – cited above – that use spatial econometric methods to evaluate environmental quality. Still other spatial analyses – beginning with work by Can (1990; 1992) – have found that there is a high degree of heterogeneity in housing attribute prices (Mulligan *et al.*, 2002; Fik *et al.*, 2003; Bitter *et al.*, 2007). This branch of research is not explored in the present report, but the authors intend to pursue it in future

work.

The first step of hedonic price analysis is inarguably an outstanding tool for probing the kinds of environmental quality and other non-market goods that influence housing markets and for estimating their marginal influence on housing prices. But, while notable exceptions continue to arise – Ho and Hite (2008)’s evaluation of cancer mortality and Bin *et al.* (2011)’s evaluation of sea-level rise are two good examples – first-step analysis seems to have reached the limit of its ability to yield much fresh insight into household behavior and/or to help refine public policy. It has long been understood that people expect to pay premiums for housing attributes they like and expect to be compensated for those they dislike, so it is easy to assert that environmental quality matters to housing markets. But quantifying the various exchanges involved is much more difficult, because holistic valuation requires knowing the aggregate relationship between the price paid and the quantity consumed, which means moving on to, and coming up with, a believable second-step implicit demand function. The difficulty lies in finding theoretically sound and empirically tractable ways of doing so – that is, of identifying the demand equation.

While this project stops short of identifying structural demand parameters it delivers the foundation necessary for deriving them – and begins to explore what they might look like. There is no scientific consensus on whether or not the hedonic method can precisely measure deep demand parameters, but it is nonetheless the best available tool. For that reason, the model delivered herein is a powerful tool for exploring demand for any number of non-market goods that are traded in the apartment market of the SMA. There is no “one-size-fits-all” solution for deriving demand parameters, but we believe that the model described in the following chapter is a tool that can be used to estimate them.

CHAPTER 3

Research Setting and Dataset

The empirical analysis is set in the Seoul metropolitan area – mapped in Figure 3-1 – which consists of three regions: the city of Seoul, the city of Incheon, and Gyeonggi-do. The empirical analysis focuses on the apartment market in the SMA since it is currently the most popular type of residence. For example, the proportion of the apartment out of the total housing stocks has increased from 7.0 % in 1980 to 58.4 % in 2010 and represents the most popular housing type in Korea as shown in Table 3-1. And this proportion becomes larger when it comes to the SMA as shown in Table 3-2.

|| Figure 3-1 || The Seoul Metropolitan Area

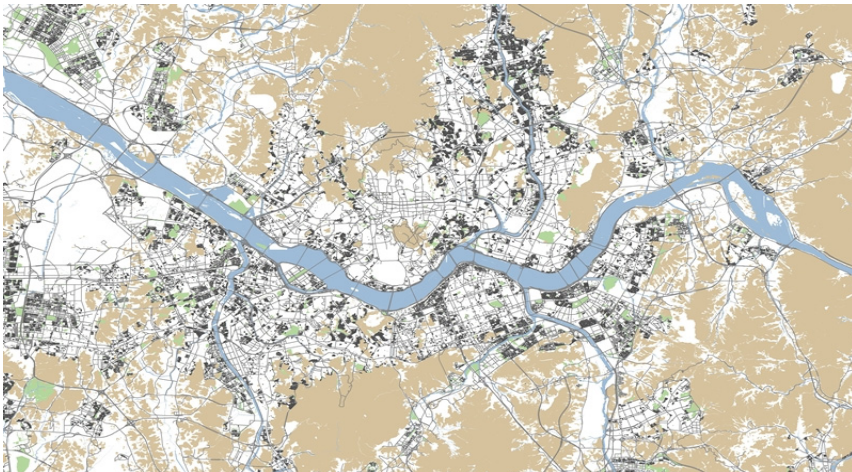


Table 3-1 | Nation-wide Proportion of Apartment over Time

Nationwide	1980	1990	2000	2005	2010
Total Housing (1,000)	5,319	7,160	10,959	13,223	14,677
Apartment (1,000)	374	1,628	5,231	6,963	8,576
Percent (%)	7.0	22.7	47.7	52.7	58.4

Source: KOSIS, Housing Census.

Table 3-2 | Proportion of Apartment over Time in the SMA

Nationwide	1980	1990	2000	2005	2010
Total Housing (1,000)	1,646	2,739	4,576	5,782	6,565
Apartment (1,000)	224	894	2,470	3,363	4,154
Percent (%)	13.6	32.6	54.0	58.2	63.3

Source: KOSIS, Housing Census.

The data, which originate mainly from the real transaction price dataset of the Ministry of Land, Infrastructure, and Transportation (MOLIT), include 458,941 transactions for apartment homes that took place between 2012 and 2014. The average sales price is 323 million KRW and the total amount of transactions used for the research amounts to 148 trillion KRW during the period. Given Korea’s unique approach to the rental market, Jeon-se, an interesting question is: why not use Jeon-se rents in a revealed preference analysis? Previous analyses employed Jeon-se price (Yoon and Choi, 2011; Kim and Kwon, 2014) based on the assumption that there would be no speculation involved or, in other words, no investment values are in play – so only real amenities are reflected in Jeon-se price. Especially Yoon and Choi (2011) mention that they used the Jeon-se price because the study area is known to be a good area for real estate investment. But Jeon-se price has increased rapidly – and the Jeon-se market has been volatile – in recent years, which is partly attributed to the imbalance in the supply and demand in the Jeon-se market. And, it is not clear that only real amenities are reflected in the Jeon-se price – nor has Jeon-se price been shown to be superior to sales data. In addition, it seems that there is not much difference between using sales data and Jeon-se data according to previous literature (Jin and Son,

2005). In this respect, we assume that real transacted values used in the present research are as good as Jeon-se prices and are more appropriate measures than asking prices employed in many previous analyses.

The average prices per square meters are 5.74 million KRW for city of Seoul, 2.77 million KRW for city of Incheon, and 3.23 million KRW for Gyeonggi-do, which shows that there exist regional differences in average sales prices as shown in Table 3-3.

The number of transactions is different across regions as shown in Figure 3-2 and transacted prices are also very different across regions as

Table 3-3 | Average Transaction Prices in the SMA by Size

(unit: tens of thousands KRW/m²)

Size	Region	Seoul	Incheon	Gyeonggi
	under 60m ²	obs	69,722	36,936
mean		580.5	267.8	317.1
min		123.3	75.0	33.3
max		2,160	643.8	1,840
60-85m ²	obs	77,117	34,585	91,330
	mean	542.3	272.9	322.0
	min	153.0	100.0	36.5
	max	2,250	541.2	1,220
85-135m ²	obs	24,572	12,345	31,108
	mean	597.7	310.7	343.9
	min	150.0	102.5	69.6
	max	2,250	621.9	1,250
over 135m ²	obs	6,847	1,655	5,425
	mean	781.1	322.4	327.9
	min	185.5	122.3	74.9
	max	3,370	951.9	1,350
Total	obs	178,258	85,521	195,200
	mean	574.1	277.1	323.6
	min	123.3	75.0	33.3
	max	3,370	951.9	1,840

Note: The real transaction price dataset of the Ministry of Land, Infrastructure, and Transportation(MOLIT), 2012~2014.

shown in Figure 3-3 and they are based on year 2010-2014. Table 3-4 also shows that there exists a huge price difference within a city. For example, average price in Gangnam is 9.23 million KRW while is 4.93 million KRW in other areas in Seoul, which indicates that Gangnam premium could exist even after controlling other favorable factors such

Figure 3-2 Frequency of Transactions in the SMA

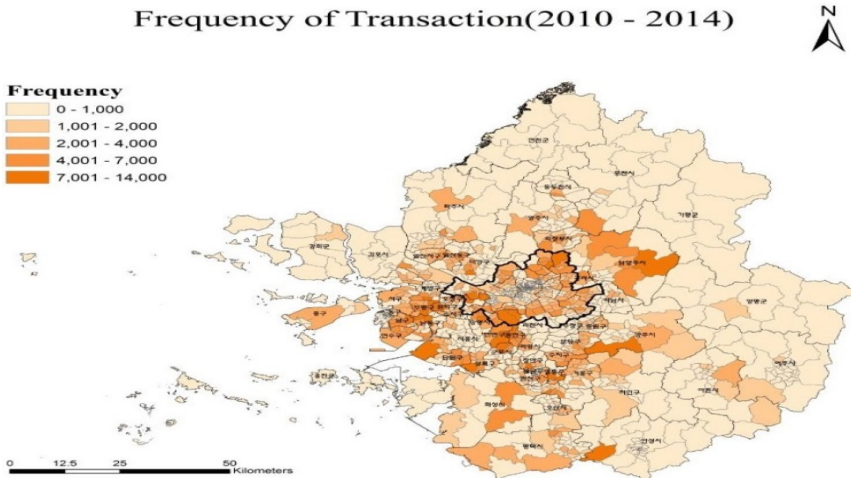


Figure 3-3 Transaction Price in the SMA

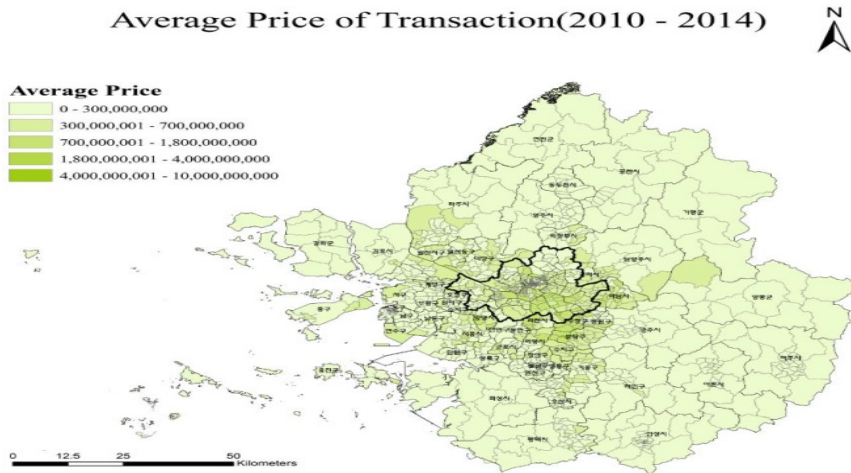


Table 3-4 | Average Transaction Prices within Seoul

(unit: tens of thousands KRW/m²)

Size \ Region		Region	
		Gangnam	Other Seoul
Total	obs	33,480	144,778
	mean	923.2	493.3
	min	217.1	123.3
	max	3,370	2,690

Note: The real transaction price dataset of the Ministry of Land, Infrastructure, and Transportation (MOLIT), 2012-2014.

as access to better education chances. The number of transactions is generally larger in small and small-medium size categories across regions. Average sales prices increase in Seoul and Incheon as the size of the apartment homes becomes large while those are about the same in Gyeonggi-do. For example, average sales prices increase from 5.80 million KRW to 7.81 million KRW in Seoul as the size become large while average prices are higher in small-medium and medium-large apartment categories in Gyeonggi-do.

An annual snapshot shows that the number of transactions has increased during the period as shown in Table 3-5.

Table 3-5 | Average Transaction Prices in the SMA by Year

(unit: tens of thousands KRW/m²)

Year \ Region		Region			
		SMA	Seoul	Incheon	Gyeonggi
2012	obs	111,168	40,572	20,039	50,557
	mean	400.9	577.0	274.2	309.7
2013	obs	149,000	60,224	29,827	58,949
	mean	406.9	560.2	271.4	318.7
2014	obs	198,811	77,462	35,655	85,694
	mean	422.6	583.3	283.5	335.2

Note: The real transaction price dataset of the Ministry of Land, Infrastructure, and Transportation(MOLIT), 2012-2014.

For example, the number of transactions increased from 111,168 in 2012 to 149,000 and 198,811 in 2013 and 2014, respectively, which can be partially attributed to a couple of financial policies favorable for housing purchase in 2014 (i.e. deregulation of LTV (Loan-to-Value) and DTI (Debt-to-Income)), coupled with low interest rates. It also shows that despite the increase in the number of transactions there exist slight ups and downs in terms of average sales prices although average prices have slightly increased during the period in the Seoul metropolitan area overall. For example, average prices per square meters in Seoul decreased from 5.77 million KRW in 2012 to 5.60 million KRW in 2013 but increased to 5.83 million KRW in 2014. It shows a slight upward real estate market environment in recent years, which is partially attributed to an over-supply regulation policy in the SMA in 2013. Nevertheless, it seems that price escalation is marginal during the period, which is partially because housing stocks were over-supplied in the SMA before the government intervention in 2013.

The empirical analysis covers the entire SMA – it is, by far, the most comprehensive analysis of the region to date. The dependent variable the analysis employs comes from the entire dataset of housing real transaction in the SMA exclusively provided by the MOLIT. The dataset was prepared after geo-coding each transaction within the digitized maps provided by KLIS (Korean Land Information System). The real transaction dataset consists of *transacted* sales prices and structural attributes of the homes, including size, floor, and age – in other words, the characteristics that make of the vector z in equation (1). Real transaction prices have been opened to public since 2006 and some empirical analyses have employed them as they are considered more precise and better representing the reality of diverse housing attributes than asking prices provided by private real estate companies. As real transaction price information, which is provided on-line, is limited and does not provide information for geo-coding, however, such empirical analyses that used real transaction prices have focused on small area case studies with small-size samples.

Compared to previous studies, the current analysis employs the total apartment transactions of the Seoul metropolitan area between 2012 and 2014 and the number of observation used in the analysis is 458,941 after

data cleaning,⁵ To the authors' knowledge, this is the first project that utilizes the entire transaction dataset of the SMA and we believe it will contribute to better understanding the Korean's behavior to open spaces and other location characteristics. The sales information is then entered into a geographic information system (GIS) and linked to other sets of data – non geo-coded data such as household travel survey data and school quality information, and other geo-coded data such as transportation networks and parcel data. If the data is not geo-coded, the data was manually geo-coded.

The model specification, as detailed in the following chapter, was informed by the literature reviewed above – but also by a number of important studies that have been conducted in Korea specifically. This literature is important because the vast preponderance of hedonic price analyses has been executed in western economies – and, therefore, are grounded in western perceptions and traditions. Like the present analysis, some of the earlier research on Korea has focused on estimating household preferences for environmental amenities. Oh and Lee (1997)'s analysis of landscape visibility found that views of water, mountains, and open space all significantly influence residential property markets. Likewise, Yang and Choei (2003), Kim and Lee (2005), Hwang *et al.* (2008), Shin *et al.* (2006) and Lee *et al.* (2008) all find that various forms of open space and environmental amenities – especially access to green areas and water, including the Han River, positively affect housing values. These and other studies – including, notably, Huh and Kwak (1994), Lee *et al.* (2006) – also establish that a fairly consistent (with western contexts) set of variables, z from equation (1), help to shape Korean housing markets. Finally, still other studies have found that education (Jung, 2006) and crime rates (Lim, 2008) are important within the Korean context.

Without detracting from the value of this pool of research – especially because it extends fairly far back in time – it is worth pointing out that it is limited in some significant ways. Foremost, most studies were not able to use the *transacted* value of housing – instead relying on the asking price, as given by real estate agents and/or others. Second, they typically involve relatively small data sets that are necessarily constrained in

⁵ The original number of transaction is 661,096.

geographic scope, focusing on particular neighborhoods within the broader Seoul metropolitan area. Finally, most of the extant Korean research does not make use of spatial econometric methods, which is understandable given the relative newness of computational methods and estimation strategies now available with the toolkit of hedonic price analysis.

Compared to what has been done before, the ensuing analysis is massively comprehensive. It involves nearly 500,000 observations of spatially explicit micro-data – including transacted prices – across the entirety of the SMA, home to about 25 million people. It also involves intricately measured spatial variables – created using the *ArcGIS* and open-source *GeoDa* software packages – plus an explicit spatial econometric strategy. For example, school quality is measured as the precise distance from the unit to the nearest middle school, plus the quality of that exact school. Specifically, the models estimated include a spatial autoregressive term, the average value of the 50 nearest apartment units, as an explanatory variable. The nearest 50 units were used – compared to, say, 4 or 5 in the American context – because of the very high density of development within Seoul and the relative homogeneity of apartments within the same building and/or complex. In short, the present analysis is, to the authors’ knowledge, among the most expansive and rigorous hedonic analyses of environmental quality that has ever been conducted in Korea – or elsewhere in the world. Moreover, though this report is self-contained, the model is expected to generate a great deal of additional scientific research including peer-reviewed articles and a book-length exploration of the deep detail captured by the general models presented here.

Last, before moving on, one elementary factor that the analysis does not capture is the importance of south-facing units. Many previous case studies of small samples have captured this and the authors’ conversations with colleagues knowledgeable of the Seoul housing market have reinforced the desirability of southern facing units. Regrettably, that information including several other variables was not available in the data described below.

CHAPTER 4

Independent Variables

Explanatory variables employed in the empirical analysis consist of unit attributes, neighborhood attributes, neighborhood income attributes, accessibility attributes, and green space attributes as shown in Table 4-1.

Unit attributes mainly come from the real transaction price dataset and include floor, area, and age of the unit, those of which have been

Table 4-1 | Definition of Explanatory Variables

Variables	Definition
Housing Price	Real transaction prices between 2012 and 2014
Unit Attributes	
Floor	Floor of housing
Area	Area of housing
Age	Age of housing
Neighborhood Attributes	
Middle school quality	Proportion of above average students of nearest MS
Distance to MS	Distance to middle schools
Density	Density of population and jobs (Dong level)
Gangnam	1 if unit is located in Gangnam, Seocho, and Songpa
Neighborhood Income	
Low-income	HH income less than 2 million ₩ > 30 %
Med-income	Nor low-income or high-income neighborhood
High-income	HH income more than 5 million ₩ > 30 %

Table 4-1 | (Continued)

Variables	Definition
Accessibility Attributes	
Distance to CBD	Distance to Seoul CBD
Commuting time	Average commuting time (Dong level)
Distance to subway	Distance to nearest subway station
Time to subway	Walking time to nearest subway station (Dong level)
Distance to road	Distance to nearest arterial
Green Space Attributes	
Distance to park	Distance to nearest park
Distance to river	Distance to nearest river

known to have significant impacts on apartment values in most previous hedonic research. As shown in Table 4-2, the average square meters is 77.7, the average floor is 8.7, and the average age of the apartments in the SMA is about 16 years. Signs of coefficients are expected + for area, + for floor, and – for age.

Neighborhood attributes come from diverse sources and some of them were manually geo-coded to match with other spatial datasets. They include school quality, distance to middle schools, combined density of population and jobs, and Gangnam binary variable for Gangnam-Gu, Seocho-Gu, and Songpa-Gu.

Quality of school is widely considered one of the most important location attributes in the SMA housing market but little attention has been paid partly due to data unavailability. Little previous research measures school quality appropriately except a couple of exceptions including a work by Jung (2006) who employed the entrance rate of SNU (Seoul National University) as proxy to school quality. Most previous empirical analyses have attempted to control for school quality by using proximity of or distance to the nearest elementary, middle or high schools (Oh and Lee, 1997; Yang and Choei, 2003; Shin *et al.*, 2006; Lee *et al.*, 2006; Hwang *et al.*, 2008; Lee *et al.*, 2008; Park and Rhim, 2010), by using college entrance rate (Huh and Kwak, 1994), or by using both with other variables (Jung, 2006; Lim, 2008). However, distance to school cannot accurately

| Table 4-2 | Descriptive Statistics

Variables	Units	Obs	Mean	Std. Dev.	Exp. Sign
Housing Price	₩	458,941	323,000,000	237,000,000	
Unit Attributes					
Area	Sq. meter	458,941	77.70111	27.14654	+
Floor	Stories	458,941	8.74388	5.888116	+
Age	Years	458,941	16.07401	7.977618	-
Neighborhood Attributes					
Middle School Quality	Percent	458,941	76.51973	9.783009	+
Distance to Middle School	Meters	458,941	542.2515	398.431	-
Density	Density	458,941	4187.349	7472.03	+
Gangnam	Binary	458,941	0.072944	0.260045	+
Neighborhood Income					
Low-income Neighborhood	Binary	458,941	0.416614	0.492998	ref
Med-income Neighborhood	Binary	458,941	0.498441	0.499998	+
High-income Neighborhood	Binary	458,941	0.084946	0.278801	+
Accessibility Attributes					
Distance to CBD	Meters	458,941	20,466.54	12,328.59	-
Commuting Time	Minutes	458,941	36.76185	6.538237	-
Distance to Subway Station	Meters	458,941	1,720.081	3,013.743	-
Walk Time to Subway Station	Minutes	458,941	11.58854	6.856567	-
Distance to Road	Meters	458,941	70.02371	52.78225	n/a
Green Space Attributes					
Distance to Park	Meters	458,941	224.4717	441.075	-
Distance to River	Meters	458,941	550.6322	474.8207	-
Year of Sale					
Sale in 2012	Binary	458,941	0.242199	0.428415	ref
Sale in 2013	Binary	458,941	0.324643	0.468242	-
Sale in 2014	Binary	458,941	0.433158	0.495513	+

Note: n/a denotes it is not priori clear and ref denotes that it is the reference variable.

measure the school quality of the neighborhood and college entrance rate also cannot represent the school quality of the neighborhood as the quota of college freshmen almost exceeded the number of high school graduates. In addition, school quality variables in the previous analyses are aggregated

at the Gu level, which is too aggregated to capture the neighborhood characteristics.

Student achievement test scores are known as a good measurement of school quality (Rosen and Fullerton, 1977; Brasington and Haurin, 2006) and Haurin and Brasington (1996) shows the pass rate on a ninth grade statewide proficiency test has a significant impact on housing values. In this respect, the current analysis attempts to employ the proportion of above-average student in the national achievement test of the nearest middle school from the individual apartment unit as proxy to school quality and the distance to the nearest middle school from the individual unit to measure neighborhood attributes.

These two variables are measured at the individual unit level after matching real transaction price data from the MOLIT, digitized maps from KLIS (Korean Land Information System) and manually geo-coded school test information from the MOE (ministry of education) with the use of GIS and expected to measure the quality of schools more accurately. SNU entrance rate at the Gu level can be a good additional variable, but it was not available. The present empirical analysis does not employ the test results of elementary schools because the national achievement test was abolished for elementary schools. It did not employ the test results of high schools because using two similar variables may increase the multicollinearity issues and that high schools are less likely to reflect neighborhood characteristics than middle schools as there are more special-purposes high schools that only outstanding students can apply for and such students can apply from other school districts. Table 4-3 shows the average proportion of above-average students by Seoul, Incheon, and Gyeonggi-do.

The variable, Gangnam, is a binary, or indicator, variable, which is set to unity if the unit is located either in Gangnam-gu, Seocho-gu, or Songpa-gu and is expected to absorb the residual effect of Gangnam including the school quality effect (i.e. 8th school district) and/or prestige effect of living in Gangnam. The density measure included to capture the magnitude of development is expected to be positively correlated with housing values.

The income level of the neighborhood is also believed to be closely related with housing prices of the neighborhood. Thus, income is included

Table 4-3 | Proportion of above-average students in the NPT by Region

Region \ Year	mean	min	max	Std. Dev.
Seoul	75.629	41.788	99.800	10.230
Incheon	77.304	55.884	96.510	8.084
Gyeonggi	71.216	19.467	99.661	11.395
Total	73.445	19.467	99.800	10.932

Note: www.schoolinfo.go.kr, Program for Korea Student Assessment, 2012.

in the empirical analysis as a form of low-income, med-income, or high-income neighborhood. Most previous research has not taken income levels into account due to data unavailability and a limited research (Huh and Kwak, 1994; Jung, 2006) has employed income tax information of the National Tax Services or income information from the employment panel survey, but at the Gu level⁶. Since the number of data points in such datasets is small and the largest neighborhood level of the current empirical analysis is Dong, however, the empirical analysis attempts to take advantage of income level information surveyed in the National Household Travel Survey. The survey was conducted in 2010 and is a 2.4~3.6% sample data. The survey asks each household's income by 6 categories. The empirical analysis aggregated proportion of each income groups at the Dong level and then created binary variables of low-income, med-income, and high-income neighborhoods so as to use them as one of the neighborhood attributes. Each neighborhood is assigned a low-income when the proportion of household with less than 2 million KRW monthly income is larger than 30 percent and a high-income when the proportion of household with more than 5 million KRW is larger than 30 percent and the rest of the neighborhoods is assigned med-income neighborhoods. Table 4-4 shows that the proportion of the first two higher income groups is the highest in Seoul (14.43%), followed by Gyeonggi-do (10.61%) and Incheon (7.27%). We believe including the income factor will contribute to better understanding the impact of environmental characteristics.

6 Gu consists of multiple Dongs in Korea and thereby larger than Dong.

Table 4-4 Household Income Level by Region

	Seoul		Incheon		Gyeonggi	
	HH	Ratio	HH	Ratio	HH	Ratio
No Answer	428	0.44	170	0.56	448	0.46
Less than 1 million KRW	11,752	12.00	4,690	15.53	11,219	11.40
1~2 million KRW	19,040	19.45	6,550	21.68	20,041	20.36
2~3 million KRW	25,767	26.32	9,221	30.52	28,981	29.44
3~5 million KRW	26,700	27.27	7,382	24.44	27,314	27.75
5~10 million KRW	12,414	12.68	1,943	6.43	9,417	9.57
More than 10 million KRW	1,810	1.85	253	0.84	1,022	1.04
Total	97,911	100.00	30,209	100.00	98,442	100.00

Note: Household Travel Diary Survey in SMA(Seoul Metropolitan Area), 2010.

Next category of explanatory variables is accessibility and consists of distance to the center of Seoul, average commuting time, distance to subway station, walking time to subway station, distance to arterial. These variables were constructed by spatially matching real transaction price data from the MOLIT, digitized maps from KLIS and transportation network data from the National Transport Database Center with the use of GIS. Distance to CBD⁷ is included in an attempt to capture the CBD effect on housing values like most previous empirical analyses (Huh and Kwak, 1994; Oh and Lee, 1997; Kim and Lee, 2005; Hwang *et al.*, 2008; Park and Rhim, 2010). Commuting time information comes from the national household travel survey and is considered as one of the important factors in a housing location choice. Commuting time employed in the analysis is the average commuting time initially measured at the household level and then aggregated at the Dong level and is expected to have a significant effect on housing values.⁸ Table 4-5 shows that the proportion of the first two groups with the shortest average commuting time (less than 30 minutes) is the largest in Seoul (48.58%), followed by

⁷ CBD refers to the center of the dong where the Blue House is located.

⁸ Commuting time could be an endogenous variable because it is determined by home buyers' existing job locations. But the present research treats it as exogenous, which is typical in the literature.

Table 4-5 | Average Commuting Time by Region

Time	Seoul		Incheon		Gyeonggi	
	HH	Ratio	HH	Ratio	HH	Ratio
Less than 15 min	128,698	21.04	43,089	23.88	17,044	28.46
15 ~30 min	168,397	27.54	49,430	27.40	18,086	30.24
30~60 min	202,324	33.08	55,528	30.78	16,866	28.20
60~120 min	100,836	16.49	26,994	14.96	66,174	11.06
More than 120 min	11,295	1.85	5,366	2.97	12,221	2.04
Total	611,550	100.00	180,407	100.00	598,192	100.00

Note: Household Travel Diary Survey in SMA(Seoul Metropolitan Area), 2010.

Incheon (50.12%) and Gyeonggi-do (58.70%).

Distance to subway station refers to the distance to the nearest subway station from individual apartment units and is expected to have a negative impact on housing values. The farther the distance, the lower is the sales price. Time to subway station is similar to distance to subway but is different in that time to subway is walk time to subway and that it was aggregated at the Dong level. Previous literature also confirms the strong positive effect of proximity to subway stations (Oh and Lee, 1997; Yang and Choei, 2003; Kim and Lee, 2005; Jung, 2006; Hwang *et al.*, 2008; Lee *et al.*, 2008; Lim, 2008; Park and Rhim, 2010; Lee *et al.*, 2013). Distance to road refers to the distance to the nearest arterial from individual apartment units but the priori expected sign is not clear because it could have a positive effect on housing values if it acts like a good accessibility but at the same time it could have a negative effect on housing values if it acts as a noise or an inconvenience factor by being too close to main roads as evidenced in previous literature (Yang and Choei, 2003).

Finally, distance to the nearest park and distance to the nearest river are included in the empirical analysis in order to estimate the impact of open spaces on housing values, the main topic of the research. Distance to park is the distance to the nearest park from individual apartment units and distance to river is the distance to the nearest river. Proximity to parks and/or rivers are known to positively influence real estate markets in Korea (Oh and Lee, 1997; Yang and Choei, 2003; Kim and Lee, 2005;

Shin *et al.*, 2006; Jung, 2006; Park and Rhim, 2010; Lee *et al.*, 2013). Ideally, the measure would be based on a more concrete definition of access – whether in the form of visibility, walking time, or something else – but this data is impossible to obtain for each apartment in the dataset. So, like most analyses that precede it, the present analysis relies on distance – with the understanding that distance is only the best available proxy for actual access. Both green space and river are also widely known to influence real estate markets in advanced economies – the question here is: how do Korean specifically respond to these amenities? By choosing well-known amenities that have been widely studied in other contexts, the present work is able to benchmark Korea-specific findings against what is known more globally.

CHAPTER 5

Model and Estimation Results

The modeling framework and data described in the preceding chapters were combined to estimate the model described in Table 5-1. As explained, the model engages 458,941 transactions across the SMA. All of the explanatory variables are statistically significant deep within a 99% confidence interval and the Adjusted R^2 shows that the model explains nearly 90% of the home-to-home variation in transacted prices. The very high t-statistics and the large R^2 are owed to the fact that the model contains so much data. One of the troubles with stated preference methods is that repeated surveys can yield inconsistent results in practice, which is a critical problem inherent in stated preference methods because they are based on surveys which is very sensitive to questionnaires. Appendix A contains 10 tables listing the estimation results for 10 comprehensive mutually exclusive random samples of the dataset – these tables illustrate that the model yields consistent parameter estimates across randomized subsets of the data. They not only demonstrate the robustness of the model, but they also highlight a key advantage of the revealed preference approach: its stability across repeated experiments.⁹

Table 5-1 shows that all signs are as expected priori. Size of the unit and floor in which the unit is located have a positive effect on housing values while age of the building has a negative impact. Middle school quality has a positive and very significant impact on housing values and proximity to schools also

⁹ We also checked how results change when smaller samples are applied to check the robustness and practical applicability, which was suggested by a referee. The results indicate that coefficients are stable when 0.3% sample (about 1,377 obs) or larger was used, which provides some tips when it is practically used.

Table 5-1 | S2SLS Estimates of Hedonic Price Function

Variables	Est. Parameter	t-Value
Constant	12.70866	377.21***
Spatial Lag	0.3087575	173.95***
Unit Attributes		
Area	0.0090999	528.32***
Floor	0.0047948	87.31***
Age	-0.0073173	-154.66***
Neighborhood Attributes		
Middle School Quality	0.0050356	121.57***
Distance to MS	-0.0000583	-66.73***
Density	0.00000134	27.7***
Gangnam	0.3582548	202.88***
Neighborhood Income		
Low-income Neighborhood	-	-
Medium-income Neighborhood	0.0234506	32.67***
High-income Neighborhood	0.1445112	89.03***
Accessibility Attributes		
Distance to CBD	-0.0000114	-248.96***
Commuting Time	-0.0019927	-38.27***
Distance to Subway Station	-0.00000139	-10***
Walk Time to Subway Station	-0.0016734	-33.04***
Distance to Road	0.0001076	17.89***
Green Space Attributes		
Distance to Park	-0.0000452	-57.34***
Distance to River	-0.0000308	-44.86***
Year of Sale		
Sale in 2012	-	-
Sale in 2013	-0.0090579	-10.78***
Sale in 2014	0.0300375	37.82***
Obs	458,941	
R ²	0.8682	

Note: The model was estimated using White-adjusted standard errors; all hypothesis tests are two-tailed;

*** denotes at $p < 0.01$; ** denotes at $p < 0.05$; * denotes at $p < 0.1$; n/s denotes not significant.

has a positive impact. More specifically, 1 percent increase in the proportion of above-average student of the nearest middle school is related with 0.5 percent increase in housing values. Density has a positive impact on housing values and the premium of Gangnam has a statistically very positive and significant effect on housing prices. Apartment values in med-income and high-income neighborhoods are more expensive compared to those in low-income neighborhoods. The negative signs of accessibility measures show proximity matters while the positive sign of the distance to arterial implies that being close to arterial creates noise and other nuisance and is negatively correlated with housing values. The coefficient of distance to park shows that being farther from parks by 100 meter is correlated with 0.45 percent decrease in housing values, which appears smaller than 2 percent decrease in a work by Shin *et al.* (2006) and 0.71 percent decrease in a work by Yang and Choei (2003). This is possibly because the present analysis covers the entire SMA and the parks covered in the present analysis include all types of parks while a work of Yang and Choei (2003) is a case study of Tok-Som River Park Shin *et al.* (2006) is a case study of the Seoul Forest Park – both of them are large-scale city parks. The negative sign of the coefficient of distance to water shows the preference of the SMA residents for being close to rivers while the magnitude is smaller than parks.

Working down through the list of explanatory variables, the estimation results reveal the following marginal implicit prices, which are monetized in Table 5-2. First, the spatial lag – constructed as the average price of the 50 nearest neighbors – accounts for the high degree of spatial interaction in the SMA apartment market. The (non-monetized) autoregressive parameter, $\hat{\lambda}$, is 0.30, indicating that, other things being equal, a home is priced at about a third of the value of surrounding housing transactions – this high degree of correspondence is expected given that many of the nearest neighbor units are within the same building and/or complex and, therefore, priced accordingly. Looking to Table 5-2 – which places the estimated marginal implicit prices in concrete, monetized terms – an additional floor of elevation adds 1,550,283 KRW to the value of a home; an additional square meter adds 2,942,233 KRW; and an additional year of age subtracts 2,365,872 KRW. In the neighborhood attributes chapter of the table, the two variables pertaining to school quality are interesting: an additional unit of middle school quality (which ranges from ~41.79 – ~99.80) adds 1,628,140 KRW and units decrease in value at a rate of

Table 5-2 | Marginal Implicit Prices Monetized for the SMA

Variables	Obs	Mean	Std. Dev.	Min	Max
Unit Attributes					
Area	458,941	2,942,233	2,157,177	163,798.2	59,700,000
Floor	458,941	1,550,283	1,136,631	86,306.4	31,500,000
Age	458,941	-2,365,872	1,734,602	-48,000,000	-131,711.4
Neighborhood Attributes					
Middle School Quality	458,941	1,628,140	1,193,714	90,640.8	33,100,000
Distance to MS	458,941	-18,849.9	13,820.31	-382,739.5	-1,049.4
Density	458,941	433.2566	317.6537	24.12	8,797.1
Gangnam	458,941	116,000,000	84,900,000	6,448,587	2,350,000,000
Neighborhood Income					
Med-income Neighborhood	458,941	7,582,185	5,559,082	422,110.8	154,000,000
High-income Neighborhood	458,941	46,700,000	34,300,000	2,601,202	949,000,000
Accessibility Attributes					
Distance to CBD	458,941	-3,685,914	2,702,427	-74,841	-205.2
Commuting Time	458,941	-644,291.4	472,379.5	-13,100,000	-35,868.6
Distance to Subway Station	458,941	-449,422.9	329,506.4	-9,125.35	-25.02
Walk Time to Subway St.	458,941	-541,053.4	396,687.8	-11,000,000	-30,121.2
Distance to Road	458,941	34,789.86	25,507.12	1,936.8	706,394
Green Space Attributes					
Distance to Park	458,941	-14,614.33	10,714.89	-296,738	-813.6
Distance to River	458,941	-9,958.436	7,301.294	-202,202	-554.4
Year of Sale					
Sale in 2013	458,941	-2,928,653	2,147,220	-59,500,000	-163,042.2
Sale in 2014	458,941	9,711,900	7,120,539	540,675	197,000,000

18,849 KRW per meter of distance from the nearest middle school. The Gangnam dummy variable is interesting because it captures the unobserved premium that residents pay for the privilege of living in this internationally prestigious district: among those that paid the premium, the average marginal implicit price is 278,000,000 KRW as shown in Table 5-3.¹⁰

¹⁰ Marginal implicit prices for the Gangnam area were calculated with the used of estimation results for the entire SMA and individual housing values in the Gangnam area.

Table 5-3 | Marginal Implicit Prices Monetized for Gangnam Area

Variables	Obs	Mean	Std. Dev.	Min	Max
Unit Attributes					
Area	33,477	7,050,003	3,848,490	909,990	59,100,000
Floor	33,477	3,714,695	2,027,796	479,480	31,200,000
Age	33,477	-5,668,962	3,094,601	-47,600,000	-731,730
Neighborhood Attributes					
Middle School Quality	33,477	3,901,251	2,129,634	503,560	32,700,000
Distance to MS	33,477	-45,167	24,655.98	-378,950	-5,830
Density	33,477	1,038.144	566.707	134	8,710
Gangnam	33,477	278,000,000	152,000,000	35,800,000	2,330,000,000
Neighborhood Income					
Med-income Neighborhood	33,477	18,200,000	9,917,626	2,345,060	152,000,000
High-income Neighborhood	33,477	112,000,000	61,100,000	14,500,000	939,000,000
Accessibility Attributes					
Distance to CBD	33,477	-8,831,969	4,821,239	-74,100	-1,140
Commuting Time	33,477	-1,543,813	842,744.1	-13,000,000	-199,270
Distance to Subway Station	33,477	-1,076.88	587.8528	-9,035	-139
Walk Time to Subway St.	33,477	-1,296,440	707,707.1	-10,900,000	-167,340
Distance to Road	33,477	83,361.39	45,505.73	10,760	699,400
Green Space Attributes					
Distance to Park	33,477	-35,018	19,115.79	-293,800	-4,520
Distance to River	33,477	-23,861.8	13,025.8	-200,200	-3,080
Year of Sale					
Sale in 2013	33,477	-7,017,464	3,830,728	-58,900,000	-905,790
Sale in 2014	33,477	23,300,000	12,700,000	3,003,750	195,000,000

Next, the accessibility attributes illustrate that homes decrease in value at a rate of 3,686 KRW per meter of distance from the Seoul CBD; 644,291 KRW per minute of commuting time; 449 KRW per meter of distance to the nearest subway station; and 541,053 KRW per minute of time it takes to walk to the nearest subway station. Arterial roads are disamenities that negatively affect housing prices due to their traffic and, among other things, the noise and air pollution they produce so homes increase in price at a rate of 34,790 KRW per meter from arterials. Access to parks and water are both desirable, so homes decrease in value at rates of 14,614 KRW and 9,958 KRW per meter of distance:

homes located closer to these amenities are worth more than those located at a distance.

With the marginal implicit prices in hand, it is possible to make a first pass at recovering deep demand parameters – namely, the relationship between price and the quantity consumed or, in other words, the slope of the economist’s downward-sloping demand curve – from the first-step hedonic. Doing this is controversial, so it is important to note that, at present, there is *no* scientific consensus on the viability of estimates derived in this manner: some researchers believe it is possible, and some do not. (For extended discussions, see handbooks by: Champ *et al.*, 2003; Bockstael and McConnel, 2007; Navrud and Ready, 2007; and Johnston *et al.*, 2015.) Moreover, estimating these structural models involves solving a complicated identification problem that must bear out both logically and mathematically (see Angrist and Pischke, 2009; 2015). No effort is made to identify a structural model here – instead, only rough estimates are presented. Finally, because the present effort is strictly exploratory, in an effort to break the endogeneity a bit, spatial lags of the marginal implicit prices are used as proxies, so these values are close to the actual marginal implicit price that is paid, but not exact.

These estimates – of so-called Hicksian (1943) compensated demand functions for proximity of parks and rivers – are presented in Table 5-4 and Table 5-5. The models were estimated using a “garden variety” (Rosen, 1974) 2SLS approach, and a heteroskedasticity-consistent covariance matrix was used in each case to correct standard errors. In these equations, the dependent variables are distance from the nearest park and distance from the nearest river, respectively. The endogenous explanatory variable, $\hat{\pi}_{ik}$ from equation (2), is the natural log of the marginal implicit price of proximity to the nearest park and nearest river: $\text{proximity} = \text{distance} \times -1$. Both equations resemble downward sloping demand curves because of the negative coefficients on the marginal implicit prices: the higher the price, the lower the quantity demanded. The equations also contain income variables, illustrating that people living in medium-income and high-income neighborhoods demand greater proximity – plus the natural log of distance from the CBD, illustrating that households living farther out demand less proximity. To be clear: these estimates give a rough sense of what the market demand curves for proximity to parks and rivers in Seoul, South Korea might look like.

| Table 5-4 | Demand Estimation of Park

Variables	Coefficient	t-Statistic
C	1360.696	6.915067
Spatial lag	-49.08005	-3.167567
Med-income Neighborhood	163.0586	46.97958
High-income Neighborhood	153.4414	11.33315
LOG(Dist. From CBD)	-125.2296	-22.29125
Adjusted R-squared	0.041288	
Included observations	458941	

| Table 5-5 | Demand Estimation of River

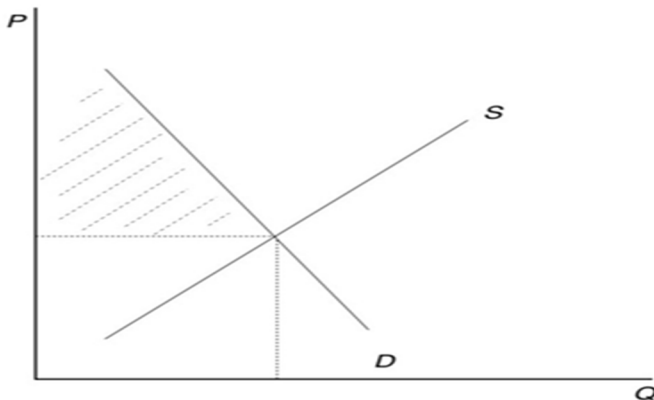
Variables	Coefficient	t-Statistic
C	515.6285	24.25127
Spatial lag	-10.55416	-6.926353
Med-income Neighborhood	12.57474	8.403999
High-income Neighborhood	46.95419	15.89386
LOG(Dist. From CBD)	-100.9143	-87.77933
Adjusted R-squared	0.021553	
Included observations	458941	

The problem, of course, is that identifying the true structural parameters is not the “garden variety” 2SLS problem it was once thought to be (Brown and Rosen, 1982; Bartik, 1987). So while these equations have been solved using 2SLS, the instruments used are rather arbitrary and their statistical properties have not been tested (see Carruthers and Clark, 2010). Coming up with the true deep demand parameters will require a rigorous search for better instrumental variables – and that task is left to further research. For the time-being, however, Table 5-4 and Table 5-5 illustrate the basic methodology set out in Chapter 2 of this report – and, as promised, give a at least ~ rough sense of what the Korean market demand curves might look like.

Before moving on to a final discussion, it is important to underscore the importance of the findings so far. The first-step model represents the most comprehensive hedonic model ever constructed of the SMA's housing market. While many similar analyses have been conducted, none have been so comprehensive. What-is-more, prior to 2006, virtually all hedonic analyses set in Korea relied upon the asking price of housing – not the transacted price. This is an important point because all of the information used here is real data on real people making real transactions in the face of real budget constraints. And, the data is precisely geocoded, enabling detailed perhaps the most detailed measurement of distance and proximity related variables conducted within Korea to date. While the present interest is specifically on amenity variables – including proximity to parks and water, plus the prestige of living in Gangnam – it is important to realize that, at the core, this model is a powerful instrument that, going forward, may be used to estimate values (and eventually, demand) for any number of additional factors of interest to KDI or allied agencies. The randomized estimates presented in Appendix A help to establish the case that the values – which are derived from estimated parameters – are solid estimates of their true but unknown values.

Finally, the two second-step models bring the econometric methodology to a tentative close, by suggesting the form of Korean market demand curves for two environmental amenities. Ultimately, as shown in Figure 5-1, market demand curves are what is needed for estimating the consumer surplus needed

|| Figure 5-1 || Consumer Surplus



for benefit cost analysis. While this work does not present a true structural model, it does deliver the first ever glimpse of the market demand for environmental quality in Korea through the lens of hedonic price analysis – arguably the most powerful revealed preference method available.

CHAPTER 6

Policy Implications and Future Research

The preceding analysis has important policy implications. Foremost, as mentioned in the opening chapter, PIMAC (and other similar agencies) must often rely heavily on stated preference methods because the practical value of stated preference methods often outweighs the practical value of revealed preference methods. But, the model delivered along with this report is a robust, stand-alone tool that - with some additional work, specific to the application in question - can be used to complement stated preference analyses carried out by PIMAC. This is not just a matter of academic curiosity: stated and revealed preference methods should converge on similar results (Champ *et al.*, 2003; Freeman *et al.*, 2014) especially when non-use values are expected minimal, so comparing the two can be useful for determining the validity of existing WTP estimates. It is highly recommended that the model developed in this project be applied to several well-established PIMAC projects - and that the findings be compared side-by-side. Such an exercise would be constructive and revelatory - ideally, it would help to increase the faith that PIMAC places in its very strong stated preference analyses.

Beyond this project-based recommendation, the model is primed to probe a host of policy relevant questions that have significant bearing on quality of life within the SMA, plus Korea as a nation. The estimates related to green space and water illustrate that these amenities are important to the Korean public and, therefore, reinforce the notion that the Korean government should do what it can to preserve existing natural resources and expand the supply of environmental amenities. But, by how much? This question is not resolved within the current report - but the groundwork for answering it has been laid.

Similarly, this project has laid the groundwork for a deep - and spatially explicit - exploration of the value of public education within the SMA. The educational variables are the most precise used to date and the model has established the basis for deep exploration following the path identified by Black (1999), Brasington (2003), Chesire and Sheppard (2004), and others. Educational competition is both a productive and destructive force within Korea, a nation which correctly recognizes that its fortunes are tied to its human capital. The downside of the Korean drive toward education may be the private education market - which places tremendous financial strain on Korean households, not to mention psychological pressure on Korean youth. Understanding the demand for public education is of no small consequence in a nation this driven toward educational excellence - so future research by the authors will delve into demand for public education in detail.

And, education is but one of many human-made amenities at important within the SMA. An interesting - and potentially exciting - result is that related to the Gangnam district. At present, this dummy variable captures a lot of things - not the least of which is the prestige of living in Gangnam - but it almost certainly captures the rich mix of neighborhood amenities including nightlife, shopping, and more that the neighborhood has to offer. (This does not include the influence on school quality, because that is controlled for separately within the model.) So, an outstanding extension of this project would be to “unpack” the Gangnam variable in order to understand more explicitly what is so special about the district – and how (or if) it should be replicated elsewhere.

Next, the SMA, like so many other cities around the globe, faces tremendous problems associated with traffic congestion. This wastes time and productivity - time stuck in traffic = lost productivity = major financial consequences - so preferences or, more specifically, *tolerances for* alternative commuting modes and durations need to be explored. Here again, the present report lays the groundwork for such an analysis - and future research by the authors will explore the situation in detail. In such an analysis it might even be worth treating commuting time as an endogenous variable – especially if microdata on commuting can be obtained and matched with the sales data - microdata on commuting is necessary for doing an analysis in which rents and commuting time are endogenously determined. Moreover, traffic congestion is not just a problem of wasted time and productivity: it contributes to greenhouse gas emissions and lowered air quality, which Korea has gone to great lengths

to improve over the past three decades. Understanding the nexus of demand on environmental quality and commuting times (or modes) in the form of cross-price elasticities is necessary in order to solve some of these complicated and often publicly divisive issues.

Finally, it is important to recognize that the hedonic price method is not prescriptive from a policy perspective. Rather, the model developed and presented in this report forms the foundation for calculating benefits associated with the amenities (and dis-amenities) discussed throughout – and more. It is the tool needed to calculate Hicksian demand functions and consumer surplus associated with each of the component (z) of the first-step hedonic. But, in order to use it to inform what governments *should do*, policy scenarios need to be developed and then estimated benefits can be weighed against known or estimated costs. Such policy scenarios may initially be theoretical – for example, what is the value of giving every household immediate (say, 100-meter) access to a park? And then such scenarios can be attuned to become more practical: in practice, what sort of infill development of parks can be done in order to achieve such a result, and what are the costs of doing so? But these questions must be carefully and rigorously investigated before prescribing government policy. The present project has delivered the tool for estimating the benefit side of any number of policy scenarios – including scenarios that might involve entering additional variables (z) into the models. So, while the present analysis does not go on to provide prescriptive policy implications, it is nonetheless important to policy because it delivers a key tool necessary for evaluating any number of practical policy objectives.

In sum, it should be clear that the policy implications of this project are extensive – and bounded perhaps only by the imagination of the analyst. As stated through this report, it comes accompanied with the data and solid model that can be adapted to and used for any number of applications. An overarching recommendation is that PIMAC apply it to several stated preference scenarios as a means of developing complementary evidence related to them.

CHAPTER 7

Summary and Conclusion

The current empirical analysis is set in the Seoul metropolitan area and attempted to analyze the Korean population's behavior vis-à-vis to open space and other factors that determine housing prices. Using the comprehensive real transaction price data and other geocoded socio-economic data, the analysis reveals that marginal implicit prices can be monetized by using estimates from the revealed preference method of hedonic price analysis and shows the SMA residents are willing to pay higher premiums for green and open spaces and other favorable unit and location characteristics. For example, the present analysis shows that homes decrease in value at rates of 14,614 KRW and 9,958 KRW per meter of distance: homes located closer to these amenities are worth more than those located at a distance. It implies that the government needs to pay a great deal of attention in a location decision of green and open spaces since new investment in green and open spaces would be likely to entail positive externalities or pitfalls in general.

The present analysis also suggests that, having marginal implicit prices in hand, a global demand curve can be derived – which can be then used as an important tool to estimate economic benefits of both environmental and non-environmental attributes of the project of our interests. It is important that economic benefits of environmental projects – public goods for which there is no entrance fee and therefore economic benefits cannot be estimated with a conventional economic analysis - can be estimated with revealed preference methods (i.e. hedonic price model) which are considered theoretically and empirically more sound than stated preference methods such as contingent valuation method because revealed preference methods analyze the behavior of

actual market participants with advanced statistical methods.

Nevertheless, we should be cautious when applying hedonic price models to estimate economic benefits of environmental projects when the size and scale of the investment projects are large. This is because the scale and size of public goods investment projects that PIMAC analyzes are often so large that the spatially influenced area is also often large, which implies that it is likely that non-use values – which revealed preference methods cannot capture by nature - are in play. A vast size of area set in the present analysis helps to estimate economic benefits of large-scale projects. If non-use values are in play, however, socio-economic benefits will be, in theory, smaller than benefits predicted by contingent valuation methods. In such cases, we need to be cautious for applying revealed preference methods. Nevertheless, contingent valuation methods are subject to various types of biases arisen from diverse sources inherent in surveys and the well-known fact that free riders consuming public goods are less likely to state their WTP accurately. This often entails political conflicts in an investment decision making, which gives lights to consideration of revealed preference methods such as hedonic price models given that a more robust structural model is developed by the research followed.

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Appendix

Table A1 | 2SLS Estimates of Hedonic Function – Random Seed 1

Instrumental variables (2SLS) regression	Number of obs	=	45,343
	Wald chi2(19)	=	267380.88
	Prob > chi2	=	0.0000
	R-squared	=	0.8692
	Root MSE	=	.2111

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnwprice	.3140297	.0055425	56.66	0.000	.3031665 .3248929
xarea	.00911	.0000547	166.60	0.000	.0090028 .0092171
xfloor	.0047337	.0001743	27.16	0.000	.0043921 .0050753
xage	-.0073227	.0001499	-48.87	0.000	-.0076164 -.0070289
xmsqual	.0050278	.0001314	38.26	0.000	.0047702 .0052854
xdmsch	-.0000579	2.73e-06	-21.18	0.000	-.0000633 -.0000525
xden	1.19e-06	1.51e-07	7.89	0.000	8.97e-07 1.49e-06
xgstyle	.3647314	.005628	64.81	0.000	.3537007 .375762
xmedinc	.0225743	.0022784	9.91	0.000	.0181087 .0270398
xhighinc	.1352502	.0051854	26.08	0.000	.125087 .1454135
xdcbd	-.0000111	1.43e-07	-77.65	0.000	-.0000114 -.0000108
xavgcom	-.0016929	.0001645	-10.29	0.000	-.0020153 -.0013705
xdstation	-1.49e-06	4.42e-07	-3.38	0.001	-2.36e-06 -6.28e-07
xtwmetro	-.0014002	.0001608	-8.71	0.000	-.0017153 -.0010851
xdarterial	.0001222	.0000191	6.39	0.000	.0000847 .0001597
xdpark	-.0000421	2.50e-06	-16.86	0.000	-.000047 -.0000372
xdwater	-.0000378	2.18e-06	-17.32	0.000	-.0000421 -.0000335
xy13	-.0086025	.0026587	-3.24	0.001	-.0138134 -.0033916
xy14	.0282574	.0025155	11.23	0.000	.0233271 .0331876
_cons	12.58987	.1050629	119.83	0.000	12.38395 12.79579

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

Table A2 | 2SLS Estimates of Hedonic Function – Random Seed 2

Instrumental variables (2SLS) regression

Number of obs	=	45,953
Wald chi2(19)	=	268712.35
Prob > chi2	=	0.0000
R-squared	=	0.8678
Root MSE	=	.21229

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnwprice	.3062328	.0056289	54.40	0.000	.2952003	.3172653
xarea	.009077	.0000542	167.54	0.000	.0089708	.0091832
xfloor	.0047097	.0001744	27.00	0.000	.0043678	.0050516
xage	-.0072794	.0001499	-48.55	0.000	-.0075733	-.0069856
xmsqual	.0050521	.000131	38.56	0.000	.0047954	.0053089
xdmsch	-.0000595	2.80e-06	-21.27	0.000	-.000065	-.000054
xden	1.31e-06	1.52e-07	8.57	0.000	1.01e-06	1.60e-06
xgstyle	.3494035	.0055514	62.94	0.000	.3385229	.3602841
xmedinc	.0254249	.0022716	11.19	0.000	.0209726	.0298772
xhighinc	.1512046	.0051725	29.23	0.000	.1410666	.1613426
xdcbd	-.0000115	1.45e-07	-79.11	0.000	-.0000118	-.0000112
xavgcom	-.0017981	.0001648	-10.91	0.000	-.0021211	-.001475
xdstation	-1.38e-06	4.51e-07	-3.06	0.002	-2.26e-06	-4.95e-07
xtwmetro	-.001617	.0001612	-10.03	0.000	-.001933	-.001301
xdarterial	.0001137	.0000191	5.97	0.000	.0000764	.0001511
xdpark	-.0000527	2.66e-06	-19.79	0.000	-.0000579	-.0000475
xdwater	-.0000338	2.18e-06	-15.49	0.000	-.0000381	-.0000296
xy13	-.0074341	.0026745	-2.78	0.005	-.0126759	-.0021922
xy14	.0309039	.0025238	12.24	0.000	.0259573	.0358505
_cons	12.7544	.1069464	119.26	0.000	12.54478	12.96401

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro wdarterial wdpark wdwater wy13 wy14

| Table A3 | 2SLS Estimates of Hedonic Function – Random Seed 3

Instrumental variables (2SLS) regression

Number of obs	=	46,155
Wald chi2(19)	=	270647.55
Prob > chi2	=	0.0000
R-squared	=	0.8682
Root MSE	=	.21223

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnwprice	.3074383	.0056498	54.42	0.000	.2963649 .3185118
xarea	.0091397	.0000545	167.80	0.000	.0090033 .0092465
xfloor	.004769	.0001746	27.31	0.000	.0044267 .0051112
xage	-.0072322	.0001501	-48.18	0.000	-.0075264 -.006938
xmsqual	.0051037	.0001314	38.85	0.000	.0048462 .0053612
xdmsch	-.0000556	2.81e-06	-19.79	0.000	-.0000611 -.0000501
xden	1.55e-06	1.58e-07	9.83	0.000	1.24e-06 1.86e-06
xgstyle	.3675758	.0056344	65.24	0.000	.3565326 .3786189
xmedinc	.0253994	.0022708	11.19	0.000	.0209487 .0298501
xhighinc	.1423882	.0051379	27.71	0.000	.132318 .1524583
xdcbd	-.0000115	1.46e-07	-78.49	0.000	-.0000117 -.0000112
xavgcom	-.0022013	.0001652	-13.33	0.000	-.002525 -.0018776
xdstation	-1.27e-06	4.37e-07	-2.91	0.004	-2.13e-06 -4.14e-07
xtwmetro	-.0013976	.0001597	-8.75	0.000	-.0017106 -.0010846
xdarterial	.0000866	.0000188	4.60	0.000	.0000497 .0001234
xdpark	-.0000493	2.54e-06	-19.42	0.000	-.0000543 -.0000443
xdwater	-.0000296	2.16e-06	-13.70	0.000	-.0000338 -.0000254
xy13	-.0090672	.0026625	-3.41	0.001	-.0142857 -.0038488
xy14	.0335496	.0025167	13.33	0.000	.028617 .0384823
_cons	12.7271	.1072561	118.66	0.000	12.51688 12.93732

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

| Table A4 | 2SLS Estimates of Hedonic Function – Random Seed 4

Instrumental variables (2SLS) regression

Number of obs	=	45,843
Wald chi2(19)	=	264547.60
Prob > chi2	=	0.0000
R-squared	=	0.8664
Root MSE	=	.21361

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnwprice	.304449	.0057165	53.26	0.000	.2932448 .3156531
xarea	.0090536	.0000548	165.21	0.000	.0089462 .009161
xfloor	.0048368	.000176	27.49	0.000	.004492 .0051817
xage	-.0072715	.0001509	-48.19	0.000	-.0075673 -.0069758
xmsqual	.0051833	.0001323	39.17	0.000	.004924 .0054427
xdmsch	-.0000638	2.80e-06	-22.83	0.000	-.0000693 -.0000583
xden	1.42e-06	1.48e-07	9.56	0.000	1.13e-06 1.71e-06
xgstyle	.3497065	.0056003	62.44	0.000	.3387302 .3606828
xmedinc	.0219139	.0022916	9.56	0.000	.0174225 .0264053
xhighinc	.1523932	.0051928	29.35	0.000	.1422156 .1625709
xdcbd	-.0000115	1.46e-07	-78.75	0.000	-.0000118 -.0000112
xavgcom	-.0022773	.0001666	-13.67	0.000	-.0026038 -.0019508
xdstation	-1.99e-06	4.39e-07	-4.54	0.000	-2.85e-06 -1.13e-06
xtwmetro	-.0018421	.0001616	-11.40	0.000	-.0021588 -.0015253
xdarterial	.0001486	.0000192	7.73	0.000	.0001109 .0001863
xdpark	-.0000409	2.40e-06	-17.03	0.000	-.0000456 -.0000362
xdwater	-.0000269	2.20e-06	-12.27	0.000	-.0000312 -.0000226
xy13	-.0115415	.0026903	-4.29	0.000	-.0168144 -.0062686
xy14	.0298258	.0025407	11.74	0.000	.024846 .0348055
_cons	12.7985	.1085394	117.92	0.000	12.58577 13.01124

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

Table A5 | 2SLS Estimates of Hedonic Function – Random Seed 5

Instrumental variables (2SLS) regression

Number of obs	=	46,013
Wald chi2(19)	=	265618.54
Prob > chi2	=	0.0000
R-squared	=	0.8666
Root MSE	=	.21191

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnwprice	.3061478	.0056871	53.83	0.000	.2950014	.3172943
xarea	.0089971	.0000547	164.51	0.000	.0088899	.0091043
xfloor	.0050644	.0001735	29.19	0.000	.0047243	.0054045
xage	-.0071553	.0001501	-47.66	0.000	-.0074495	-.006861
xmsqual	.0051215	.0001313	39.02	0.000	.0048642	.0053787
xdmsch	-.0000576	2.77e-06	-20.80	0.000	-.000063	-.0000521
xden	1.39e-06	1.51e-07	9.21	0.000	1.10e-06	1.69e-06
xgstyle	.3658106	.0056264	65.02	0.000	.3547831	.3768382
xmedinc	.020746	.0022658	9.16	0.000	.0163052	.0251869
xhighinc	.1415326	.0051368	27.55	0.000	.1314647	.1516005
xdcbd	-.0000113	1.45e-07	-78.33	0.000	-.0000116	-.000011
xavgcom	-.0020109	.0001641	-12.25	0.000	-.0023326	-.0016893
xdstation	-1.61e-06	4.37e-07	-3.68	0.000	-2.46e-06	-7.50e-07
xtwmetro	-.0015402	.0001596	-9.65	0.000	-.001853	-.0012275
xdarterial	.0001137	.0000188	6.03	0.000	.0000767	.0001506
xdpark	-.0000408	2.41e-06	-16.88	0.000	-.0000455	-.000036
xdwater	-.0000272	2.18e-06	-12.47	0.000	-.0000315	-.0000229
xy13	-.0040911	.0026582	-1.54	0.124	-.009301	.0011189
xy14	.036346	.0025072	14.50	0.000	.0314319	.04126
_cons	12.74624	.1077905	118.25	0.000	12.53497	12.95751

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

| Table A6 | 2SLS Estimates of Hedonic Function – Random Seed 6

Instrumental variables (2SLS) regression

Number of obs	=	46,012
Wald chi2(19)	=	272557.48
Prob > chi2	=	0.0000
R-squared	=	0.8698
Root MSE	=	.21035

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
lnwprice	.317226	.0055627	57.03	0.000	.3063234	.3281286
xarea	.0090616	.0000543	166.82	0.000	.0089552	.0091681
xfloor	.0049381	.0001727	28.59	0.000	.0045995	.0052767
xage	-.0073661	.0001479	-49.81	0.000	-.007656	-.0070763
xmsqual	.005032	.0001304	38.59	0.000	.0047765	.0052875
xdmsch	-.0000592	2.74e-06	-21.57	0.000	-.0000646	-.0000538
xden	9.85e-07	1.50e-07	6.59	0.000	6.92e-07	1.28e-06
xgstyle	.354847	.0054763	64.80	0.000	.3441137	.3655804
xmedinc	.0200261	.0022553	8.88	0.000	.0156058	.0244464
xhighinc	.136877	.0050294	27.22	0.000	.1270195	.1467345
xdcbd	-.0000113	1.44e-07	-78.32	0.000	-.0000116	-.000011
xavgcom	-.002002	.0001634	-12.25	0.000	-.0023222	-.0016817
xdstation	-1.08e-06	4.38e-07	-2.45	0.014	-1.93e-06	-2.17e-07
xtwmetro	-.0016768	.0001584	-10.59	0.000	-.0019872	-.0013664
xdarterial	.0000779	.0000189	4.12	0.000	.0000409	.000115
xdpark	-.0000481	2.50e-06	-19.28	0.000	-.000053	-.0000432
xdwater	-.0000321	2.15e-06	-14.92	0.000	-.0000363	-.0000279
xy13	-.010896	.002636	-4.13	0.000	-.0160624	-.0057295
xy14	.0252887	.0024935	10.14	0.000	.0204016	.0301757
_cons	12.55379	.1055883	118.89	0.000	12.34684	12.76074

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

| Table A8 | 2SLS Estimates of Hedonic Function – Random Seed 8

Instrumental variables (2SLS) regression

Number of obs	=	45,827
Wald chi2(19)	=	257756.50
Prob > chi2	=	0.0000
R-squared	=	0.8636
Root MSE	=	.21273

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnxprice	.3016143	.0057033	52.88	0.000	.290436 .3127925
xarea	.0090945	.000055	165.24	0.000	.0089866 .0092024
xfloor	.0045943	.0001747	26.29	0.000	.0042518 .0049368
xage	-.0072887	.0001506	-48.41	0.000	-.0075838 -.0069936
xmsqual	.0050429	.0001327	38.01	0.000	.0047828 .005303
xdmsch	-.000053	2.74e-06	-19.32	0.000	-.0000584 -.0000476
xden	1.19e-06	1.54e-07	7.72	0.000	8.87e-07 1.49e-06
xgstyle	.3697683	.0056701	65.21	0.000	.3586552 .3808814
xmedinc	.0237077	.0022908	10.35	0.000	.0192177 .0281976
xhighinc	.1442388	.0051657	27.92	0.000	.1341141 .1543634
xdcbd	-.0000115	1.47e-07	-78.16	0.000	-.0000118 -.0000112
xavgcom	-.0018549	.0001656	-11.20	0.000	-.0021795 -.0015303
xdstation	-1.61e-06	4.40e-07	-3.66	0.000	-2.47e-06 -7.48e-07
xtwmetro	-.0018368	.0001616	-11.37	0.000	-.0021536 -.00152
xdarterial	.0000899	.0000192	4.68	0.000	.0000523 .0001276
xdpark	-.0000453	2.49e-06	-18.19	0.000	-.0000502 -.0000404
xwater	-.000029	2.17e-06	-13.37	0.000	-.0000332 -.0000247
xy13	-.0111419	.0026824	-4.15	0.000	-.0163994 -.0058845
xy14	.0301012	.002525	11.92	0.000	.0251523 .0350501
_cons	12.84564	.1081388	118.79	0.000	12.6337 13.05759

Instrumented: lnwprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wwater wy13 wy14

Table A9 | 2SLS Estimates of Hedonic Function – Random Seed 9

Instrumental variables (2SLS) regression

Number of obs	=	45,887
Wald chi2(19)	=	275509.13
Prob > chi2	=	0.0000
R-squared	=	0.8708
Root MSE	=	.21071

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnxprice	.3123885	.0055249	56.54	0.000	.3015599 .3232172
xarea	.0092157	.0000544	169.55	0.000	.0091091 .0093222
xfloor	.0046847	.000172	27.24	0.000	.0043476 .0050218
xage	-.0074709	.0001491	-50.11	0.000	-.0077631 -.0071787
xmsqual	.0048598	.0001292	37.62	0.000	.0046066 .0051131
xdmsch	-.0000592	2.75e-06	-21.53	0.000	-.0000645 -.0000538
xden	1.48e-06	1.56e-07	9.46	0.000	1.17e-06 1.78e-06
xgstyle	.3482525	.0055393	62.87	0.000	.3373957 .3591093
xmedinc	.0236353	.0022551	10.48	0.000	.0192154 .0280551
xhighinc	.1475037	.0051002	28.92	0.000	.1375076 .1574998
xdcbd	-.0000112	1.43e-07	-78.79	0.000	-.0000115 -.000011
xavgcom	-.0020282	.0001637	-12.39	0.000	-.002349 -.0017073
xdstation	-1.89e-06	4.36e-07	-4.33	0.000	-2.74e-06 -1.03e-06
xtwmetro	-.0016835	.0001592	-10.57	0.000	-.0019956 -.0013714
xdarterial	.0001096	.000019	5.77	0.000	.0000724 .0001469
xdpark	-.0000456	2.52e-06	-18.07	0.000	-.0000506 -.0000407
xdwater	-.0000328	2.15e-06	-15.20	0.000	-.000037 -.0000285
xy13	-.0085412	.0026367	-3.24	0.001	-.0137091 -.0033733
xy14	.0285561	.0024944	11.45	0.000	.0236672 .033445
_cons	12.64594	.1049198	120.53	0.000	12.4403 12.85157

Instrumented: lnxprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdcbd xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdcbd wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14

Table A10 2SLS Estimates of Hedonic Function – Random Seed 10

Instrumental variables (2SLS) regression	Number of obs	=	46,000
	Wald chi2(19)	=	272853.68
	Prob > chi2	=	0.0000
	R-squared	=	0.8693
	Root MSE	=	.21104

lnxprice	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
lnxprice	.3061907	.0055918	54.76	0.000	.2952309 .3171505
xarea	.0090904	.0000542	167.80	0.000	.0089842 .0091966
xfloor	-.004829	.0001727	27.97	0.000	-.0044906 -.0051674
xage	-.0076236	.0001507	-50.57	0.000	-.0079191 -.0073282
xmsqual	.0050039	.0001305	38.34	0.000	.0047482 .0052597
xdmsch	-.0000574	2.76e-06	-20.79	0.000	-.0000628 -.000052
xden	1.61e-06	1.58e-07	10.16	0.000	1.30e-06 1.92e-06
xgstyle	.3513342	.0055849	62.91	0.000	.340388 .3622804
xmedinc	.0257695	.0022608	11.40	0.000	.0213386 .0302005
xhighinc	.1501324	.0050897	29.50	0.000	.1401568 .160108
xdbcdb	-.0000116	1.45e-07	-79.96	0.000	-.0000119 -.0000113
xavgcom	-.0021873	.0001641	-13.33	0.000	-.002509 -.0018657
xdstation	-4.61e-07	4.32e-07	-1.07	0.286	-1.31e-06 3.85e-07
xtwmetro	-.0019223	.0001604	-11.98	0.000	-.0022367 -.0016079
xdarterial	.0000923	.000019	4.86	0.000	.0000551 .0001295
xdpark	-.0000491	2.57e-06	-19.11	0.000	-.0000542 -.0000441
xdwater	-.0000311	2.16e-06	-14.36	0.000	-.0000353 -.0000268
xy13	-.0088663	.00265	-3.35	0.001	-.0140602 -.0036724
xy14	.0277896	.0025016	11.11	0.000	.0228865 .0326927
_cons	12.7806	.1062975	120.23	0.000	12.57226 12.98894

Instrumented: lnxprice
 Instruments: xarea xfloor xage xmsqual xdmsch xden xgstyle xmedinc
 xhighinc xdbcdb xavgcom xdstation xtwmetro xdarterial xdpark
 xdwater xy13 xy14 warea wfloor wage wmsqual wdmsch wden
 wgstyle wmedinc whighinc wdbcdb wavgcom wdstation wtwmetro
 wdarterial wdpark wdwater wy13 wy14