Urban Forestry & Urban Greening 33 (2018) 16–26

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Estimating urban green space production in the macroeconomy: From public goods to a profitable method of investment

Liang Zhao, Weizhen Chen*

College of Architecture and Urban Planning, University of Tongji, Shanghai, CHN 200092, China

ARTICLE INFO

Keywords:
Capital circulation
Econometrics
GDP
Investment
Simultaneous equations model (SEM)
Space production
Urban green space

ABSTRACT

Accompanied by long-term urbanization, the Chinese production of urban green space (UGS) is gradually transforming into a land operation strategy for local governments to maximize land lease revenue. This paper presents empirical research on different types of investment, urban space, and gross domestic product (GDP) with a simultaneous equations model (SEM) of econometrics to test the capital circulation and accumulation of UGS production in China. The regression results strongly support our hypothesis that UGS production contributes to GDP growth and that there is an economic feedback loop between them. One billion RMB of the government's fixed-asset investments produces 0.899 km^2 UGS in the long term, and this UGS yields 1.749 billion RMB tertiary industry GDP in return. Thus, the total return rate in the representative economic chain of "fixed-asset investment-UGS-tertiary industry GDP" is greater than 174.9%. However, this percentage also reveals the weakness of providing rewards in maximizing land lease relative to urban industrial, traffic and residential spaces. We also estimate the lagged correlation coefficient with a rational distributed lag model, showing that the production of UGS has a longer-term and more profitable influence on tertiary industry GDP than on secondary industry GDP. The long-run effect of investment on UGS lasts for approximately five years in producing secondary industry GDP and more than ten years in producing tertiary industry GDP. A continuous increase in fixed-asset investments in UGS would achieve a balanced return rate (100%) and start to produce profits after the 4th year, according to the economic chain of ΔFAI-ΔUGS-ΔTGDP.

1. Introduction

The Chinese economic reform and "Open Door" policy were initiated in 1978. Subsequently, the urbanization level of China increased from 22% in 1983–59% in 2017, according to official statistics, and it is estimated that it will reach 75% by the middle of the 21st century. In China, the urbanization process is a form of "hybrid urbanization" that involves a combination of socialist and market economies (McGee, 2009). Accompanied by the long-term urbanization in China, the social production of urban green space (UGS), as well as other kinds of urban space, is gradually transforming into a land operation strategy for local governments to maximize land lease revenue in the circulation and accumulation of macroeconomic capital.

It is argued that Lefebvre's theory of the "production of urban space" (Lefebvre, 1991) offers a useful approach in explaining this phenomenon, and the political economy concept it adopts helps identify the major driving forces in the urbanization process (McGee, 2009). By using this concept, many researchers have offered new views of urban space production worldwide (Harvey, 1990a,b; Klink, 2013; McGee, 2009; Purcell, 1997; Raco and Gilliam, 2012). "UGS production", a concept and a framework elaborated in Chapter 2, is used to discuss the logics, mechanisms and practices of the social production process of UGS. The mechanism of UGS production mainly follows political and socio-economic logics which can be estimated by empirical research. Generally, three aspects of studies are crucial in explaining the socio-economic mechanism of UGS production: the driving force behind UGS, the benefits of UGS, and the mechanism between them.

Regarding the first aspect, five major driving forces of UGS's changes have been identified: socio-economic, political, technological, natural, and cultural (Brandt et al., 1999), and the social, economic, and political driving forces frequently interact with each other (Chen and Wang, 2013b; James et al., 2009). Socio-economic and political factors (e.g., developmental history, urban morphology and land area, population densities, GDP, income, education, social preference, management, and policies) affect the planning, construction, and maintenance of UGSs in direct or indirect ways (Chen and Wang, 2013a; Hill et al., 2010; Kendal et al., 2012; Li et al., 2005; Tan et al., 2013;

* Corresponding author.
E-mail addresses: 1410147@tongji.edu.cn (L. Zhao), 03022@tongji.edu.cn (W. Chen).

https://doi.org/10.1016/j.ufug.2018.04.017
Received 22 October 2017; Received in revised form 5 April 2018; Accepted 25 April 2018
Available online 30 April 2018
1618-8667/

Visscher et al., 2016; Young, 2011; Zhao et al., 2013; Zhou and Wang, 2011; Zhu and Zhang, 2008). Characterized by a luxury effect (Hope et al., 2003; Mennis, 2006), the distribution of vegetation has been determined by income based on social stratification (Jenerette et al., 2013; Landry and Chakraborty, 2009; Wolch et al., 2014; Zhu and Zhang, 2008), with the wealthy moving to landscapes with higher plant diversity (Hope et al., 2003) or altering their local environment by planting more trees (Mennis, 2006). As a result, income may be the most important variable contributing to the distribution of urban tree canopy coverage (Schwarz et al., 2015), which is in contrast with previous research suggesting that education level is a better predictor of urban tree cover than income (Heynen and Lindsey, 2003; Kendal et al., 2012; Luck et al., 2009; Troy et al., 2007). In China, the demographic transfer and gross domestic product (GDP) growth are key factors in explaining the changes of UGS coverage (Chen and Wang, 2013a). Additionally, recent research has documented that a combination of economic growth, climate change, and urban greening policies is the most likely cause of urban green coverage changes in Chinese cities (Yang et al., 2014) while land-based finance has been revealed to be the primary determinant of the UGS provision in China (Chen and Wang, 2013a; Chen and Hu, 2015; Zhao et al., 2013).

Regarding the second aspect, UGSs provide a wide array of economic, social, physical, psychological, and environmental benefits (e.g., Baycan-Levent and Nijkamp, 2009; Chen and Jim, 2008; Landry and Chakraborty, 2009; Nowak and Dwyer 2007; Payton et al., 2008; Peckham et al., 2013; Schetke et al., 2016; Shackleton et al., 2015; Swanwick et al., 2003). Much of the economic valuation literature regarding UGS pays close attention to how urban trees or green spaces contribute to property values (e.g., Donovan and Butry, 2010; Orford, 1999; Wu et al., 2015a,b), whereas some other studies focus on the converted monetary valuation of environmental services (Tyrväinen, 2001; Garmendia et al., 2016). Nine types of economic benefits (property values, construction savings, operation and maintenance savings, replacement avoidance, visitor spending, tax revenue, economic development, job creation, and increase enrollment) are valued for each landscape case in the "Landscape performance series" of America. During the past few years, a new type of potential economic benefit yielded by top-down land finance has led to the argument that governments should produce more favorable urban built environments to attract more investment, both in developed and developing countries (Baycan-Levent and Nijkamp, 2009; Ding, 2003; Peterson, 2008).

A few socio-economic mechanisms have already been revealed. It has long been extensively argued that few private entities proactively provide public UGS because of its public goods characteristics and the spatial spillover effect of its benefits (Choumert and Salanié, 2008; Choumert and Cormier, 2011; Salanié, 2000), although UGS provides environmental benefits as natural infrastructure (Beatley, 2000; James et al., 2009; Waldheim, 2006) and significantly increases house prices (e.g., Brasington and Diane, 2005; Orford, 1999; Xiao et al., 2016). However, the production of UGS is central to the economic development of a country. On one hand, the coverage of UGS has a close relationship with GDP. This relationship is characterized by an environmental Kuznets curve (EKC) (Chen and Wang, 2013a; Dinda, 2004; Kijima et al., 2010), which previous studies have suggested to be a U-shaped curve (Kijima et al., 2010) and an N-shaped curve in the case of China (Chen and Wang, 2013a). On the other hand, if local governments seek to maximize land lease revenue, public parks in many cities might be transformed into high-value-added land, such as commercial zones or residential buildings, as predicted by the "Pareto-optimal" theory (Chen and Hu, 2015; Cheng and Masser, 2003; Choumert and Cormier, 2011; Jim and Liu, 2000).

Theoretically, the production of urban space is essential and plays an important role in capitalism, which has been generalized by the classic three-stage capital circulation model (Harvey, 1990a,b). In this model, urban spaces are treated as capital and taken into a secondary circuit centered on man-made environments or even a tertiary circuit represented by technology research and public utility investment. Accordingly, UGS has been addressed as an undifferentiated commodity or economic good following the logic of markets (Chen and Hu, 2015; Chen and Wang, 2013a; Panduro and Veie, 2013; Zhu and Zhang, 2008), and it has been inevitably evaluated based on its monetary value since the eighteenth century (Ginn and Demeritt 2009; Harvey, 1996). In theories of neoclassical economics, the efficient management of UGS calls for criteria and indicators expressed in monetary terms for evaluating public policies and for reaching the economic Pareto optimality (Choumert and Salanié, 2008).

In addition, some researchers focus on system dynamic analyses of urban growth boundaries and urban ecological land change possibilities. The forests, bodies of water, wetland and grassland outside urban growth boundaries have a higher possibility of being transformed into urban construction lands if the lands are flat and near roads and city centers (Peng et al., 2017). They also have a higher possibility of being transformed into the same type of their ambient land already constructed, which is conceptualized as "spatial autocorrelation" (Anselin, 2003; Zank et al., 2016). However, these studies are more objective on the land transformation phenomenon and seldom focus on revealing the political and socio-economic mechanisms.

In explaining the socio-economic mechanism of UGS production, different types of research approaches have been applied, including willingness to pay (WTP) to test the fictitious investment costs of UGS (e.g., Majumdar et al., 2011; Mell et al., 2016; Yang et al., 2017), the hedonic price model (HPM) to test the UGS's spillover monetary values (e.g., Brasington and Diane, 2005; Jiao and Liu, 2010; Jim and Chen, 2006; Luttik, 2000; Lutzenhiser and Netusil, 2001; Orford, 1999; Panduro and Veie, 2013; Saphores and Li, 2012; Xiao et al., 2016; Wu and Dong, 2014; Wu et al., 2015a,b), and other multiple linear regression models comprising price-relevant variables to test the relationship between UGS coverage and GDP, for example (Chen and Wang, 2013a; Chen and Hu, 2015).

To the best of our knowledge, only a few studies emphasize the socio-economic mechanism of UGS production in macroeconomics and the roles that UGS production has played in macroeconomic capital circulation and accumulation. Whether UGS production follows the concept of "space capitalization" and the three-stage model of capital circulation described by Harvey (1985) is still unknown. Although land-based finance has been revealed by some researchers to be the driving force behind UGS provision (Chen and Wang, 2013a; Chen and Hu, 2015), there is a lack of empirical evidence regarding how direct investment produces UGS and how much financial reward, such as increased GDP, is yielded by the production of UGS.

In this context, we test a hypothesis describing the capital circulation and accumulation of urban space production (see Fig. 1) that argues that urban spaces are mainly produced economically by the fixed-asset investments (FAI) from the government and real estate investments (REI) from private entities, and these newly added urban spaces could lead to GDP growth. Thereafter, new investments increase as a result of the increase in GDP. These three processes result in macroeconomic capital circulation and accumulation of urban space production. We estimate UGS production in the entire urban system. The specification of the econometric model, study area, data source and selected variables are reported in Chapter 3. The regression results are presented and discussed in Chapter 4, and the conclusions are provided in Chapter 5.

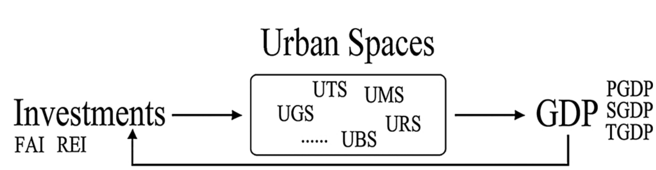

Fig. 1. Hypothesis on capitalist circulation and accumulation of urban space production.

Table 1
Variables and data description.

Variable	Definition	Mean	S.D.	Min.	Max.	ADF Result of θ before FD	ADF Result of θ after FD
ΔUGS	Increase of urban green space area in a built-up district across two adjacent years (km^2)	32.14	33.69	−24.84	200.89	0.031	−0.282
ΔUMS	Increase of urban industrial space area in a built-up district across two adjacent years (km^2)	11.45	38.92	−470.29	304.12	0.019	−0.983
ΔUTS	Increase of urban traffic space area in a built-up district across two adjacent years (km^2)	11.32	22.02	−158.85	107.54	0.059	−0.905
ΔURS	Increase of urban residential space area in a built-up district across two adjacent years (km^2)	19.69	35.76	−129.59	316.17	0.033	−0.721
ΔUBS	Increase of urban commercial space area in a built-up district across two adjacent years (km^2)	13.30	33.55	−117.78	316.06	0.084	−1.217
ΔFAI	Increase of fixed-asset investment by government in a built-up district across two adjacent years (billion RMB)	3.18	9.07	−44.00	39.47	−0.034	−1.355
ΔREI	Increase of real estate investment by private entities in a built-up district across two adjacent years (billion RMB)	20.58	25.59	−29.97	126.86	−0.021	−0.343
ΔGDP	Increase of industry gross domestic product across two adjacent years (billion RMB)	10.23	11.27	−12.55	52.47	0.020	−0.100
ΔPGDP	Increase of primary industry gross domestic product across two adjacent years (billion RMB)	10.23	11.27	−12.55	52.47	0.044	−0.422
ΔSGDP	Increase of secondary industry gross domestic product across two adjacent years (billion RMB)	59.69	70.49	−134.27	359.48	0.003	−0.207
ΔTGDP	Increase of tertiary industry gross domestic product across two adjacent years (billion RMB)	63.46	72.52	0.71	417.79	0.090	**0.027**
ΔNGC	The number of cities newly assessed as "Garden Cities" across two adjacent years	0.61	1.12	0.00	8.00	0.104	−0.513
ΔUGC	Increase in urban green coverage rate in a built-up district across two adjacent years (100%)	0.86	1.93	−8.70	10.54	−0.069	−1.092
ΔPOP	Increase of population across two adjacent years (thousand people)	0.76	1.55	−9.86	12.48	0.060	−0.840
ΔREV	Increase of revenue across two adjacent years (billion RMB)	16.47	20.73	−106.54	146.72	0.066	−0.113
ΔSP	Increase of commercial housing sale prices across two adjacent years (thousand RMB/m^2)	0.36	0.57	−1.66	4.64	0.065	−0.599

The equation of the ADF test is $\Delta y_t = \alpha + \theta y_{t-1} + \gamma \Delta y_{t-1} + e_t$.
The closer θ is to 0, the more believable as I (1) process.
The valuable should be differenced when $\theta > -0.1$, which is agreed upon by most economists. ΔTGDP still has a little time trends after the first-difference.

2. The definition and framework of UGS production research

The production of UGS is fundamentally based on theories elaborated by the geography and social-economics literature, including the "production of space" ideological theory (Lefebvre, 1991), the "three-stage model of capital circulation" in the postmodern period (Harvey, 1985, 1990a, 1990b), and the Marxist urban political ecology, which is a critical theoretical approach that moves beyond the debate of environmental justice (Heynen et al., 2006; Holifield et al., 2009; Kitchen, 2013; Swyngedouw and Heynen, 2003), among many others. An early researcher, Lefebvre (1991), clarified that "(social) space is a (social) product" in his classic 'production of space' ideology. A more rational concept reflecting the current tide of thought is "the capitalization of space" ideology, in which urban space is no longer treated as a static container within which urban socio-economic activities unfold; rather, it is an indispensable outlet to accommodate surplus value generated by capital production processes and to avert the built-in crises of capitalism (Christophers, 2011; Harvey, 1985, 2012).

Following the research on urban space production around the world (Harvey, 1990a,b; Klink, 2013; McGee, 2009; Purcell, 1997; Raco and Gilliam, 2012), we use "UGS production" as a concept to discuss the social production of UGS in modern society. The meaning of "production" is fundamentally different from the concept of "construct" given its economic concern for capital and social concern for human rights, and we limit the UGS production research into a framework with three components: logics, mechanisms and practices.

The logics of UGS production, as we discussed in the first paragraphs in this chapter, involve conceptual integration among theories from geography, sociology, economics, ecology and other natural, social, and engineering sciences. The most thought-provoking logics are those focusing on the political and socio-economic aspects between humans and nature. For example, should we admit that the "nature" attribution of forests, waterfronts and other green spaces in cities vanished during the process of urbanization (Lefebvre, 1991)? Do we agree with the dialectical thought that "each of an ecological planning is a political-economic planning" (Harvey, 1996)? These questions are hard to answer without empirical mechanism research to provide evidence.

Our empirical research mainly focuses on identifying the macro-economic mechanisms of UGS production in order to reveal important evidence that helps form a judgement on the UGS production issue. At the practice level, these mechanisms could be used in designing enforceable urban development policies or programed into expert system software to simulate and predict urban land transformation. Calculating economic rationality, guaranteeing the operability of sustainable urban development policy, and ensuring equitable UGS availability and accessibility might be the most important three directions of practical applications after the UGS production mechanisms are revealed.

3. Model specification and data

3.1. Econometric models

Considering the reciprocal cause-effects relationship among investment, urban space and GDP, we have no choice but to use a simultaneous equations model (SEM) instead of a multiple linear regression model to evaluate this hypothesis loop (Greene, 2011; Wooldridge, 2002). Our SEM is initially based on three groups of equations, corresponding to the three progresses shown in Fig. 1:

$$US_{it} = f(INV_{it}, GDP_{it}, PV_{it}) \quad \text{(I)}$$

$$GDP_{it} = f(INV_{it}\ US_{it}, PV_{it}) \quad \text{(II)}$$

$$INV_{it} = f(GDP_{it}, US_{it}, PV_{it}) \quad \text{(III)}$$

US includes the variables of UGS, UMS, UTS, URS, and UBS, which

Fig. 2. The observed 31 provinces and their urban land usage in built-up districts (China, 2015).

respectively represent urban green, industrial, traffic, residential, and commercial spaces in a built-up urban district. INV, includes the variables of FAI and 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 predetermined variables set according to the circumstances of each group. The subscript (it) represents province i in year t. We test the three groups of equations with two exact SEMs:

1. A three-equation SEM that mainly focuses on the relationships among FAI, UGS, and GDP. The exact SEM is given in Eqs. (1)–(3) as follows:

$$\Delta UGS_{it} = a_0 + a_1\Delta UGS_{it-1} + a_2\Delta FAI_{it} + a_3\Delta GDP_{it} + a_4\Delta REI_{it} + a_5\Delta NGC_{it} + a_6\Delta UGC_{it} + a_7\Delta SP_{it} + a_8\Delta POP_{it} + \Delta u_{it} \quad (1)$$

$$\Delta GDP_{it} = b_0 + b_1\Delta GDP_{it-1} + b_2\Delta FAI_{it} + b_3\Delta UGS_{it} + b_4\Delta UMS_{it} + b_5\Delta UTS_{it} + b_6\Delta URS_{it} + b_7\Delta UBS_{it} + b_8\Delta REI_{it} + b_9\Delta REV_{it} + b_{10}\Delta POP_{it} + \Delta u_{it} \quad (2)$$

$$\Delta FAI_{it} = c_0 + c_1\Delta FAI_{it-1} + c_2\Delta GDP_{it} + c_3\Delta UGS_{it} + c_4\Delta REV_{it} + c_5\Delta SP_{it} + c_6\Delta POP_{it} + \Delta u_{it} \quad (3)$$

2. A nine-equation SEM that focuses on all variables shown in Fig. 1. The exact SEM is given in Eqs. (1′)–(9′) as follows:

$$\Delta UGS_{it} = a_0 + a_1\Delta UGS_{it-1} + a_2\Delta FAI_{it} + a_3\Delta REI_{it} + a_4\Delta SGDP_{it} + a_5\Delta TGDP_{it} + a_6\Delta NGC_{it} + a_7\Delta UGC_{it} + a_8\Delta POP_{it} + \Delta u_{it} \quad (1')$$

$$\Delta UMS_{it} = b_0 + b_1\Delta UMS_{it-1} + b_2\Delta FAI_{it} + b_3\Delta SGDP_{it} + b_4\Delta TGDP_{it} + b_5\Delta UGS_{it} + b_6\Delta UTS_{it} + b_7\Delta POP_{it} + \Delta u_{it} \quad (2')$$

$$\Delta UTS_{it} = c_0 + c_1\Delta UTS_{it-1} + c_2\Delta FAI_{it} + c_3\Delta SGDP_{it} + c_4\Delta TGDP_{it} + c_5\Delta UGS_{it} + c_6\Delta UMS_{it} + c_7\Delta URS_{it} + c_8\Delta UBS_{it} + c_9\Delta POP_{it} + \Delta u_{it} \quad (3')$$

$$\Delta URS_{it} = d_0 + d_1\Delta URS_{it-1} + d_2\Delta FAI_{it} + d_3\Delta FAI_{it-1} + d_4\Delta REI_{it} + d_5\Delta REI_{it-1} + d_6\Delta SGDP_{it} + d_7\Delta TGDP_{it} + d_8\Delta UGS_{it} + d_9\Delta UMS_{it} + d_{10}\Delta UTS_{it} + d_{11}\Delta UBS_{it} + d_{12}\Delta POP_{it} + \Delta u_{it} \quad (4')$$

$$\Delta UBS_{it} = e_0 + e_1\Delta UBS_{it-1} + e_2\Delta FAI_{it} + e_3\Delta FAI_{it-1} + e_4\Delta REI_{it} + e_5\Delta REI_{it-1} + e_6\Delta SGDP_{it} + e_7\Delta TGDP_{it} + e_8\Delta UGS_{it} + e_9\Delta UMS_{it} + e_{10}\Delta UTS_{it} + e_{11}\Delta URS_{it} + e_{12}\Delta POP_{it} + \Delta u_{it} \quad (5')$$

$$\Delta SGDP_{it} = f_0 + f_1\Delta SGDP_{it-1} + f_2\Delta FAI_{it} + f_3\Delta FAI_{it-1} + f_4\Delta REI_{it} + f_5\Delta TGDP_{it} + f_6\Delta UGS_{it} + f_7\Delta UMS_{it} + f_8\Delta UTS_{it} + f_9\Delta URS_{it} + f_{10}\Delta UBS_{it} + f_{11}\Delta PGDP_{it} + f_{12}\Delta REV_{it} + f_{13}\Delta POP_{it} + \Delta u_{it} \quad (6')$$

$$\Delta TGDP_{it} = g_0 + g_1\Delta TGDP_{it-1} + g_2\Delta FAI_{it} + g_3\Delta REI_{it} + g_4\Delta SGDP_{it} + g_5\Delta UGS_{it} + g_6\Delta UTS_{it} + g_7\Delta UMS_{it} + g_8\Delta URS_{it} + g_9\Delta UBS_{it} + g_{10}\Delta REV_{it} + \Delta g_{11}\Delta POP_{it} + \Delta u_{it} \quad (7')$$

$$\Delta FAI_{it} = h_0 + h_1\Delta FAI_{it-1} + h_2\Delta SGDP_{it} + h_3\Delta TGDP_{it} + h_4\Delta UGS_{it} + h_5\Delta UMS_{it} + h_6\Delta REV_{it} + h_7\Delta POP_{it} + \Delta u_{it} \quad (8')$$

$$\Delta REI_{it} = i_0 + i_1\Delta REI_{it-1} + i_2\Delta FAI_{it} + i_4\Delta SGDP_{it} + i_5\Delta TGDP_{it} + i_6\Delta UGS_{it} + i_7\Delta UMS_{it} + i_7\Delta UTS_{it} + i_8\Delta URS_{it} + i_8\Delta UBS_{it} + i_{10}\Delta SP_{it} + i_{11}\Delta SP_{it-1} + i_{12}\Delta POP_{it} + \Delta u_{it} \quad (9')$$

The definitions, units, and descriptive statistics regarding the variables are summarized in Table 1. Some details are illustrated here: 1. We have already tested the autoregressive coefficient of each variable with the augmented Dickey-Fuller (AFD) unit root test (Baneriee et al., 1993; Dickey and Fuller, 1979; Wooldridge, 2002) and found that first-differenced (FD)

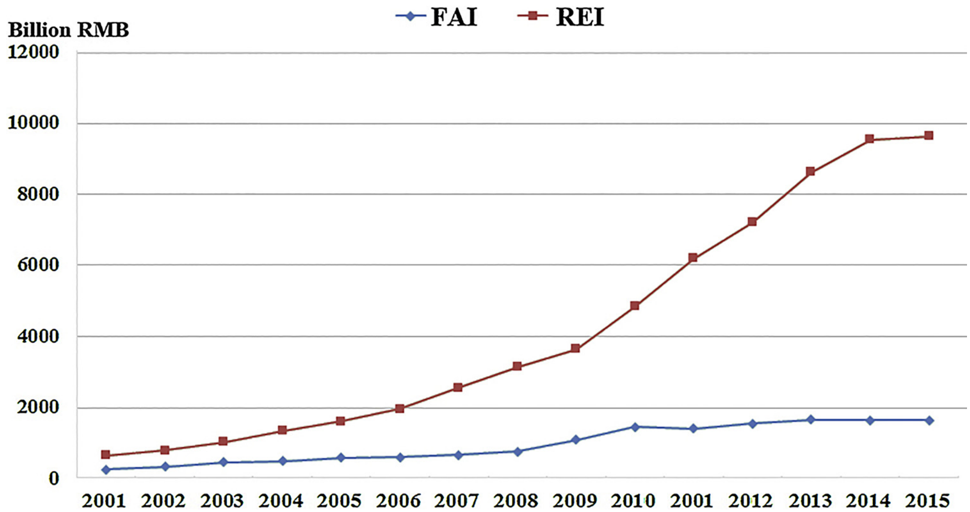

Fig. 3. Annual fixed-asset investment and real estate investment in China, 2001–2015.

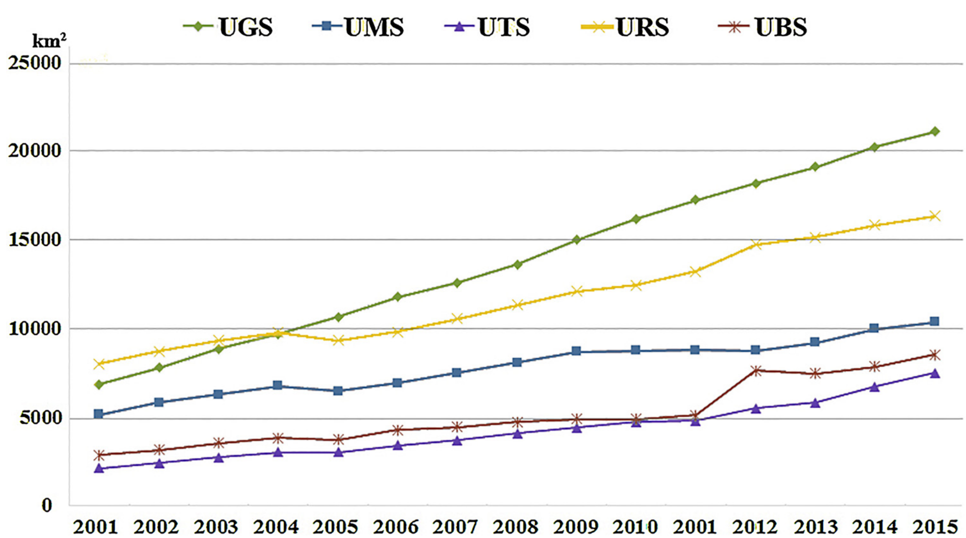

Fig. 4. Annual area of urban spaces in China, 2001–2015.

variables are better used to eliminate the time trends (see Table 1 and Figs. 4–6). Fixed effects such as location and natural conditions that did not change remarkably over time are differenced and disappear simultaneously in the FD model. 2. 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) (Wooldridge, 2002). 3. 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. We have already made a test to confirm that PGDP has no significant correlation with FAI and UGS. 4. The computation was performed using the econometrics software package Eviews 9. Eqs. (1)–(3) were estimated using two-stage least squares (2SLS), and Eqs. (1′)–(9′) were estimated via three-stage least squares (3SLS) given the large number of equations (Greene, 2011; Wooldridge, 2002).

The variables FAI, UGS, and GDP may affect one another for more than one year. In a finite distributed lag model, for example,

$$y_t = a_0 + a_1x_t + a_2x_{t-1} + a_3x_{t-2} + \ldots + a_nx_{t-n+1} + \Delta u_t$$

The impact propensity, which reflects the first year's effect, is a_1 and the long-run propensity (LRP), which reflects the q years' long-run effect, is equal to $a_1 + a_2 + a_3 + \ldots + a_n$. The LRP is more easily calculated in a rational distributed lag (RDL) model in which a one-year-lagged dependent variable is added (Wooldridge, 2002). In an RDL model,

$$y_t = a_0 + by_{t-1} + a_1x_t + \Delta u_t$$

The impact propensity is a_1, the LRP is $a_1/(1\text{-}b)$, and the lag coefficient in each year is calculated by $a_n = (b^{n-1})*a_1$.

3.2. Data sources

Annual panel data from 31 provinces in China (all provinces in Mainland China, including 4 municipalities directly under the central government; see Fig. 2) during the period of 2000–2015 are addressed to structure a year-based data set of nearly 450 observable records, excluding Taiwan, Hong Kong, and Macau due to data shortages. We obtained data mainly from the yearbooks of China, including the China Urban Construction Statistical Yearbook (2000–2015), China Statistical Yearbook (2000–2015), China Real Estate Statistical Yearbook (2000–2015), China Energy Statistical Yearbook (2000–2015), and China Finance Yearbook (2000–2015). The five types of urban space in built-up urban district in our study are defined and categorized according to the Chinese "Standard of urban land classification (2011)".

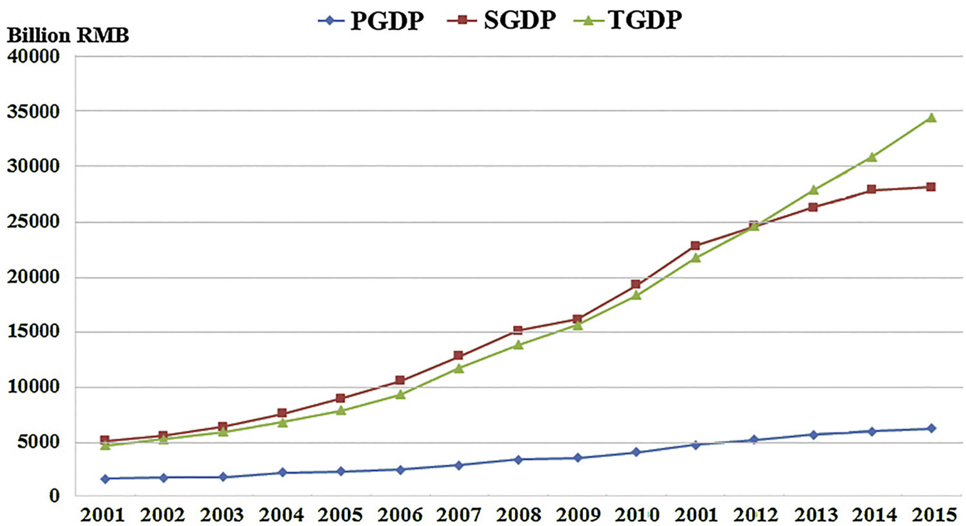

Fig. 5. Annual primary, secondary, and tertiary industry GDP in China, 2001–2015.

Table 2
Regression results of Eqs. (1)–(3) in the SEM of UGS production.

Equation	(1)	(2)	(3)
Dependent Variables	ΔUGS	ΔGDP	ΔFAI
Lag-One Dependent Variable	0.303****	0.347****	−0.167***
Endogenous Variables			
ΔFAI	0.486***	−5.181**	
ΔGDP	0.108****		−0.072****
ΔUGS		1.170****	0.282****
Predetermined Variables			
ΔREI	−0.088	0.588****	
ΔNGC	0.663		
ΔUGC	3.835****		
ΔUMS		0.507	
ΔUTS		0.052	
ΔURS		0.396**	
ΔUBS		−0.604****	
ΔREV		2.612****	0.296****
ΔSP	−6.316***	10.821	2.500**
ΔPOP	1.946***	10.890****	0.578
Constant	3.587	0.260	−1.086
Adjusted R-squared	0.54	0.70	−0.14
Observations	413		
Years of data	2001–2015		

*P < 0.1.
** P < 0.05.
*** P < 0.01.
**** P < 0.001.

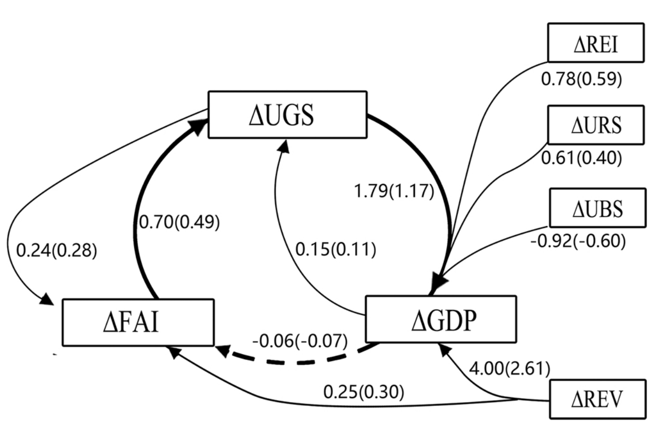

Fig. 6. Capitalist circulation and accumulation of urban space production. The coefficients are the LRP with corresponding impact propensity in parentheses.

The built-up urban district is an administrative and developed area of a city or a town, where the agricultural area and natural forests are excluded.

These yearbooks also reflect three aspects of background relevant to urban space during the period of 2000–2015 in China: First, the capital circulation and accumulation in China were characterized by a transitional flow of investments from industrial production to land-based development during the last decade of the twentieth century (Wu, 1999), leading to an unprecedented pace of housing construction (Chen, 1996). The unsustainable bubble of real estate investment in China (Cao et al., 2008; Lin and Yi, 2011) was likely to be reversed after the year 2014 according to the data we collected (see Fig. 3). Second, fixed-asset investments were mostly used for traffic (> 50%), whereas urban greening excess urban drainage after 2008 accounted for the second-largest proportion of the total fixed-asset investment. Therefore, UGS in Chinese cities experienced a consistent increase from 2001 to 2015 and represents the largest proportion in Chinese urban land usage (see Figs. 2 and 4). Third, China experienced a process reducing the proportion of secondary industry and increasing the proportion of tertiary industry starting in 2001, which was characterized by the slogan “retreat from two into three.” Accordingly, the average proportions of the primary, secondary, and tertiary industry GDP changed from 5:46:49 in 2001–5:42:54 in 2015 (see Fig. 5).

4. Results and discussion

4.1. The results of the three-equation SEM

The regression results for Eqs. (1)–(3) are presented in Table 2 and mapped in Fig. 6. The results for Eq. (1) show that the increase in fixed-asset investment by government (ΔFAI) plays an important role in producing UGS. The coefficients of ΔFAI ($a_2 = 0.486$, $P < 0.001$) suggest that 1 billion RMB of the government’s fixed-asset investments produce 0.486 km^2 of UGS in a short period of time. The LRP of this coefficient, calculated according to equation LRP = $a_1/(1-b)$ (as we illustrate in Chapter 3) is 0.697, which means that 0.697 km^2 of UGS will be produced over a long period of time, and 0.211 km^2 of UGS will be produced after the first year.

The results for Eq. (2) show that newly produced UGS has created a large amount of economic profit. ΔUGS has a significant positive correlation with ΔGDP ($b_3 = 1.170$, $P < 0.001$), suggesting that 1 km^2 of newly built UGS can yield 1.170 billion RMB GDP over a short time and 1.792 billion RMB GDP over a long time. Overall, the results confirm the original hypothesis that UGS production could lead to GDP growth and is a profitable capital accumulation process in the macroeconomy.

Table 3
Regression results for Eqs. (1′)–(9′) in the SEM of urban space production.

Equation	(1′)	(2′)	(3′)	(4′)	(5′)	Equation	(6′)	(7′)	(8′)	(9′)
Dependent Variables	ΔUGS	ΔUMS	ΔUTS	ΔURS	ΔUBS	Dependent Variables	ΔSGDP	ΔTGDP	ΔFAI	ΔREI
Lag-One Dependent Variable	0.248****	0.110***	0.009	−0.057	−0.031	Lag-One Dependent Variable	0.322***	0.779****	−0.056	0.500****
Endogenous Variables						Endogenous Variables				
ΔFAI	0.676****	1.672****	−0.569***	0.093	0.236	ΔFAI	−1.631**	0.612		−0.467
ΔREI	−0.231**			−0.861****	−0.686****	ΔREI	0.067	0.607****		
ΔSGDP	0.113***	−0.034	−0.012	0.317****	0.368****	ΔSGDP		−0.488**	−0.044*	0.481****
ΔTGDP	0.099****	−0.110***	0.072****	0.001	−0.076	ΔTGDP	−0.386****		−0.084****	−0.040
ΔUGS		0.257**	−0.104	−0.237*	−0.038	ΔUGS	0.721****	0.430**	0.136**	−0.279**
ΔUMS			0.513****	0.586****	−0.976****	ΔUMS	0.999***	−0.298	0.120****	0.107
ΔUTS		1.304****		0.358	2.401****	ΔUTS	−1.824**	−2.048****		1.469****
ΔURS			−0.040		−0.134**	ΔURS	0.158	1.414****		−0.923****
ΔUBS			0.169***	−0.086		ΔUBS	0.588*	0.385****		−0.636****
Predetermined Variables						Predetermined Variables				
ΔFAI(-1)				0.641***	−0.580****	ΔPGDP	1.082****			
ΔREI(-1)				0.782****	0.287*	ΔFAI(-1)	1.096***			
ΔNGC	13.402****					ΔSP				−1.216
ΔUGC	3.840****					ΔSP(-1)				3.549*
ΔPOP	2.933***	−3.019***	1.166*	−1.666	−2.152**	ΔREV	1.700****	0.708***	0.312****	
						ΔPOP	4.672**	7.424****	0.743*	−1.867*
Constant	−1.467	−7.394	5.227	5.059	−7.278	Constant	3.854	2.34	0.369	−0.595
Adjusted R-squared	0.27	0.37	0.22	0.32	−1.19	Adjusted R-squared	0.13	0.32	0.09	−0.89
Observations	414									
Years of data	2001–2015									

* P < 0.1.
** P < 0.05.
*** P < 0.01.
**** P < 0.001.

However, beyond supporting the original hypothesis, the results indicate that the capital circulation has a break between ΔGDP and ΔFAI (see Eq. (3), $c_2 = -0.072$, $P < 0.001$), suggesting that the production of UGS is a one-directional accumulation process represented by the economic chain of ΔFAI-ΔUGS-ΔGDP. The revenue (ΔREV) plays an important role in increasing fixed-asset investment but the GDP dose not. In addition, real estate investment by private entities (ΔREI) and commercial housing sale prices (ΔSP) have negative correlations with ΔUGS. This suggests a large risk in providing UGS for citizens if the unprecedented pace of housing construction does not stop.

4.2. The results of the nine-equation SEM

The regression results for the correlations in Eqs. (1′)–(9′) are presented in Table 3 and mapped in Fig. 7. These results confirm the main results of the three-equation SEM and reflect more socio-economic mechanisms of UGS production, which can be divided into three stages: the investment, direct return and indirect return stages.

During the investment stage, the fixed-asset investment by the government (ΔFAI) also has a significant positive correlation with UGS production, whereas the real estate investment by private entities (ΔREI) does not. The coefficients of ΔFAI ($a_2 = 0.676$, $P < 0.001$) suggest that 1 billion RMB of the government's fixed-asset investments produce 0.676 km^2 of UGS in the first year and 0.899 km^2 in the long term. In contrast, the coefficients of ΔREI ($a_3 = -0.231$, $P < 0.05$) indicate that the long-lasting wave of China's real estate investment does not increase UGS but, conversely, might cause many existing UGSs to be developed. According to the regression results for Eq. (1′), the variables of ΔSGDP, ΔTGDP, ΔNGC, ΔUGC, and ΔPOP, which represent economic, political, ecological, and social driving forces, respectively, have positive correlations with ΔUGS, which is largely consistent with previous studies (Chen and Wang, 2013b; Zhao et al., 2013). Overall, the government's fixed-asset investments have made great contributions to UGS production.

At the direct return stage, UGS has created a large economic profit. ΔUGS has a significant positive correlation with ΔSGDP ($f_6 = 0.721$, $P < 0.001$) and ΔTGDP ($g_5 = 0.430$, $P < 0.05$) in the first year and a much higher correlation (1.632 and 1.946) in the long term. If we select the economic chain of ΔFAI-ΔUGS-ΔTGDP to calculate the whole correlation, we obtain 1.749 (by 0.899*1.946), suggesting that 1 RMB investment yields 1.749 RMB TGDP in return.

At the indirect return stage, ΔUGS has a positive correlation with ΔUMS ($b_5 = 0.257$, $P < 0.05$); thus the UGS production is a starting point for increasing ΔUMS, ΔUTS, ΔURS, and ΔUBS over the next several years that has a dramatic ability to stimulate the increase of GDP (see Fig. 7). The other indirect approach to obtain economic return is the re-investment processes using ΔSGDP and ΔTGDP created by ΔUGS.

With the three-stage arguments above, we deduce that the production of UGS is a profitable means of investment for achieving profits during the urbanization process in China. ΔFAI-ΔUGS-ΔTGDP is the most important economic chain in UGS production. The fixed-asset investment by the Chinese government in a built-up district is mainly spent on transportation facility construction and urban greening. For the latter, financial expenditures are directly spent on the recovery of the right to use the corresponding land and to improve the quality of green spaces. However, the mechanism from ΔUGS to ΔTGDP is more complicated and beyond the scope of our study. TGDP is comprised mainly by wholesale, retail, transportation, storage, postal services, accommodation, catering, tourism, banking and real estate marketing in China. In addition to the tourism development directly brought by UGS, two aspects that affect all components of TGDP are worth to paying attention to: the factor of demographic transfer and the new economic models raised by landscapes.

On the whole, the nine-equation SEM presents a more complex capital flow than the three-equation SEM. It starts primarily with fixed-asset investments in UGS, UTS, and UMS and real estate investments in URS and UBS, and it is completed with the goals of increasing of SGDP and TGDP. The variables of ΔSGDP and ΔTGDP have no positive influence on ΔFAI in Eq. (8′). In Eq. (9′), the percentage of urban green space coverage (ΔUGC) and urban transport space (ΔUTS) is the most important factor in attracting real estate investment (ΔREI). In conclusion, different types of urban space have their own production

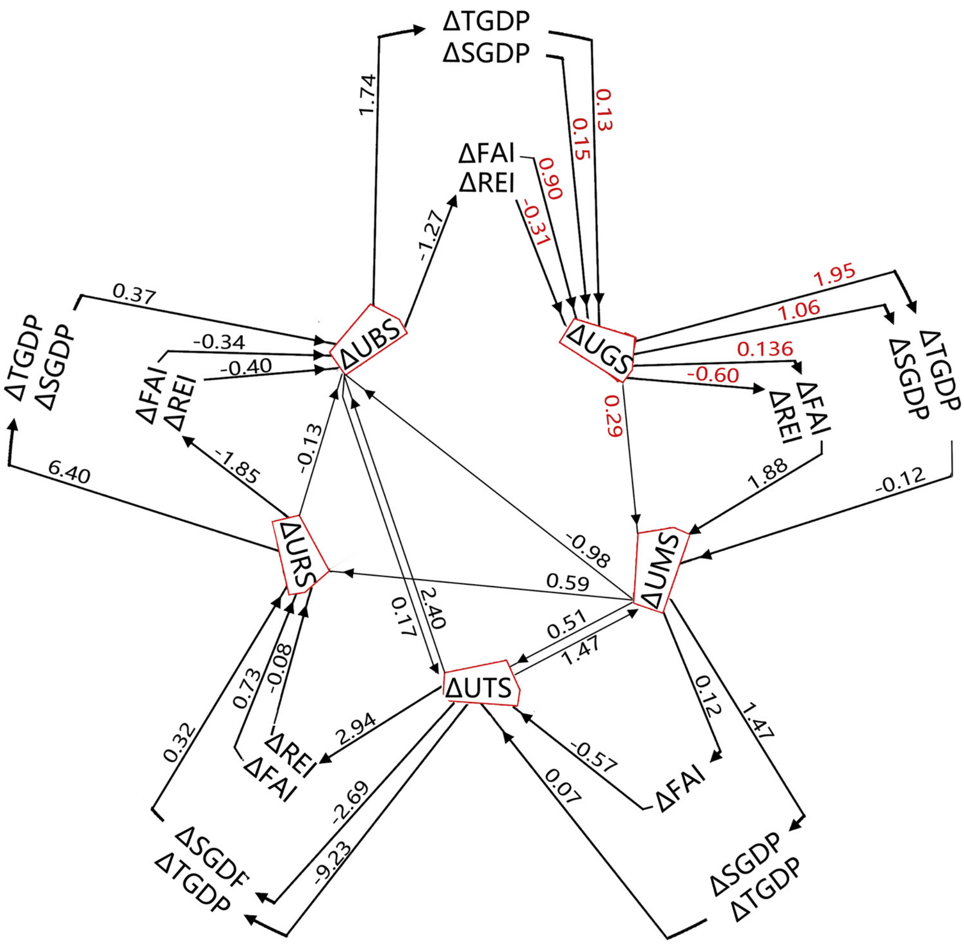

Fig. 7. Capitalist circulation and accumulation of five types of urban space. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
The coefficients are the LRP.
The investment and direct return stages' coefficients of UGS are in red.

Table 4
Comparison of return rates among different types of urban spaces.

Urban space	Economic chain	Return rate
ΔUGS	ΔFAI-ΔUGS-ΔSGDP	95.4%
	ΔFAI-ΔUGS-ΔTGDP	174.9%
	ΔFAI-ΔUGS-ΔUMS-ΔURS-ΔTGDP	98.6%
ΔUMS	ΔFAI-ΔUMS-ΔSGDP	276.4%
	ΔFAI-ΔUMS-ΔUTS-ΔUBS − ΔTGDP	370.6%
	ΔFAI-ΔUMS-ΔUTS-ΔREI	281.9%
	ΔFAI-ΔUMS-ΔUTS-ΔUMS − ΔTGDP	370.6%
	ΔFAI-ΔUMS-ΔURS-ΔTGDP	709.9%
ΔUTS	ΔFAI-ΔUTS-ΔSGDP-ΔURS-ΔTGDP	314.0%
	ΔFAI-ΔUTS-ΔTGDP	526.1%
ΔURS	ΔFAI-ΔURS-ΔTGDP	467.2%
	ΔREI-ΔURS-ΔREI	14.8%
ΔUBS	ΔREI-ΔUBS-ΔREI	50.8%

processes, features, complexities and roles in Chinese macroeconomic capital circulation and accumulation.

4.3. Comparison of return rates among different types of urban spaces

Most of the positive return rates of the economic chain in the nine-equation SEM, calculated by the product of coefficients, are summarized in Table 4 to provide a comparison. These return rates of the economic chain indicate capital circulation, whereas a return rate > 100% implies a process of capital accumulation.

The best chain for reaping profit is ΔFAI-ΔUMS-ΔURS-ΔTGDP, achieving a rate of 709.9%, followed by ΔFAI-ΔUTS-ΔTGDP (526.1%) and ΔFAI-ΔURS-ΔTGDP (467.2%), indicating that urban industrial, traffic, and residential spaces play pivotal roles in promoting economic growth. In comparison, the chain of ΔFAI-ΔUGS-ΔTGDP (174.9%), with a moderate return rate, shows that the production of UGS is not the most profitable activity but is still a capital accumulation process.

However, the return rate of 174.9% in ΔFAI-ΔUGS-ΔTGDP also reveals the weakness of providing rewards in maximizing land lease revenue. As a result, it is not surprising that UGS might be transformed into high-value-added land, such as commercial zones or residential buildings, to realize Pareto-optimality. The government's standards on urban green coverage in China, such as the standard of the "National Garden Cities" with a requirement on urban green space coverage ≥31%, play a crucial role in Chinese UGS provision. In addition, urban spaces are not the only factors that stimulate economic growth, and economic clusters have been recognized as important elements of urban regional economic and spatial planning strategies (Yang et al., 2015); therefore, urban commercial space with a normal accumulation rate of 50.8% is not surprising. In other words, the production of UGS (via fixed-asset investment of governments) relies on the size of the area to achieve GDP growth, but the production of UBS (via real estate investments of private entities) does not.

4.4. The lagged distribution of the coefficient in the long run

As an RDL model, the ten-year lag distributions of coefficients

Table 5
The lagged distribution of coefficients and the ten-year simulation of UGS production.

The year after the increase in FAI	1	2	3	4	5	6	7	8	9	10
Coefficient of ΔFAI-ΔUGS	0.6760	0.1676	0.0416	0.0103	0.0026	0.0006	0.0002	0.0000	0.0000	0.0000
Coefficient of ΔUGS-ΔSGDP	0.7210	0.2322	0.0748	0.0241	0.0078	0.0025	0.0008	0.0003	0.0001	0.0000
Coefficient of ΔUGS-ΔTGDP	0.4300	0.3350	0.2609	0.2033	0.1584	0.1234	0.0961	0.0749	0.0583	0.0454
Increase the FAI by one unit in one particular year.	1	0	0	0	0	0	0	0	0	0
Return rate of ΔFAI-ΔUGS-ΔSGDP	0.4874	0.2778	0.1194	0.0459	0.0166	0.0058	0.0020	0.0007	0.0002	0.0001
Return rate of ΔFAI-ΔUGS-ΔTGDP	0.2907	0.2985	0.2504	0.1995	0.1565	0.1222	0.0953	0.0742	0.0578	0.0450
Increase the FAI by one unit in each year.	1	1	1	1	1	1	1	1	1	1
Return rate of ΔFAI-ΔUGS-ΔSGDP	0.4874	0.7652	0.8846	0.9305	0.9472	0.9530	0.9550	0.9556	0.9558	0.9559
Return rate of ΔFAI-ΔUGS-ΔTGDP	0.2907	0.5892	0.8396	1.0392	1.1957	1.3179	1.4132	1.4874	1.5452	1.5903

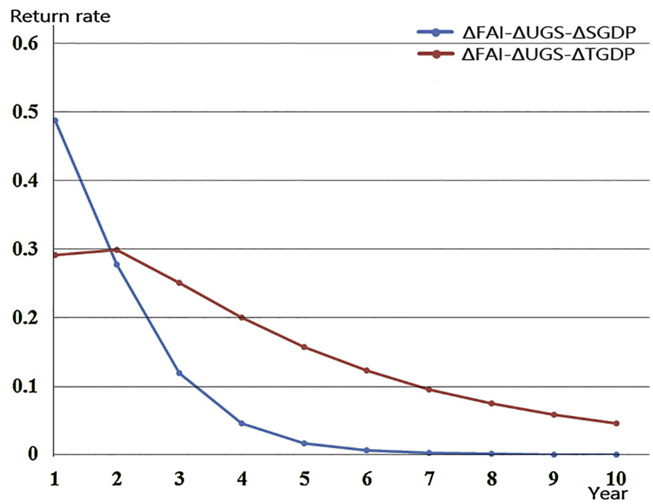

Fig. 8. Return rate curve of UGS production for 1 unit of ΔFAI in one particular year.

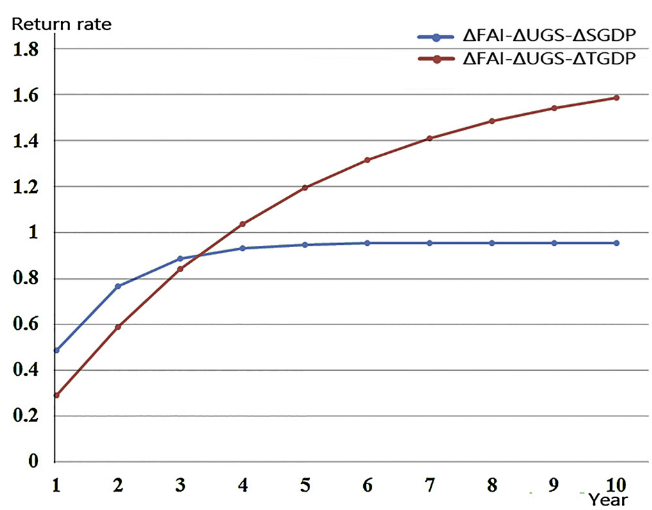

Fig. 9. Accumulated return rate curve of UGS production for 1 unit of ΔFAI in each year.

relevant to UGS are summarized in Table 4 using the equation $a_n = (b^{n-1})^*a_1$, as we illustrate in Chapter 3. It is easier to simulate two common investment situations: increase the FAI by one unit in one particular year or in each year. The long-run return rates of the two economic chains (ΔFAI-ΔUGS-ΔSGDP and ΔFAI-ΔUGS-ΔTGDP) in the nine-equation SEM were calculated using the matrix of these lag coefficients. The return rate is the sum of all the input-output products of the coefficients in the particular lagged year.

The values of the return rates of the two situations described above are simulated and presented in Table 5, with Figs. 8 and 9 showing the return rate curves. These curves clarify three economic mechanisms of UGS production: 1. The production of UGS has a longer-term influence on the TGDP than on the SGDP. The two curves reveal an X-shaped crossing, suggesting that the long-run effect of investment lasts for approximately five years in producing SGDP and more than ten years in producing TGDP (see Fig. 8). 2. The economic chain of ΔFAI-ΔUGS-ΔTGDP is more profitable than ΔFAI-ΔUGS-ΔSGDP. The accumulated annual return rate increases to 1.6 in the 10th year by producing TGDP, but it is always less than 1.0 by producing SGDP (see Fig. 9). 3. The continuous fixed-asset investments on UGS achieve an annual balanced return rate in the 4th year (equal to 100%) and start to make profits after that year according to the chain of ΔFAI-ΔUGS-ΔTGDP (see Fig. 9).

5. Conclusions

This research provides a test among investment, urban space, and GDP using a simultaneous SEM of econometrics, incorporating an RDL model to test the capital circulation and accumulation of UGS production with an FD data treatment method. The primary hypothesis is that UGS production is an important driver of GDP, which goes beyond the existing findings that GDP is a driving force behind UGS production (Chen and Wang, 2013a; Chen and Hu, 2015; Zhao et al., 2013). In fact, our regression results reveal an economic feedback loop between UGS and GDP, and our results shed light on the accurate economic costs and profits of UGS production during the fast-growing urbanization process in China.

In the three-equation SEM, 1 billion RMB of the government's fixed-asset investments produce 0.486 km^2 of UGS in the first year and 0.697 km^2 of UGS in a long period of time. Newly produced UGS has created a large economic profit. 1 km^2 of newly built UGS can yield 1.170 billion RMB GDP in the first year and 1.792 billion RMB GDP in a long period of time. Overall, the results confirm the original hypothesis that UGS production is a profitable capital accumulation process in macroeconomy combined with the socialistic system.

The nine-equation SEM presents a more complex capital flow than the three-equation SEM. Different types of urban space have their own production processes, features, complexities and roles in the Chinese macroeconomic capital circulation and accumulation. In the nine-equation SEM, Three stages of UGS production – the investment stage, direct return stage, and indirect return stage – were clarified, and accurate return rates in each stage were calculated. ΔFAI-ΔUGS-ΔTGDP is the most important economic chain in UGS production. 1 billion RMB of the government's fixed-asset investments produce 0.899 km^2 UGS in the long term, and these UGS yields 1.749 billion RMB tertiary industry GDP in return. We are also interested in the horizontal comparison of return rates among green, industrial, traffic, residential, and commercial urban spaces. The economic chain of ΔFAI-ΔUGS-ΔTGDP (174.9%) is not the most profitable but is still a profitable means of capital accumulation. However, this percentage also reveals the weakness in providing rewards in maximizing land lease relative to UTS, UMS and URS.

As an RDL model, the ten-year lag return rate of UGS production is calculated. The production of UGS has a longer-term and more profitable influence on the TGDP than on the SGDP. The long-run effect of investment lasts for approximately five years in producing SGDP and more than ten years in producing TGDP. The continuous fixed-asset investments on UGS start to produce profits after the 4th year according to the chain of ΔFAI-ΔUGS-ΔTGDP.

UGS has long been thought to be a non-profit good with a strong spatial spillover effect (Choumert and Cormier, 2011; Salanié, 2000). However, as our tests clarified, the production of UGS has gradually become a profitable method of investment during macroeconomic capital circulation and accumulation. It contributes to GDP growth and is a lucrative land operation strategy for local governments. Some specific characteristics in China, such as the development status, the method of metropolitan governance, the dense population in cities and limited urban land resources distinguish the Chinese production of UGS from that of other countries and there are few empirical studies that can be used for a comparison. Nevertheless, all these economic mechanisms of UGS production could provide solid evidence for "UGS production" framework and for governments' decision making to guide local municipalities toward providing a sustainable green landscape for urban living.

Acknowledgements

This work was supported by the Global Environment Facility of the World Bank [No. 1-A-CS-014]. The author thanks Professor Noelwah R. Netusil at Reed College, USA for suggestions in econometrics and anonymous referees for their comments.

References

Anselin, L., 2003. Spatial externalities: spatial multipliers and spatial econometrics. Int. Reg. Sci. Rev. 26 (2), 153–166.
Baneriee, A., Dolado, J., Galbraith, J.W., Hendry, D.F., 1993. Co-integration, Error-correction, and the Economic Analysis of Non-stationary Data. Oxford University Press, Oxford.
Baycan-Levent, T., Nijkamp, P., 2009. Planning and management of urban green spaces in Europe: comparative analysis. J. Urban Plan. Dev. 135, 1–12.
Beatley, T., 2000. Green Urbanism: Learning from European Cities. Island Press.
Brandt, J., Primdahl, J., Reenberg, A., 1999. Rural land-use and dynamic forces –analysis of 'driving forces' in space and time. In: Krönert, R., Baudry, J., Bowler, I.R., Reenberg, A. (Eds.), Land-use Changes and Their Environmental Impact in Rural Areas in Europe. UNESCO, Paris, France, pp. 81–102.
Brasington, D.M., Diane, H., 2005. Demand for environmental quality: a spatial hedonic analysis. Reg. Sci. Urban Econ. 35, 57–82.
Cao, G., Feng, C., Tao, R., 2008. Local land finance in China's urban expansion: challenges and solutions. China World Econ. 16, 19–30.
Chen, W.Y., Hu, F.Z.Y., 2015. Producing nature for public: land-based urbanization and provision of public green spaces in China. Appl. Geogr. 58, 32–40.
Chen, W.Y., Jim, C.Y., 2008. Assessment and valuation of the ecosystem services provided by urban forests. In: Carreiro, M.M., Song, Y.C., Wu, J. (Eds.), Ecology, Planning and Management of Urban Forests. Springer, New York.
Chen, W.Y., Wang, D.T., 2013a. Urban forest development in China: natural endowment or socioeconomic product? Cities 35, 62–68.
Chen, W.Y., Wang, D.T., 2013b. Economic development and natural amenity: an econometric analysis of urban green spaces in China. Urban For. Urban Green. 12, 435–442.
Chen, A., 1996. China's urban housing reform: price-rent ratio and market equilibrium. Urban Stud. 33, 1077–1092.
Cheng, J., Masser, I., 2003. Urban growth pattern modeling: a case study of Wuhan city, PR China. Landsc. Urban Plann. 62, 199–217.
China Energy Statistical Yearbook (2000–2015). Beijing: China Finance Press.
China Finance Yearbook (2000–2015). Beijing: China Finance Press.
China Real Estate Statistical Yearbook (2000–2015). Beijing: China Finance Press.
China State Statistical Bureau (2000–2015). China Statistical Yearbook. Beijing: China Statistical Press.
China Urban Construction State Statistical Bureau (2000–2015). China Urban Construction Statistical Yearbook. Beijing: China Statistical Press.
Choumert, J., Cormier, L., 2011. The provision of urban parks: an empirical test of spatial spillovers in an urban area using geographic information systems. Ann. Reg. Sci. 47, 437–450.
Choumert, J., Salanié, J., 2008. Provision of urban green spaces: some insights from economics. Landscape Res. 33, 331–345.
Christophers, B., 2011. Revisiting the urbanization of capital. Ann. Assoc. Am. Geogr. 101 (6), 1347–1364.
Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74, 427–431.
Dinda, S., 2004. Environmental Kuznets curve hypothesis: a survey. Ecol. Econ. 49, 431–455.
Ding, C., 2003. Land policy reform in China: assessment and prospects. Land Use Policy 20, 109–120.
Donovan, G.H., Butry, D.T., 2010. Trees in the city: valuing street trees in Portland, Oregon. Landsc. Urban Plann. 94 (2), 77–83.
Garmendia, E., Apostolopoulou, E., Adamsa, W.M., 2016. Biodiversity and green infrastructure in Europe: boundary object or ecological trap? Land Use Policy 56, 315–319.
Ginn, F., Demeritt, D., 2009. Nature: a contested concept. In: Clifford, N.J., Holloway, S.L., Rice, S.P., Valentine, G. (Eds.), Key Concepts in Geography, 2nd ed. SAGE: London and Thousand Oaks, Calif, pp. 300–311.
Greene, W.H., 2011. Econometric Analysis, 7th ed. Prentice Hall, Upper Saddle River.
Harvey, D., 1985. The Urbanization of Capital. Blackwell, Oxford, UK.
Harvey, A., 1990a. The Econometric Analysis of Economic Time Series, 2nd ed. MIT Press, Cambridge, MA.
Harvey, D., 1990b. The Condition of Postmodernity-an Enquiry into the Origins of Cultural Change. Blackwell, Oxford.
Harvey, D., 1996. Justice, Nature and the Geography of Difference. Blackwell, Oxford.
Harvey, D., 2012. Rebel Cities: From the Right to the City to the Urban Revolution. Verso, New York.
Heynen, N.C., Lindsey, G., 2003. Correlates urban forest canopy cover: implications for local public works. Public Works Manage. Policy 8, 33–47.
Heynen, N., Perkins, H.A., Roy, P., 2006. The political ecology of uneven urban green space: the impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. Urban Aff. Rev. 42 (1), 3–25.
Hill, E., Dorfman, J.H., Kramer, E., 2010. Evaluating the impact of government land use policies on tree canopy coverage. Land Use Policy 27, 407–414.
Holifield, R., Porter, M., Walker, G., 2009. Introduction spaces of environmental justice: frameworks for critical engagement. Antipode 41, 591–612.
Hope, D., Gies, C., Zhu, W., Fagab, W.F., Redman, C.L., Grimm, N.B., Nelson, A.L., Martin, C., Kinzig, A., 2003. Socioeconomics drive urban plant diversity. Proc. Natl. Acad. Sci. 100 (15), 8788–8792. Https://lafoundation.org/research/landscape-performance-series/.
James, P., Tzoulas, K., Adams, M.D., Barber, A., Box, J., Breuste, J., Elmqvist, T., Frith, M., Gordon, C., Greening, K.L., Handley, J., Haworth, S., Kazmierczak, A.E., Johnston, M., Korpela, K., Moretti, M., Niemelä, J., Pauleit, S., Roe, M.H., Sadler, J.P., Thompson, C.W., 2009. Towards an integrated understanding of green space in the European built environment. Urban For. Urban Plan. 8, 65–75.
Jenerette, G.D., Miller, G., Buyantuev, A., Pataki, D.E., Gillespie, T.W., Pincetl, S., 2013. Urban vegetation and income segregation in dry lands: a synthesis of seven metropolitan regions in the southwestern United States. Environ. Res. Lett. 8, 1–8.
Jiao, L., Liu, Y., 2010. Geographic field model based hedonic valuation of urban open spaces in Wuhan, China. Landsc. Urban Plann. 98, 47–55.
Jim, C.Y., Chen, W.Y., 2006. Impacts of urban environmental elements on residential housing prices in Guangzhou (China). Landsc. Urban Plann. 78, 422–434.
Jim, C.Y., Liu, H.H.T., 2000. Statutory measures for the protection and enhancement of the urban forest in Guangzhou city, China. Forestry 73, 311–329.
Kendal, D., Williams, N.S.G., Williams, K.J.H., 2012. Drivers of diversity and tree cover in gardens: parks and streetscapes in an Australian city. Urban For. Urban Green. 11, 257–265.
Kijima, M., Nishide, K., Ohyama, A., 2010. Economic models for the environmental Kuznets curve: a survey. J. Econ. Dynam. Control 34, 1187–1201.
Kitchen, L., 2013. Are trees always 'Good'? Urban political. ecology and environmental justice in the valleys of south wales. Int. J. Urban Reg. Res. 37 (6), 1968–1983.
Klink, J., 2013. Development regimes, scales and state spatial restructuring: change and continuity in the production of urban space in metropolitan Rio de Janeiro, Brazil. Int. J. Urban Reg. Res. 37.4, 1168–1187.
Landry, S.M., Chakraborty, J., 2009. Street trees and equity: evaluating the spatial distribution of an urban amenity. Environ. Plann. A 41, 2651–2670.
Lefebvre, H., 1991. The Production of Space, vol. 32–33. Blackwell, Oxford, pp. 49–65.
Li, F., Wang, R., Liu, X., Zhang, X., 2005. Urban forest in China: development patterns: influencing factors and research prospects. Int. J. Sustain. Dev. World Ecol. 12, 197–204.
Lin, G.C.S., Yi, F., 2011. Urbanization of capital or capitalization on urban land? Land development and local public finance in urbanizing China. Urban Geogr. 32, 50–79.
Luck, G.W., Smallbone, L.T., Obrien, R., 2009. Socio-economics and vegetation change in urban ecosystems: patterns in space and time. Ecosystems 12, 604–620.
Luttik, J., 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. Landsc. Urban Plann. 48 (3–4), 161–167.
Lutzenhiser, M., Netusil, N.R., 2001. The effect of open spaces on a home's sale price. Contemp. Econ. Policy 19, 291–298.
Majumdar, S., Deng, J.Y., Zhang, Y.Q., Pierskalla, C., 2011. Using contingent valuation to estimate the willingness of tourists to pay for urban forests: a study in Savannah, Georgia. Urban For. Urban Green. 10, 275–280.
McGee, T.G., 2009. Interrogating the production of urban space in China and Vietnam under market socialism. Asia Pac. Viewpoint 50 (2), 228–246.
Mell, I.C., Henneberry, J., Hehl-Lange, S., Keskin, B., 2016. To green or not to green: establishing the economic value of green infrastructure investments in The Wicker Urban Sheffield. For. Urban Green. 18, 257–267.
Mennis, J., 2006. Socioeconomic-vegetation relationships in urban, residential land: the case of Denver, Colorado. Photogramm. Eng. Remote Sens. 72, 933.
Nowak, D.J., Dwyer, J.D., 2007. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J.E. (Ed.), Urban and Community Forestry in the Northeast,

2nd ed. Springer-Verlag, Berlin, pp. 25–46.
Orford, S., 1999. Valuing the Built Environment: GIS and House Price Analysis. Ashgate, London.
Panduro, T.E., Veie, K.L., 2013. Classification and valuation of urban green spaces–a hedonic house price valuation. Landscape Urban Plann. 120, 119–128.
Payton, S., Lindsey, G., Wilson, J., Ottensmann, J.R., Man, J., 2008. Valuing the benefits of the urban forest; a spatial hedonic approach. J. Environ. Plan. Manage. 51 (6), 717–736.
Peckham, S.C., Duinker, P.N., Ordóñez, C., 2013. Urban forest values in Canada: views of citizens in Calgary and Halifax. Urban For. Urban Green. 12, 154–162.
Peng, J., Zhao, M.Y., Guo, X.N., Pan, Y.J., Liu, Y.X., 2017. Spatial-temporal dynamics and associated driving forces of urban ecological land: a case study in Shenzhen City, China. Habitat Int. 60, 81–90.
Peterson, G.E., 2008. Unlocking Land Values to Finance Urban Infrastructure. The World Bank, Washington DC.
Purcell, M., 1997. Ruling Los Angeles: neighborhood movements, Urban regimes, and the production of space in southern California. Urban Geogra. 18 (8), 684–704.
Raco, M., Gilliam, K., 2012. Geographies of abstraction, urban entrepreneurialism, and the production of new cultural spaces: the West Kowloon Cultural District, Hong Kong. Environ. Plann. A 44 (2012), 1425–1442.
Salanié, B., 2000. Microeconomics of Market Failures. MIT Press, Cambridge, MA, pp. 238.
Saphores, J.D., Li, W., 2012. Estimating the value of urban green areas: a hedonic pricing analysis of the single family housing market in Los Angeles, CA. Landscape Urban Plann. 104, 373–387.
Schetke, S., Qureshi, S., Lautenbach, S., Kabisch, N., 2016. What determines the use of urban green spaces in highly urbanized areas? – Examples from two fast growing Asian cities. Urban For. Urban Green. 16, 150–159.
Schwarz, K., Fragkias, M., Boone, C.G., Zhou, W., McHale, M., Grove, J.M., et al., 2015. Trees grow on money: urban tree canopy cover and environmental justice. PLoS One 10 (4), e0122051.
Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., Kaoma, H., 2015. Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. Landscape Urban Plann. 136, 76–86.
Swanwick, C., Dunnett, N., Woolley, H., 2003. Nature, role and value of green space in towns and cities: an overview. Built Environ. 29 (2), 94–106.
Swyngedouw, E., Heynen, N.C., 2003. Urban political ecology: justice and the politics of scale. Antipode 35, 898–918.
Tan, P.Y., Wang, J., Sia, A., 2013. Perspectives on five decades of the urban greening of Singapore. Cities 32, 24–32.
Troy, A.R., Grove, J.M., O'Neil-Dunne, J.P.M., Pickett, S.T.A., Cadenasso, M.L., 2007. Predicting opportunities for greening and patterns of vegetation on private urban lands. Environ. Manage. 40, 394–412.
Tyrväinen, L., 2001. Economic valuation of urban forest benefits in Finland. J. Environ. Manage. 62 (1), 75–92.
Visscher, R.S., Nassauer, J.I., Marshall, L.L., 2016. Homeowner preferences for wooded front yards and backyards: implications for carbon storage. Landsc. Urban Plann. 146, 1–10.
Waldheim, C., 2006. The Land Urbanism Reader. Princeton Architectural Press.
Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health: and environmental justice: the challenge of making cities 'just green enough'. Landsc. Urban Plann. 125, 234–244.
Wooldridge, J.M., 2002. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, MA.
Wu, W.J., Dong, G.P., 2014. Valuing the green amenities in a spatial context. J. Reg. Sci. 54 (4), 569–585.
Wu, Q., Li, Y., Yan, S., 2015a. The incentives of China's urban land finance. Land Use Policy 42, 432–442.
Wu, J.S., Wang, M.J., Li, W.F., Peng, J., Huang, L., 2015b. Impact of urban green space on residential housing prices: case study in shenzhen. J. Urban Plann. Dev. 141 (4).
Wu, F.L., 1999. The 'game' of landed-property production and capital circulation in China's transitional economy, with reference to Shanghai. Environ. Plann. A 31, 1757–1771.
Xiao, Y., Li, Z.G., Webster, C., 2016. Estimating the mediating effect of privately-supplied green space on the relationship between urban public green space and property value: evidence from Shanghai, China. Land Use Policy 54, 439–447.
Yang, J., Huang, C.H., Zhang, Z.Y., Wang, L., 2014. The temporal trend of urban green coverage in major Chinese cities between 1990 and 2010. Urban For. Urban Green. 13 (1), 19–27.
Yang, Z.S., Hao, P., Cai, J.M., 2015. Economic clusters: a bridge between economic and spatial policies in the case of Beijing. Cities 42, 171–185.
Yang, X., Yi, L., Yan, G., Yuan, Y., 2017. Estimating the willingness to pay for green space services in Shanghai: implications for social equity in urban China. Urban For. Urban Green. 26, 95–103.
Young, R.F., 2011. Planting the living city: best practices in planning green infrastructure–results from major U. S. citie. J. Am. Plann. Assoc. 77, 368–381.
Zank, B., Bagstad, K.J., Voigt, B., Villa, F., 2016. Modeling the effects of urban expansion on natural capital stocks and ecosystem service flows: a case study in the Puget Sound, Washington, USA. Landsc. Urban Plann. 149, 31–42.
Zhao, J., Chen, S., Jiang, B., Ren, Y., Wang, H., Vause, J., Yu, H., 2013. Temporal trend of green space coverage in China and its relationship with urbanization over the last two decades. Sci. Total Environ. 442, 455–465.
Zhou, X., Wang, Y.C., 2011. Spatial–temporal dynamics of urban green space in response to rapid urbanization and greening policies. Landsc. Urban Plann. 100, 268–277.
Zhu, P., Zhang, Y., 2008. Demand for urban forests in United States cities. Landscape Urban Plann. 84, 293–300.