Estimating Economic Benefits from Urban Green Space in Shaanxi Province with a Simultaneous Equations Model (SEM)

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Abstract. In this paper, the economic benefits from urban green space in Shaanxi Province are estimated with a simultaneous equations model (SEM) in this paper. The conclusion is drawn as follows: (1) With the increase of investment, the urban green space of Shaanxi province has been continuously expanding. However, the new urban green space has not generated any social and economic benefits yet, and each square kilometer of it requires an investment of 80 million yuan of GDP. (2) Investment plays an important role in generating new urban green space. The coefficient of investment (a2=4.89, p<0.05) indicates that a private real estate investment of 1 billion yuan can generate 4.890 square kilometers of urban green space. (3) Among five urban spatial models, the expansion of urban transportation space and urban industrial space can promote the growth of GDP and bring new social and economic benefits. In the end, possible reasons on these results are discussed in order to provide a frame of reference to promote the development of urban green space planning in Shaanxi province.

1. Introduction

With the rapid development of urbanization, the levels of social economy and people’s living standards have been continuously improving. However, it has also caused a series of problems, such as housing congestion, traffic congestion, environmental pollution, which has decreased residents’ well-being and impeded the civilization progress of cities. According to the report of the 19th National Congress of the Communist Party of China, “as socialism with Chinese characteristics has crossed the threshold into a new era, the principle contradiction facing Chinese society has evolved. What we now face is the contradiction between the people’s ever-growing needs for a better life and unbalanced and inadequate development”. In China, urban green space is an important indicator to measure the comprehensive service functions and the urban civilization degree of modern cities [1]. The cultural service function of its ecosystem is an important manifestation of the “human-oriented” social-natural complex ecosystem, and also an important factor to meet people’s needs for a better life [2]. That is to say, urban green space can not only provide suitable ecological environment for living beings, but also provide comfortable living environment for urban residents.

A large number of studies at home and abroad show that as a type of green infrastructure, urban green space can generate a wide range of benefits, mainly including physical, psychological, environmental, and socioeconomic benefits [3]. Foreign studies on urban green space benefits mainly focus on three aspects: (1) physical benefits. A large number of studies have shown that urban green space can provide residents with a place to do physical exercise, which can benefit their health and then reduce mortality and morbidity of chronic diseases [4]. For example, a survey in New Zealand found that though green space is not associated with overweight or general poor health, it can improve cardiovascular diseases.
which are caused by overweight or obesity indeed [5]. Another example shows that through a systematic review of related publications, Michelle et al. found that there was a negative correlation between urban green space and mortality, heart rates and violence, and a positive correlation with attention, emotion and physical activities[6]. (2) Psychological benefits. Some studies have found that the accessibility, quantity and attribute of public green space are related to the mental health of local residents in the development of new neighborhoods, and mental health is more related to the quality of green space than to the quantity of green space [7]. In addition, the level of residents’ mental health is positively correlated with the area of green space near their residence, the time they stay in the green space and the frequency of using the green space [8]. Urban residents’ exposure to nature in the green space is helpful to reduce pressure and relax tension [9]. (3) Environmental benefits. Urban green space has many environmental functions, including support for urban biodiversity, carbon dioxide sequestration, noise attenuation, rainwater infiltration, groundwater replenishment, mitigation of heat island effect, local climate stabilization and reduction of urban temperature through air [10]. Urban green space is considered as a natural element in the city. In the multi-functional research on improving urban green space, urban green space is called “the lung of city” which can be utilized for ventilation and irrigation [11]. In order to adapt to the urban climate in India, Indian scholar Dhanapal proposed an economic and effective urban green space planning based on ecological system, which clearly pointed out that green space has the functions of mitigating climate change, improving hydrology, and providing a buffer zone for extreme flood events [12].

Domestic researches on the benefits of urban green space mainly focus on socioeconomic benefits. For example, Hong Kong scholar Wendy Chen pointed out that during the urbanization process of 285 cities in China from 2001 to 2009, the relationship between government land property income and urban green space, especially the area of urban public green space, has gradually shifted from positive correlation to negative correlation [13]. Domestic scholars Zhao Liang et al. have carried out empirical researches on relationships among types of investments, types of urban space (especially urban green space) and capital accumulation and circulation composed by GDP. The results show that per million RMB of fixed asset investment in China can increase 0.899km2 of urban green space and bring 1.75 million RMB of GDP growth[14]. Domestic scholar Xiao Yang used Hedonic model to evaluate people’s willingness to pay for the urban green space in Shanghai and social equity reflected in their attitudes. The results show that Shanghai’s housing prices have not been significantly affected by urban green space, and people have a greater preference for privatized green space in their communities [15].

From existing related researches at home and abroad, it can be found that foreign researches on the benefits of urban green space have gained rich results. Their research methods are diverse, focusing on qualitative and quantitative analysis, and their research content is relatively extensive, involving many aspects of the physical benefits, psychological benefits and environmental benefits generated by urban green space. However, there is little research on the social and economic benefits of urban green space in foreign researches. As for domestic researches, only a few have been done on the socioeconomic benefits of urban green space. Based on this fact, this paper attempts to evaluate the economic benefits of urban green space in Shaanxi Province. The complex relationship between urban green space, GDP and investment, can be reflected by a simultaneous equation model that uses several interrelated equations to express the interdependence of economic variables in an economic system more clearly. Therefore, this paper adopts a SEM model from econometric method to discuss the relationship between urban green space, investment and GDP in Shaanxi province, and to evaluate the economic benefits generated from the urban green space here. The results of this study will help urban planners better acknowledge the economic benefits of urban green space and then allocate urban green space in a more scientific and reasonable way.

2. Models, variables and data sources

2.1. Models
Considering the interrelationship among multiple variables, this paper uses a simultaneous equations model (SEM) instead of a multiple linear regression model to evaluate the relationship among investment, urban space and GDP. This SEM is initially based on three groups of equations, corresponding to the three progresses shown as follows:

\[ \text{UST} = f(\text{INV}_t, \text{GDP}_t, \text{PV}_t) \]
\[ \text{GDP}_t = f(\text{INV}_t, \text{UST}, \text{PV}_t) \]
\[ \text{INV}_t = f(\text{GDP}_t, \text{UST}, \text{PV}_t) \]

Urban space (US) includes urban green space (UGS), urban industrial space (UMS), urban transportation space (UTS), urban residential space (URS) and urban business space (UBS). Investment (INV), includes the variables of fixed asset investment (FAI) and real estate investment (REI), which respectively represent fixed asset investment by the governments and real estate investments by private entities. GDP includes the variables SGDP and TGDP, respectively representing the secondary and tertiary industry GDP. The variables of US, GDP, and INV are endogenous variables, while PV represents pre-determined variables set according to the circumstances of each group. The subscript (t) represents year t. The three groups of equations with two exact SEMs are tested.

2.2. Variables

| VARIABLE | AVERAGE | VARIANCE |
|----------|---------|----------|
| GDP (billion RMB) | 377.1355 | 59.85362 |
| PGDP (billion RMB) | 36.50982 | 3.228664 |
| SGDP (billion RMB) | 196.4041 | 37.47145 |
| TGDP (billion RMB) | 144.2488 | 22.73666 |
| FAI (billion RMB) | 288.0181 | 121.6507 |
| REI (billion RMB) | 43.3633 | 15.30126 |
| UGS (km²) | 114.292 | 89.29226 |
| UBS (km²) | 47.35733 | 28.01688 |
| UMS (km²) | 119.0207 | 18.10341 |
| UTS (km²) | 119.052 | 46.59326 |
| URS (km²) | 218.612 | 35.01246 |
| UGC (%) | 36.668 | 4.440801 |
| NG | 138.6 | 59.96644 |
| POP (thousand) | 37404 | 469.9475 |
| REV (billion RMB) | 2.752062 | 1.308858 |
| SP (thousand RMB/m²) | 1.470537 | 0.14788 |

These data all follow time-series which must be analyzed through unit root test at first to determine whether they are stationary time series or first-order integrated series. In unit root test, each variable is tested for its horizontal value and first-order lag numerical value, and is tested for its stationarity according to the P values corresponding to the augmented Dickey-Fuller (ADF) and PP statistics. It can be seen from Fig.1 that in the unit root test of horizontal values, the time series are not stationary; while in the unit root test of the first-order lag numerical value, the time series is stationary for most variables. Therefore, it can be presumed that most of these time series are first-order integrated series. In model regression, bringing in their lag terms can avoid obtaining pseudo regressive coefficients, and first-differenced (FD) variables are better used to eliminate the time trends.

It should be noted that this SEM is also a rational distributed lag (RDL) model in which we add a one-year-lagged dependent variable in each equation with the purpose of calculating the corresponding impact propensity and long-run propensity (LRP). Meanwhile, our SEM is based on a few reasonable hypotheses, including the hypothesis that the lag endogenous variables are exogenous variables and
that the primary industry GDP (PGDP) in the nine-equation SEM is reasonably assumed to be an exogenous variable in an urban system.

2.3. Data sources
This paper selects 16 variables including gross production value, respective output value of primary industry, secondary industry and tertiary industry, fixed asset investment, real estate development investment, urban green space, urban business space, urban residential space, urban transportation space, urban industrial space, urban green space coverage rate, number of parks, number of population, financial income and commercial housing price. The selection of these variables is based on the classification criteria from Zhao Liang, a domestic scholar, in his study of economic benefits of urban green space in China.

3. Survey of research area and data sources

3.1. Survey of research area
Shaanxi Province has a total land area of about 205,600 square kilometers, accounting for 2.145% of the country's total land area. From 2003 to 2017, the urban space (built-up area) increased from 477.64 square kilometers to 1287.05 square kilometers. Urban green space in the province increased from 32.42 square kilometers to 289.58 square kilometers. Green space coverage increased from 28.7% to 39.9%, and the number of parks increased from 43 to 259.

From 2003 to 2017, the province’s GDP increased from 258.772 billion yuan to 218.9881 billion yuan. Investment in fixed assets increased from 106.765 billion yuan to 234.6821 billion yuan. Shaanxi Province, as the central region in the western region of China, is at the core for driving the economic and social development of the western region in China’s strategy of western development.

3.2. Data sources
The data used in this paper are mainly obtained from China Urban Construction Statistical Yearbook (2003–2017), China Real Estate Statistical Yearbook (2003–2017), Shaanxi Statistical Yearbook (2003–2017), Department of Natural Resources of Shaanxi Province (2003–2017), and The Statistics Communique on National Economy and Social Development of Shaanxi (2003–2017). Due to the difficulty in obtaining the data and the accuracy of the model results affected by the length of years, the data in the period from 2003 to 2017 is selected for a total of 15 years.

4. Results and discussion

4.1. The results of the three-equation SEM
Table 2: The results of the three-equation SEM

| Equation | (1)     | (2)     | (3)     |
|----------|---------|---------|---------|
| Dependent Variables | DUGS     | DGDP     | DREI     |
| Lag-One Dependent Variable | 0.448236** | 1.107087*** | 0.194464 |
| Endogenous Variables | DREI     | 4.890079** | 5.232393*** |
| DGDP     | -0.473691 | 0.140831** |
| DUGS     | -0.884596*** | 0.021682 |
| Predetermined Variables | DNG     | 1.523208*** |
|        | DUMS     | 0.933203*** |
|        | DUTS     | -86.17024*** | -1.997161*** |
|        | DURS     | 0.993692 | -0.845401*** |
|        | DUBS     | 1.34988*** |
|        | DREV     | 137.4616*** |
|        | DPOP     | 0.522065*** |
|        | DSP      | -9.047893 |
| Constant | -20.37663* | 0.354595 |
| Adjusted R^2 | 0.757154 | 0.608806 |

Beyond supporting the original hypothesis, the results of the three-equation SEM are presented as following:

Equation (1) shows that investment plays an important role in the production of urban green space. The coefficient of investment \( a_2 = 4.89, p < 0.05 \) indicates that a private real estate investment of 1 billion yuan can produce 4.890 square kilometers of urban green space.

Equation (2) shows that certain funds are required for the construction and maintenance of new urban green space. There is a negative correlation between urban green space and GDP \( b = -0.88, p < 0.01 \), indicating that a new 1 square kilometer of urban green space requires 80 million GDP.

Equation (3) shows that an economic feedback effect exists between GDP and investment \( c_2 = 0.14, p > 0.05 \), indicating that the increase of investment can promote the growth of GDP and then the increase of GDP can lead to a new round of investment.
4.2. The results of the nine-equation SEM

The results of the nine-equation SEM are showed in Figs. 3, 4, 5:

Equation (1) shows that the value of fixed asset investment (FAI) is 1.873, which indicates that the increase of fixed asset investment from government can promote the expansion of urban living space.

Equation (2) shows that the value of real estate development investment (REI) is 6.317, indicating that the increase of private real estate investment can promote the output value of the secondary industry. At the same time, the value of urban residential space (URS) is -0.264, indicating that with the increase of urban residential space, the output value of secondary industry decreases.

Equation (3) shows that the value of the secondary industry (SGDP) is 0.100, indicating that the increase of the output value of the secondary industry can promote the investment in private real estate.

Table 3. The results of Eqs. (1) - (3)

| Equation | (1) | (2) | (3) |
|----------|-----|-----|-----|
| Dependent Variables | DURS | DSGDP | DREI |
| Lag-One Dependent Variable | -0.684992*** | 0.020194 | -0.209669 |
| Endogenous Variables | | | |
| DREI | -6.033041 | 6.317792*** | |
| DSGDP | 0.106064 | | 0.100654* |
| DURS | | -0.264449** | -0.004893 |
| Predetermined Variables | | | |
| DFAI | 1.873108** | | 0.165502*** |
| DPOP | 0.263702** | | |
| DUGS | | | |
| DUMS | | 0.555334*** | |
| DUTS | | -0.622689 | |
| DUBS | | 3.380596** | |
| DREV | | | -226.2774* |
| DSP | | | -2.164884 |
| Constant | -49.96360** | -28.14856 | -1.171940 |
| Adjusted R^2 | 0.809859 | 0.959488 | 0.889999 |

* P < 0.1. ** P < 0.05. *** P < 0.01.

The results of of the nine-equation SEM are showed in Figs. 3, 4, 5:

Equation (4) shows that the value of fixed asset investment (FAI) is 1.873, which indicates that the increase of fixed asset investment from government can promote the expansion of urban living space.

Equation (2) shows that the value of real estate development investment (REI) is 6.317, indicating that the increase of private real estate investment can promote the output value of the secondary industry. At the same time, the value of urban residential space (URS) is -0.264, indicating that with the increase of urban residential space, the output value of secondary industry decreases.

Equation (3) shows that the value of the secondary industry (SGDP) is 0.100, indicating that the increase of the output value of the secondary industry can promote the investment in private real estate.

Table 4. The results of Eqs. (4) - (6)

| Equation | (4) | (5) | (6) |
|----------|-----|-----|-----|
| Dependent Variables | DUMS | DTGDP | DREI |
| Lag-One Dependent Variable | -0.572238** | -0.425259 | 0.533855 |
| Endogenous Variables | | | |
| DREI | -3.741378** | 0.289513 | |
| DTGDP | 3.450682* | | 0.724227* |
| DUMS | | 0.041715 | -0.091567** |
| Predetermined Variables | | | |
| DREV | -83.89880 | -13.01226 | |
| DPOP | | 0.033672** | -0.012893 |
| Constant | 23.23348 | 6.781379** | -0.699907 |
| Adjusted R^2 | 0.673926 | 0.683078 | 0.549134 |

* P < 0.1. ** P < 0.05. *** P < 0.01.
Equation (4) shows that the value of fixed asset investment (FAI) is -3.741, indicating that the increase of private real estate investment can promote the expansion of urban industrial space.

Equation (5) shows that the value of real estate investment (REI) is 0.287, indicating that with the increase of private real estate investment, the output value of the tertiary industry can be increased.

Equation (6) shows that the value of the output value of the tertiary industry (TGDP) is 0.724, indicating that the increase of the output value of the tertiary industry can promote the investment in private real estate. At the same time, the value of urban industrial space (UMS) is -0.091, indicating that with the increase of urban commercial space, private real estate investment decreases.

Table.5 The results of Eqs. (7) - (9)

| Equation | (7) Dependent Variables | DUTS | DSGDP | DFAI |
|----------|-------------------------|------|-------|------|
|          | Lag-One Dependent Variable | -1.259670*** | -0.315060 | 0.280977 |
|          | Endogenous Variables | DFAI | -0.072347 | -0.027232 |
|          |                          | DSGDP | -0.290885** | 0.263209 |
|          |                          | DUTS | 1.650401** | -0.919120 |
|          | Predetermined Variables | DSP | 52.96482*** |
|          |                          | DREI | 3.025205** |
|          |                          | DPOP | -0.213696* |
|          |                          | DREV | 46.48106 |
|          | Constant | 25.40820*** | 12.94541 | 14.37546 |
|          | Adjusted R^2 | 0.627990 | 0.733919 | 0.299875 |

* P < 0.1. ** P < 0.05. *** P < 0.01.

Equation (7) shows that the value of real estate development investment (FAI) is 0.072, indicating that the increase of private real estate investment can promote the expansion of urban traffic space.

Equation (8) shows that the value of urban traffic space (UTS) is 1.650, indicating that with the expansion of urban traffic space, the output value of secondary industry can be promoted.

Equation (9) shows that the value of the output value of the secondary industry (SGDP) is 0.263, indicating that the increase of the output value of the secondary industry can promote the investment in private real estate.

4.3. Economic benefits from urban green space in Shaanxi province

![Figure 1. The relationship diagram of economic benefits from urban green space in Shaanxi province](image)
According to the results of the three-equation SEM, the relationship diagram of economic benefits from urban green space in Shaanxi province is concluded in Picture 2, i.e.: ① Investment plays an important role in expanding urban green space. The coefficient of investment (a2=4.89, p<0.05) indicates that a private real estate investment of 1 billion yuan can produce 4.890 square kilometers of urban green space. ② Certain funds are required for the construction and maintenance of new urban green space. There is a negative correlation between urban green space and GDP (b=0.88, p<0.01), indicating that a new 1 square kilometer of urban green space requires 80 million GDP. ③ An economic feedback effect exists between GDP and investment (c2=0.14, p>0.05), indicating that the increase of investment can promote the growth of GDP and then the increase of GDP can lead to a new round of investment.

According to the results of the nine-equation of SEM, the relationship among urban residential space, urban industrial space, GDP and investment in Shaanxi province is described: ① the relationship among urban residential space, investment and GDP. The increase of investment in fixed assets can promote the expansion of urban residential space, which has a negative correlation with the output value of the secondary industry, however, indicating that with the increase of urban residential space the output value of the secondary industry decreases. ② the relationship among urban industrial space, investment and GDP. The increase of private real estate investment can also promote the expansion of urban industrial space, which can then promote the output value of the secondary industry. ③ The increase of investment in fixed assets can promote the expansion of urban transportation space, which can then promote the output value of the secondary industry as well.

5. Conclusions

5.1. Conclusions
This research provides a test among investment, urban space, and GDP using a simultaneous SEM of econometrics to estimate the economic benefits from urban green space in Shaanxi province. Through such research, conclusions can be drew as follows:

(1) With the increase of investment, the urban green space of Shaanxi province has been continuously expanding. However, the new urban green space has not generated any social and economic benefits yet, and each square kilometer of it requires an investment of 80 million yuan of GDP.

(2) Investment plays an important role in generating new urban green space. The coefficient of investment (a2=4.89, p<0.05) indicates that a private real estate investment of 1 billion yuan can generate 4.890 square kilometers of urban green space.

(3) Among five urban spatial models, the expansion of urban transportation space and urban industrial space can promote the growth of GDP and bring new social and economic benefits.

5.2. discussion
There is a negative correlation between urban green space and GDP in Shaanxi Province so that no economic benefits have been generated with the expansion of urban green space in Shaanxi Province. Possible reasons for this result may due to the fact that as Shaanxi Province is located in an economically underdeveloped area, the resources have not been fully exploited and its arable land and pastoral land areas are not included as indicators in the study. On the other hand, as the procedural justice research of urban green space planning in Shaanxi province is still in the exploratory stage, the public can hardly participate in the planning, construction and post-management in a positive way. Therefore, in the planning and construction of urban green space, more public involvement should be considered. In addition, urban green space managers can think about how to promote the use of green space at night by providing more light so that urban residents can better enjoy the benefits provided by urban green space.

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