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ANALYZING CONTRIBUTION OF ACCESSIBILITY TO SUBWAY STATIONS TO REGIONAL DEVELOPMENT AND DIFFERENT LEVERAGING EFFECT OF STATIONS: A COMPREHENSIVE EMPIRICAL STUDY ON SEOUL

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Abstract. *Easy access to public transportation is well-known as a key factor to facilitate development of a local region. This study investigates how much accessibility to subway stations contributes to land price in an Asian mega city, Seoul. This study covers entire regions of Seoul distinctively from previous studies that select only a part of regions. Thus, the resulting figures are exact parameters rather than estimated ones. We also figure out diverse effect of stations leveraging contribution of accessibility to land price.*

Keywords: Public transportation, Accessibility, Land price, Seoul

1. **Introduction.** Easy access to public transportation is well-known as a key factor to facilitate development of a local region. This study investigates how much accessibility to public transportation contributes to regional development in a quantitative manner. We analyze correlation between land price, which represents a level of commercial development, and accessibility to subway, which is the most important transportation mode in huge cities.

There have been a number of similar studies in transportation and real-estate research fields (which are summarized in Section 2). One distinctive point of this study from others is comprehensive coverage of the target regions. Our analysis is based on a large-scale real world data collected from an Asian mega city, Seoul. For finely fragmented land segments covering most of the geographical area of Seoul, we analyzed their land prices and distance to subway stations. Previous studies targeted only near-station regions of a couple of stations [6-9]. Thanks to this comprehensive coverage, we could extract exact contribution of the accessibility to land price rather than estimating it from a selected sample.

This study makes another distinguishing point by describing the station-wise diversity of the accessibility contribution. To this end, we formulated a model to estimate individual stations' effect leveraging contribution of accessibility to land price. These leveraging effects are compared with the network centrality of stations. In social-network analysis (SNA), centrality indicates the extent to which an entity is located at a center of a network. We compute four centrality measures (degree, betweenness, closeness and eigenvector) of each station in the subway network and analyze their correlation with the leveraging effects. It is found that closeness centrality best describes the station-wise diversity.

2. **Literature Review.** An approach to estimate impact of environmental components in forming market price of land or houses is called a hedonic pricing method [1]. A number of studies have conducted hedonic pricing regression on accessibility to rail stations in

different countries and regions such as Atlanta [2] and San Francisco [3] in the U.S., London [4] in Europe, and Hong Kong [5] in Asia. Their findings can be generally summarized that proximity to rail stations contributes to house or land price positively by easy access and neighborhood commercial services and negatively by noise, pollution and crime [2]. Also, the contribution largely varies on studying regions.

It is worth to review empirical studies in Seoul in more detail. In previous studies, it is confirmed that accessibility to a subway station significantly affects land or house price, at least in near-station area. Won and Son [6] and Bae et al. [7] assessed impact of a newly constructed subway line to houses prices in near-station area. They found that the price increase was significant. Kim and Zhang [8] analyzed 731 land values in Seoul and found that the value is most vulnerable to distance to the central business district. On the other hand, the station contribution may vary between stations. Choi et al. [9] compared two regions divided by Hangang-river and found that distance range within which land price is affected by a station is different between the two regions. As noted earlier, the previous studies are limited by narrow coverage of target regions and stations.

3. **Data Description.** The land price of Seoul is collected by an officially registered land segment called Phil-Ji, by which the government administrates ownership of land. One segment is usually occupied by a single building. Seoul has total 915,665 segments excluding public land. The Korean government assesses and announces per-unit (m^3) land price of each segment every year in order to provide reasonable and consistent land value information to the public[1]. This price is called officially announced land price (OALP). We gained OALP in 2014 data for Seoul from the city government's information release system.

For each land segment, its distances to subway stations are computed by geocoding; geographical locations of segments and subway stations are first represented by global positioning system (GPS) coordinates, and then, Euclidian distance between two points is computed from their coordinates. The distance is converted to an accessibility measure that corresponds to 1/distance. This analysis covers total 278 subway stations in Seoul – a couple of stations are technically not in Seoul, but included for boundary land segments.

In order to investigate different accessibility contribution of subway stations, we compute social-network centrality measures. The station centrality is computed by connections between stations; the subway network is regarded as a social network. There are four kinds of centrality measures: 1) degree centrality defined by the number of immediately connected stations, 2) betweenness centrality defined by the number of shortest paths between two stations passing through the target station, 3) closeness centrality defined by an inverse of the sum of distances to all other stations, and 4) eigenvector centrality defined by a eigenvector of the adjacency matrix representing the network [10].

4. **Analysis Models and Results.** We first represent the land price on a map of Seoul for the purpose of gaining intuition for its distribution. Next, we analyze average effect of accessibility and centrality. We also estimate different leveraging effect of individual stations, which are aggregated in the average effect.

4.1. **Graphical representation of land price in Seoul.** As mentioned above, locations of land segments are coded as GPS coordinates. We use this coordinate as a point of a map and color each point with the corresponding land price. As illustrated in Figure 1, the gradient from black to white represents price from 0 to KRW 7,000,000 (about USD 6,500). The white circles on the map denote subway stations. There are 13 subway lines

[1] http://klis.seoul.go.kr/sis/userService/etcLandInfo/etcLandInfo.do?url=/userService/etcLandInfo/jiga.

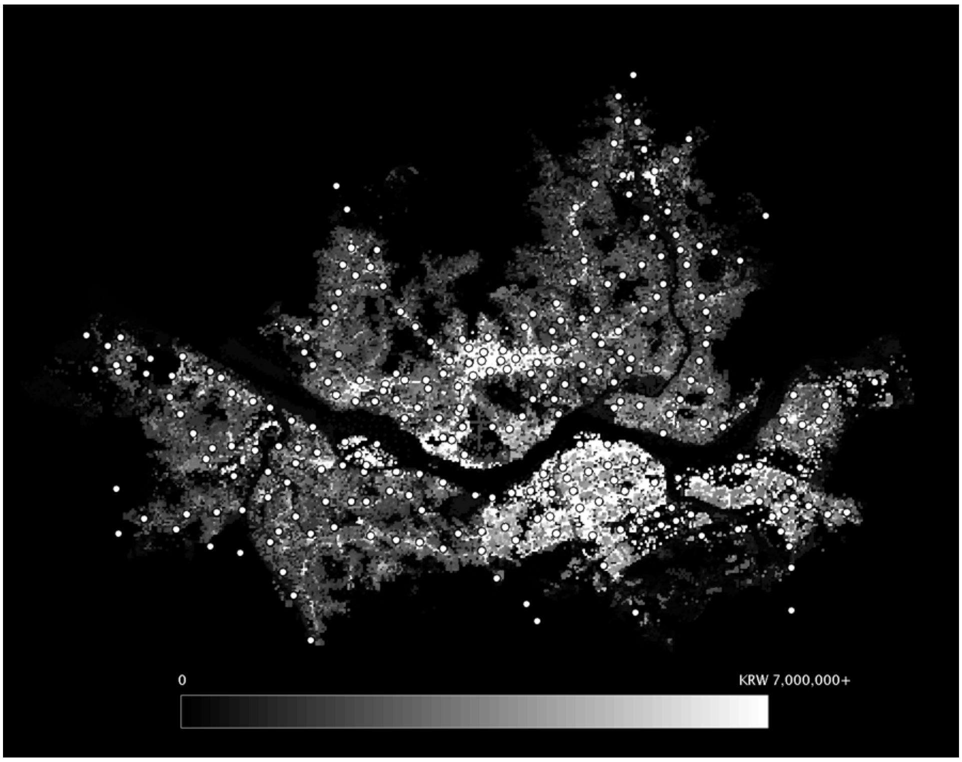

Figure 1. Land-price map of Seoul

passing through Seoul[2]. The price map shows that high-price area is concentrated along subway lines. This expectation is statistically tested in the next sections.

4.2. **Average effect of accessibility and centrality.** This study first analyzes average effect of accessibility to land price. We use accessibility of land segment i to station j, which is denoted by a_{ij}, as descriptive variables. Unlike previous studies that take into account only influence of the nearest station, our model takes near two stations – although we have investigated near three stations, accessibility scores of the second- and third-station were highly correlated ($\rho = 0.705$). The land price is converted into a normal score that corresponds to a value of a normal distribution at the same rank. We use a normal score, which is denoted by NP_i, as a response variable since the model shows higher fitness than nominal price. The regression model is as follows.
MODEL#1:

$$NP_i = \beta_0 + \sum_{k=1}^{2} \beta_k a_{i,n(i,k)} + \varepsilon_{1i}, \quad (1)$$

where $n(i,k)$ and β_k are k-th nearest station from land segment i and its marginal contribution to land price, respectively. Error term ε_{1i} is assumed to follow a normal distribution. When this model is fitted to land price, 12.84% of total variance is described by the model, in other words, $R^2 = 0.1284$ (R^2 of the model with nominal price is 0.1082). The coefficient values and their significance are summarized in Table 1. An interesting observation is that the coefficient value is bigger for the further station. This inverse order may represent duplicated contribution of stations. If even the second-nearest station of a land segment is not so far, that land is particularly convenient to access subway.

Next, we test whether centrality of a station better describes land price distribution. For four centrality measures of the nearest station, the following models are fitted to the data.

[2]A full colored version of this map is available on http://landpriceseoul.blogspot.kr.

MODEL#2:

$$NP_i = \beta_0 + \sum_{k=1}^{2} \beta_k a_{i,n(i,k)} + \beta_{BC} BC_{n(i,1)} + \varepsilon_{2i}, \tag{2}$$

MODEL#3:

$$NP_i = \beta_0 + \sum_{k=1}^{2} \beta_k a_{i,n(i,k)} + \beta_{CC} CC_{n(i,1)} + \varepsilon_{3i}, \tag{3}$$

MODEL#4:

$$NP_i = \beta_0 + \sum_{k=1}^{2} \beta_k a_{i,n(i,k)} + \beta_{DC} DC_{n(i,1)} + \varepsilon_{3i}, \tag{4}$$

MODEL#5:

$$NP_i = \beta_0 + \sum_{k=1}^{2} \beta_k a_{i,n(i,k)} + \beta_{EC} EC_{n(i,1)} + \varepsilon_{4i}, \tag{5}$$

where $BC_{n(i,1)}$, $CC_{n(i,1)}$, $DC_{n(i,1)}$ and $EC_{n(i,1)}$ are standardized betweenness, closeness, degree and eigenvector centrality of the nearest station of i, respectively, and β_{BC}, β_{CC}, β_{DC} and β_{EC} are their coefficients. As summarized in Table 1, closeness centrality (MODEL#3) best describes land price (R^2 = 18.85%) together with accessibility, although other centrality measures are also significant. Comparing to MODEL#1, it describes about 6% more variance. Another distinction is observed for contribution of the second-nearest station, which is reduced by about 25%. It can be interpreted that accessibility to a central station is as important as accessibility to multiple stations.

TABLE 1. Estimates for average effect models

Coefficient	MODEL#1 (R^2 = 12.84%)	MODEL#2 (R^2 = 13.93%)	MODEL#3 (R^2 = 18.85%)	MODEL#4 (R^2 = 13.41%)	MODEL#5 (R^2 = 13.21%)
β_0	−0.7944*	−0.7541*	−0.5763*	−0.7573*	−0.7780*
β_1	0.0331*	0.0321*	0.0316*	0.0329*	0.0334*
β_2	0.4879*	0.4592*	0.3378*	0.4622*	0.4758*
β_{BC}	–	0.1059*	–	–	–
β_{CC}	–	–	0.2632*	–	–
β_{DC}	–	–	–	0.0770*	–
β_{EC}	–	–	–	–	0.0608*

Note. p-value < 0.001.

It is worth noting that we have also fitted models specifying interaction terms between centrality and accessibility and including all centrality measures at once. Those models, however, little increased model fitness and further exacerbated multicollinearity.

4.3. **Station-wise leveraging effect.** The analysis of average effect reveals that accessibility impact on land price is quite different between stations. For example, land segments in Seocho-gu and Seongdong-gu (administrative districts in Seoul) can describe their price with station accessibility and centrality by 49.35% versus 0.67%, respectively. Each station differently leverages accessibility contribution. Thus, we formulate a following alternative model to capture the leveraging effect.

MODEL#6:

$$NP_i = \delta_0 + \sum_{j \in N(i,3)} \delta_j a_{ij} + \varepsilon_i, \tag{6}$$

where $N(i,k)$ denotes the set of k nearest stations from segment i. While coefficient β_k of MODEL#1 to MODEL#5 represents contribution of the k-th largest accessibility, δ_j of this model represents leveraging effect of a specific station j. It is assumed that every station additively contributes to price of a land segment proportionally to its accessibility. The number of independent variables is now equal to the number of the stations, 278, which is much bigger than the previous model. It is, however, not too much relatively to the number of observations (land segments). On the average, there are over 3,000 segments per station.

The model describes 38.57% of the total variance of land price ($R^2 = 0.3857$). Total 238 stations out of 278 are identified to have significant leveraging effect with p-values under 0.01. Among significant stations, most of them have positive leveraging effect; land price increases as a land segment gets closer to the station. The highest leverage stations, which are Eulji-ro, Gangnam and Samseong, are most important business centers of Seoul. The negative leveraging effect implies price decreases in an opposite manner. All the lowest leveraging stations, which are Gachon University, Gimpo airport and Magoknaru, are located at the city boundary. The full list of leveraging effects can be found at the author's blog[3].

Figure 2 shows scatter plots between leveraging effect values of 238 significant stations and their centrality measures. The slope p-values are (probability to reject H_0: slope = 0) quite low for betweenness, closeness and degree centrality measures. However, trend is most salient for closeness centrality and the R^2 value is dominantly higher than others. As also confirmed in the average effect analysis, closeness centrality is most effective to describe station-wise diversity in accessibility contribution to land price. This result gives us an intuition about relationship between regional development and convenient transportation; a convenient destination is more important than a convenient gateway. High betweenness, degree and eigenvector centrality implies that the corresponding station is important in bridging other two stations. Ironically, however, it does not guarantee commercial development of the near-station area since everyone may just pass through rather than to get off. For example, Sindorim station has the 20-th highest betweenness centrality, but its leveraging effect is even negative. Closeness centrality has a different meaning. A high-closeness station is good for people in everywhere to come together. Such a place is likely to become a center of business.

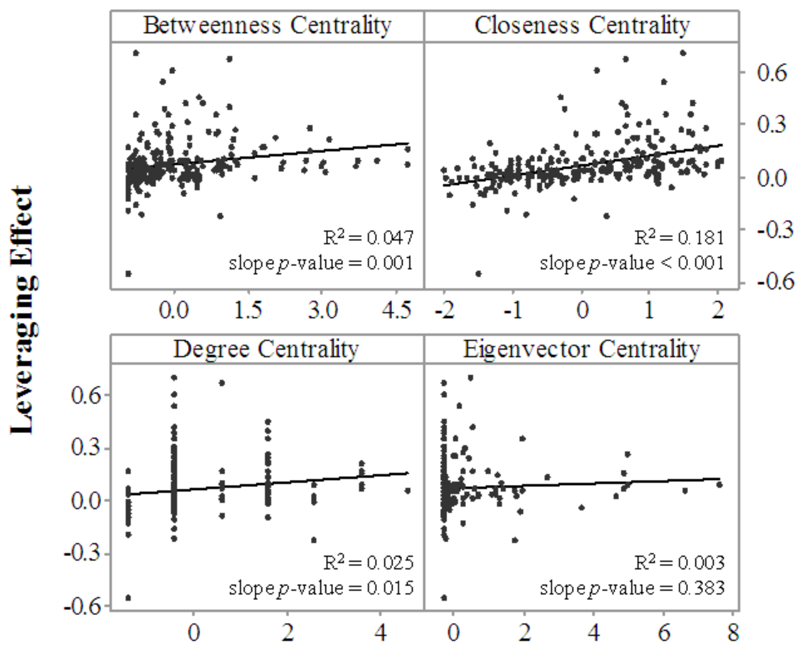

FIGURE 2. Scatter plots between leveraging effect and centrality measures

[3]http://landpriceseoul.blogspot.com.

5. **Conclusions and Future Research.** In this study, we investigated how much accessibility to subway stations contributes to land price in Seoul. The accessibility, on the average, describes 12.84% of total variance of land price and 18.85% together with closeness centrality of stations. The impacts of accessibility and centrality are identified statistically significant with very low (under 0.001) p-values. While these results are consistent with the previous studies, those figures are distinctively meaningful since they come from the total population rather than selected sample, which may incur selection bias. It is an exact statement that 'about 20% of the land price in Seoul is described by accessibility to subway stations'.

We also revealed that each station differently leverages accessibility's contribution to land price. The high leveraging effect implies that the near-station area is highly developed and a center of business. In line with this interpretation, the top-score stations in leveraging effect are located at the representative central business districts in Seoul. The leveraging effect is more strongly correlated with a closeness centrality measure than other centrality measures. We conjecture from this correlation that a geographical center is more advantageous to develop business than a transit center.

In future study, we want to extend research scope to the public bus network. It would be much harder to analyze than the subway network since it is much more complex and needs to consider individual routes. Another extension is to consider more detailed information on land segments, such as land use, floor area and height restriction. It would reveal more refined effect of public transportation.

REFERENCES

[1] S. Sirmans, D. Macpherson and E. Zietz, The composition of hedonic pricing models, *Journal of Real Estate Literature*, vol.5, no.13, pp.1-44, 2005.
[2] D. Bowes and K. Ihlanfeldt, Identifying the impacts of rail transit stations on residential property values, *Journal of Urban Economics*, vol.50, no.1, pp.1-25, 2001.
[3] F. Davis, Proximity to a rapid rail transit station as a factor in residential property values, *The Appraisal Journal*, vol.38, 1970.
[4] S. Gibbons and S. Machin, Valuing school quality, better transport, and lower crime: Evidence from house prices, *Oxf. Rev. Econ. Policy*, vol.24, no.1, pp.99-119, 2008.
[5] H. So, R. Tse and S. Ganesan, Estimating the influence of transport on house prices: Evidence from Hong Kong, *Journal of Property Valuation and Investment*, vol.15, no.1, pp.40-47, 1997.
[6] J.-M. Won and K.-B. Son, *Land Price Impact of Subway*, Seoul University Capital Region Development Institute Yeongu Nonchong, 1993.
[7] C. Bae, M. Jun and H. Park, The impact of Seoul's subway line 5 on residential property values, *Transport Policy*, vol.10, no.2, pp.85-94, 2003.
[8] J. Kim and M. Zhang, Determining transit's impact on Seoul commercial land values: An application of spatial econometrics, *International Real Estate Review*, vol.8, no.1, pp.1-26, 2005.
[9] Y. Choi, T. Kim and J. Park, Development of selection model of subway station influence area in Seoul City using chi-square automatic interaction detection, *Journal of the Korean Society for Railway*, vol.11, no.5, pp.504-512, 2008.
[10] S. Wasserman, *Social Network Analysis: Methods and Applications*, Cambridge University Press, 1994.