Environmental Science & Technology

POLICY ANALYSIS

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Landscape Urbanization and Economic Growth in China: Positive Feedbacks and Sustainability Dilemmas

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Supporting Information

ABSTRACT: Accelerating urbanization has been viewed as an important instrument for economic development and reducing regional income disparity in some developing countries, including China. Recent studies (Bloom et al. 2008) indicate that demographic urbanization level has no causal effect on economic growth. However, due to the varying and changing definition of urban population, the use of demographic indicators as a sole representing indicator for urbanization might be misleading. Here, we re-examine the causal relationship between urbanization and economic growth in Chinese cities and provinces in recent decades, using built-up areas as a landscape urbanization indicator. Our analysis shows that (1) larger cities, both in terms of population size and built-up area, and richer cities tend to gain more income, have larger built-up area expansion, and attract more population, than poorer cities or smaller cities; and (2) that there is a long-term bidirectional causality between urban built-up area expansion and GDP per capita at both city and provincial level, and a short-term bidirectional causality at provincial level, revealing a positive feedback between landscape urbanization and urban and regional economic growth in China. Our results suggest that urbanization, if measured by a landscape indicator, does have causal effect on economic growth in China, both within the city and with spillover effect to the region, and that urban land expansion is not only the consequences of economic growth in cities, but also drivers of such growth. The results also suggest that under its current economic growth model, it might be difficult for China to control urban expansion without sacrificing economic growth, and China's policy to stop the loss of agricultural land, for food security, might be challenged by its policy to promote economic growth through urbanization.

INTRODUCTION

Statistically, urbanization levels are higher in countries that have higher income, and with many studies suggesting a strong correlation between urbanization and income level, it has been a long-standing notion that urbanization promotes economic growth.[1] Because of this, accelerating urbanization has been viewed as an important instrument for economic development and reducing regional income disparity in some developing countries including China.[2−4] Recent studies, however, question this assumption. Bloom et al.[5] showed that demographic urbanization levels, measured as the share of population living in cities, have no causal effect on national wealth examined across 180 countries. Also using demographic indicators, other studies obtained similar conclusion in Africa and Asia.[6,7] However, using demographic data to represent urbanization level might be inappropriate for such analysis because the varying and changing definition of the "urban population" often makes it incomparable over time and across countries.[8−11] Urbanization is a multifaceted phenomenon, with profound changes in land use and the built environment, economic structure, social organizations, behavioral and consumption patterns, political and administrative arrangements.[12] Even assuming the result obtained by Bloom et al.[5] and other studies do establish that there is no causal linkage between demographic urbanization level and economic growth, this is not sufficient to establish there is no causal linkages between urbanization and economic growth, as there may be causal linkages between other aspects of urbanization and economic growth when measured by different, and perhaps more suitable indicators.

Land conversion is one of the key processes that characterizes urbanization,[13] and many studies reveal the process, speed, magnitude, and consequences of land use change accompanying urbanization.[14−18] We use the term *landscape urbanization* to describe and differentiate this process from *demographic urbanization* which is based on the size or share of population living in cities. A landscape urbanization indicator, such as the total built-up area in a city, may be a useful substitute for demographic urbanization indicators as it has clear and unified definition, and therefore provides new potential for

Received: October 21, 2010
Accepted: November 21, 2011
Revised: October 31, 2011
Published: November 21, 2011

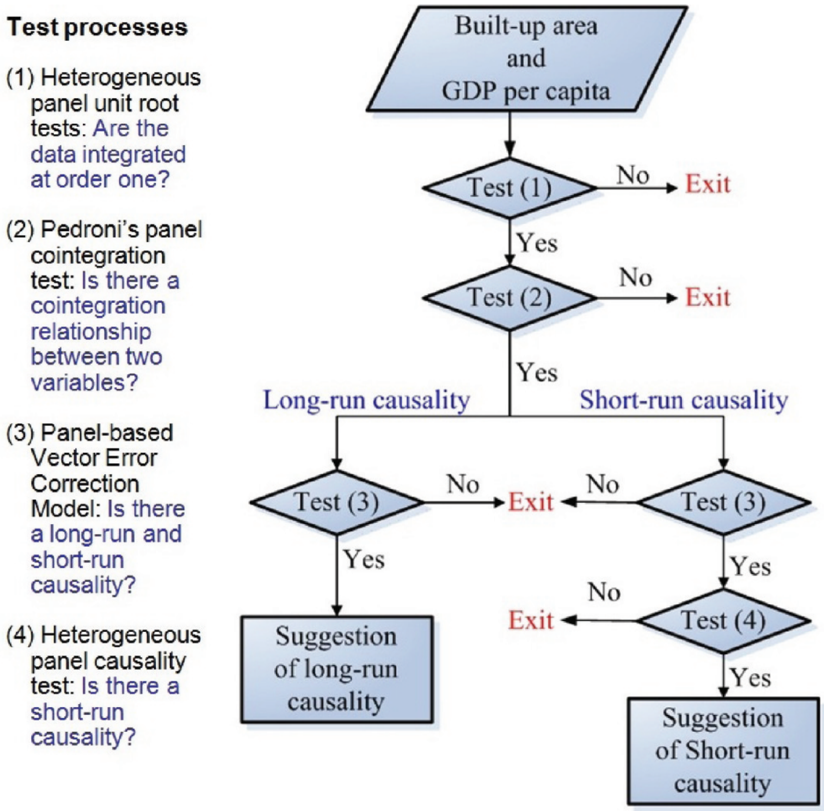

Figure 1. Flowchart of causality test.

conducting cross-country time-series analysis, using either statistical data or satellite remote sensing data. In addition to describing urbanization processes in general, landscape urbanization indicators may reveal linkages between urbanization and economic and ecological processes and environmental consequences that demographic data cannot.[13,19−21]

Many studies argue that economic growth stimulates urban expansion in China or vice versa, but these arguments are generally based on a positive correlation between these two indicators.[22−25] Yet, correlation does not necessarily mean causation. Recent study on land-use drivers in the Pearl River Delta during 1988−1996[26] found a causal linkage from foreign direct investment to urban expansion but not vice versa. Du et al.[27] found a bidirectional causality between urban land expansion and economic growth in an economic and technological development zone in Tianjin. Yet, these studies focus on specific city region or urban districts, and there is no analysis illuminating the causal relationships between urban land expansion and economic growth across a range of Chinese cities and regions.

In this work, we re-examine the causal relationship between urbanization and economic growth in the Chinese context, using built-up area as a landscape urbanization indicator. We assess patterns of urban land expansion and economic growth according to differences in city size, conduct long-term and short-term causal analysis between urban land-use expansion and economic growth, both at city level and provincial level. We end with a brief discussion on policy and scientific implications of our results.

DATA AND METHODS

To examine whether landscape urbanization boosts economic growth at the provincial and urban level, and whether economic growth causes further landscape urbanization, we examine how built-up area and economic growth changed in different cities, and conduct causality analysis between built-up area and GDP per capita. In this paper, we use the definition of causality proposed by Granger,[28] where variable X is said to be the Granger cause of Y if at time t, Y_{t+1} is better predicted by using past values of X than by not doing so. Our causality test consists of four stages (see Figure 1 for the flowchart): (1) heterogeneous panel unit root tests[29,30] to test the order of integration of variables; (2) Pedroni's panel cointegration test[31,32] to examine the long-run relationship between the variables given that all variables are first-order integrations; (3) panel-based vector error correction model (VECM)[33] to examine both short- and long-run causality; and (4) heterogeneous panel causality test[34] on the first difference of all variables to further verify short-run causality. Decisions about statistical significance of test were made on a 5% level.

As previously discussed, we use built-up area as indicator of landscape urbanization. In China, built-up area is defined as a largely continuous area covered by urban facilities but may include some isolated facilities such as airports. It is generated by the Ministry of Housing and Urban-Rural Development (MOHURD) based on two sources: (i) annual incremental data based on the actual land area that is granted the permission to be developed into urban land in each city each year; (ii) State Bureau of Surveying and Mapping performs actual measurements annually or every other year, integrating aerial photo

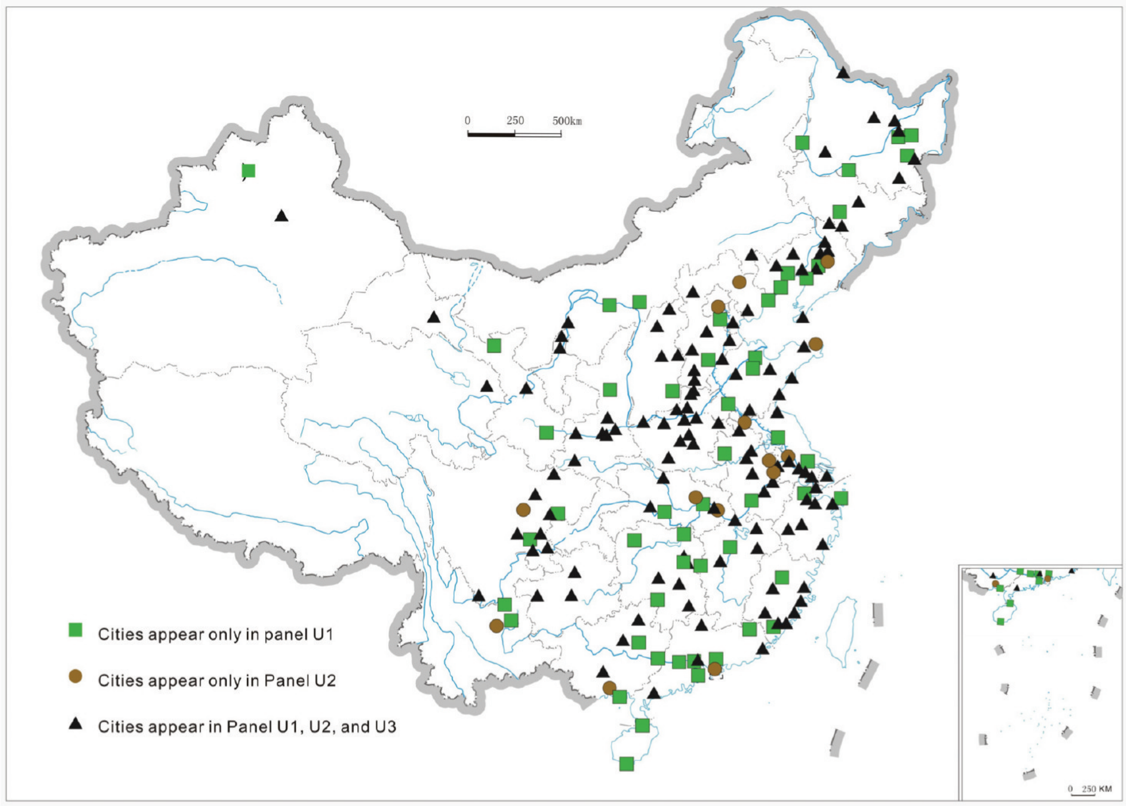

Figure 2. Spatial distribution of Chinese cities included in analysis. Panel U1 (1990−1998) consists of 174 cities. Panel U2 (1997−2006) consists of 135 cities. Panel U3 (1990−2006) consists of 121 cities that appear in both U1 and U2 panel.

and/or other remote sensing data and ground surveys. The MOHURD combines these two data source and produces the initial data. The Department of Urban Social and Economic Survey at the National Bureau of Statistics performs sample investigation in selected cities, to calibrate the initial data produced by the MOHURD. The resulting measure is considered as the best proxy of the real urban area in China.[24,35,36] According to He et al.,[37] the relative error between the derived total urban land area and the statistical built-up area data at national scale was less than 2% in 1992, 1996, and 1998, and maximum relative error at province scale did not exceed 10% with most of the provinces less than 3%.

Three panels of urban data and one panel of provincial-level data are used for the causality test. It is common in China that a city includes some counties which are largely rural. In order for the city data to reflect only urban component and exclude the counties within the city administrative boundaries, our data set exclude county level cities/towns. The GDP, year-end population, and built-up area excluding counties for the 174 Chinese cities (1990−1998) in panel U1 come from a single source, Cities China 1949−1998,[38] and the data for the 135 Chinese cities (1997−2006) in panel U2 are from the China City Statistical Yearbook series.[39] See Figure 2 for their spatial distribution map, and Supporting Information for the list of cities in each panel. We excluded those cities that do not have the full range of data for the period of interest, and those that have apparent data errors in the original database. Panel U3 consists of 121 cities that appear in both panels U1 and U2, and thus have time range of 1990−2006. All the GDP data are converted into comparable prices, and GDP per capita is calculated from GDP divided by the year-end population. We also test whether built-up area expansion contributes to regional economic growth, with a panel (P) of built-up area and GDP per capita data (1997−2006) for all 34 provincial regions except Hong Kong, Macau, and Taiwan, compiled from the China Statistical Yearbook series.[40]

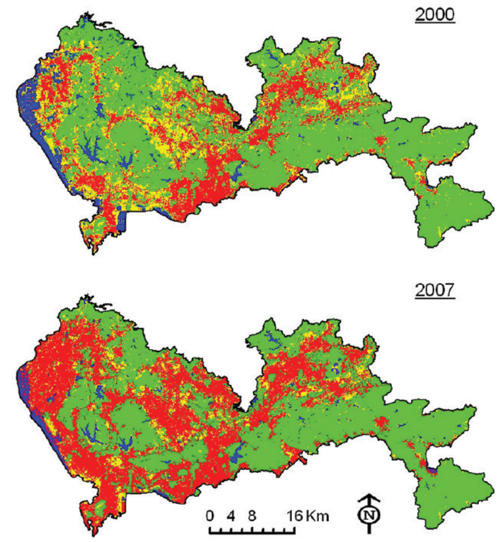

Figure 3. Rapid urban expansion of Shenzhen City from 2000 to 2007 based on remote sensing image interpretation. Red color for urban land, yellow for bare land, green for land with vegetation, blue for water body. ETM+ image on November 1st 2000, TM image on September 15th 2000, ETM+ SLC-off composite data on December 7th and November 30th 2007 are used for this comparison.

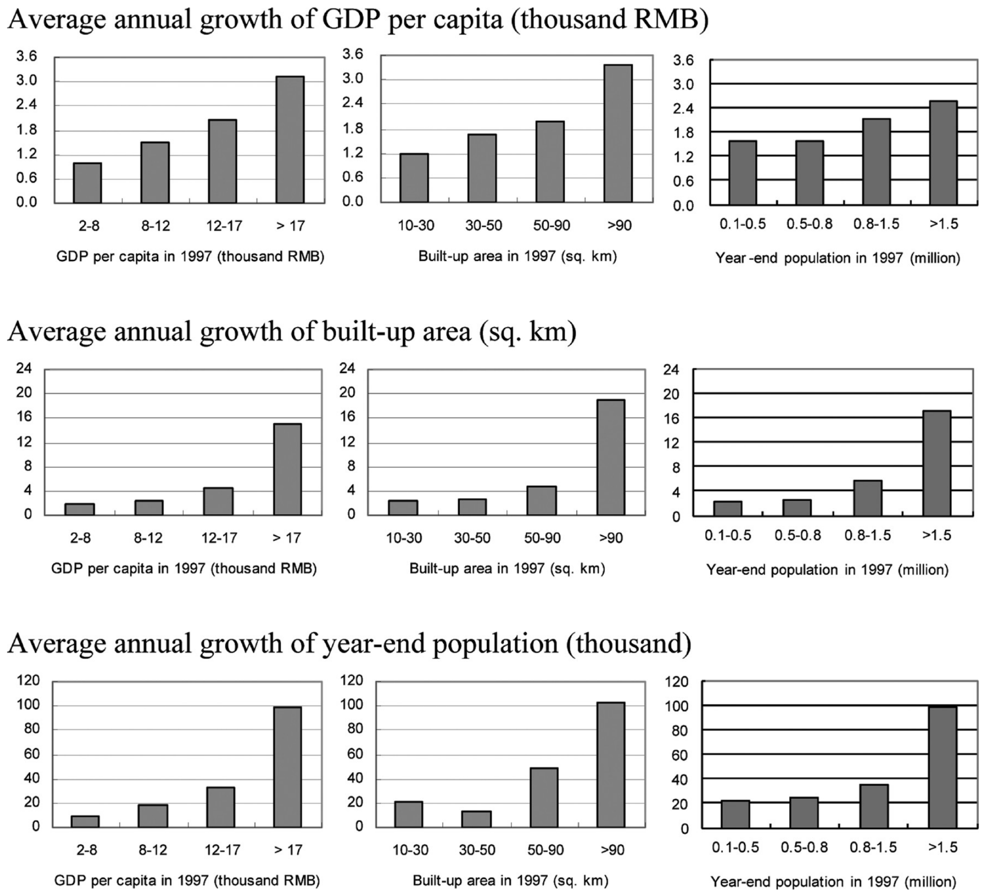

Figure 4. Average annual growth of GDP per capita, built-up area, and population of 135 Chinese cities during 1997−2006.

RESULTS

Growth Pattern of Chinese urbanization. China is experiencing unprecedented, rapid urbanization.[2,23,41] Rapid urban expansion is a spatial manifestation of this process, and has become the most significant characteristic of land-use change in China.[42] Urban land conversion is regarded as one of the primary reasons for agricultural land loss.[43] During 1997 to 2006 in China, a total of 12 869 km^2 of land was converted into built-up area.[40] In the same period, the average annual growth of built-up area in 135 cities was 5.7 km^2 every year. This figure is much higher in larger cities. For example, during this period, Shenzhen city added 66 km^2 of built-up area each year on average. Based on remote sensing image interpretation, growth in urban built-up area of Shenzhen City from 2000 to 2007 was dramatic (Figure 3). In order to achieve a better understanding of growth pattern across different cities, we have examined the growth of 135 cities in panel U2 during 1997−2006 according to cities' initial size in 1997. The average annual growth of GDP per capita, built-up area, and population increase are significantly positively correlated with initial GDP per capita, built-up area, and population size—in other words, richer cities, in terms of GDP per capita, and larger cities, in terms of demographic size and landscape size, also gain more income, have larger built-up area expansion, and attract more population—than poorer and smaller cities (Figure 4). It is important to note the cross-effect here, for example, larger cities are gaining more per capita income, and grow faster in terms of total GDP; while richer cities are expanding more in terms of size. We have also examined whether this tendency in total amount translates into difference in normalized or marginal growth rate in all measured indicators according to city size. Our results indicate no significant correlation in either case, suggesting that overall, there is no general trend that either smaller cities or larger cities grow faster in terms of growth rate (see Supporting Information for the analysis results).

Causal Effects between Built-up Area and Income Growth in China. We perform Granger causality test to further verify the existence and direction of causality between built-up area and GDP per capita in China. The results of heterogeneous panel unit root tests indicate that built-up area and GDP per capita in provincial panel and three urban panels are all integrated at order one. The results from Pedroni's method indicate the existence of cointegration between GDP per capita and built-up area in all panels, meaning there is a long-run equilibrium relationship between GDP per capita and built-up area. Once we established that the two variables are cointegrated, we use a panel-based VECM to conduct Granger causality tests. The results indicate that there are long-run bidirectional causalities between GDP per capita and built-up area in all panels (Table 1). In the short-run, provincial panel has bidirectional causality between built-up area and GDP per capita, namely the growth in built-up area cause growth in GDP per capita, and vice versa.

To further verify the short-run causal linkages, we perform Hurlin's heterogeneous panel Granger causality test. The results suggest bidirectional causality between built-up area and GDP per capita for the provincial panel. Panel U1 is too short to apply

dx.doi.org/10.1021/es202329f | Environ. Sci. Technol. 2012, 46, 132−139

Table 1. Wald F-Test Statistics from Panel-Based Vector Error Correction Model[a]

			F-statistic value	
panels	causal	result	short run	long run
U1	BU	pGDP	3.46 (0.06)	210.15 (0.00)
	pGDP	BU	0.14 (0.71)	30.79 (0.00)
U2	BU	pGDP	60.07 (0.00)	571.59 (0.00)
	pGDP	BU	15.42 (0.00)	147.01 (0.00)
U3	BU	pGDP	32.39 (0.00)	462.80 (0.00)
	pGDP	BU	1.93 (0.07)	51.96 (0.00)
P	BU	pGDP	14.93 (0.00)	45.09 (0.00)
	pGDP	BU	3.23 (0.02)	57.78 (0.00)

[a] The results suggest the existence of long-run bidirectional causalities between built-up area and GDP per capita in all panels; no short-run causality in panel U1; bidirectional short-run causalities in panel U2 and panel P; short-run causal effect from built-up area to GDP per capita in panel U3. Note: Panel U1 consists of 174 Chinese cities' annual data during 1990−1998. Panel U2 consists of 135 Chinese cities' annual data during 1994−2005. Panel U3 consists of 121 cities that appear in both U1 and U2 panel, annual data during 1990−2005. Panel P consists of 31 Chinese provinces' annual data during 1997−2006. BU and pGDP stand for built-up area and GDP per capita, respectively. The null hypothesis is non-causality. Cases with probability levels (shown in parentheses) lower than 0.05 reject the null hypothesis.

Table 2. Hurlin Heterogeneous Panel Granger Causality Test Results[a]

panel	causal	result	$\tilde{Z}_{N,T}^{HNC}$
U1	ΔBU	ΔpGDP	Lag1: N/A
	ΔpGDP	ΔBU	Lag1: N/A
U2	ΔBU	ΔpGDP	Lag1: 1.04 (0.30)
			Lag2: N/A
	ΔpGDP	ΔBU	Lag1: 0.28 (0.78)
			Lag2: N/A
U3	ΔBU	ΔpGDP	Lag1: 0.04 (0.97)
			Lag2: 1.63 (0.10)
			Lag3: 1.20 (0.23)
			Lag4: N/A
	ΔpGDP	ΔBU	Lag1: 0.57 (0.58)
			Lag2: 2.07 (0.04)
			Lag3: 1.86 (0.06)
			Lag4: N/A
P	ΔBU	ΔpGDP	Lag1: 2.34 (0.02)
			Lag2: N/A
	ΔpGDP	ΔBU	Lag1: 2.04 (0.04)
			Lag2: N/A

[a] The results indicate a bidirectional short-run causality between built-up area and GDP per capita in panel P, and a causal effect from GDP per capita to built-up area in panel U3 only under Lag2 model. Note: Panel U1 consists of 174 Chinese cities' annual data during 1990−1998. Panel U2 consists of 135 Chinese cities' annual data during 1994−2005. Panel U3 consists of 121 cities that appear in both U1 and U2 panel, annual data during 1990−2005. Panel P consists of 31 Chinese provinces' annual data during 1997−2006. BU and pGDP stand for built-up area and GDP per capita, respectively. Δ denotes the first difference of the variable. $\tilde{Z}_{N,T}^{HNC}$ is a statistic defined by Hurlin[34]. Lag1, Lag2, Lag3, and Lag4 mean Hurlin's test model of lag order 1, 2, 3, and 4, respectively. The null hypothesis is homogeneous non-causality. Cases with probability levels (shown in parentheses) lower than 0.05 reject the null hypothesis.

Hurlin's method, the causal effects in U2 panel are not significant, and causal effect from GDP per capita to built-up area in panel U3 only under Lag2 model (Table 2).

Summarizing the results, we can draw two conclusions. First, there is a long-run bidirectional causality between GDP per capita and built-up area in all panels. The three urban panel results suggest that there is a positive feedback, where urban land expansion brings about growth in GDP per capita which in turn increases urban land expansion. This positive feedback may explain the mechanism behind the trends in Figure 3, indicating an accelerating growth in GDP per capita with the growth in the city size. The provincial panel consists of total urban land expansion within the province and overall GDP per capita of the province including city and rural, so the result at the provincial panel means urban land expansion not only contributes to the city GDP, but also to the overall GDP growth of the province. This means the effect of urban expansion extends beyond the city boundary, and has spillover influences to the region surrounding the city.

Second, our results indicate that the provincial panel has short-run bidirectional causality but do not sufficiently confirm a short-run relationship in any of the three urban panels. There are several possible reasons for this. A careful study of the original data suggests that city level built-up area data sometimes increase abruptly due to the effect of large built-up area projects, while at the provincial level these steps are smoothed out by multiple cities. Since the short-run relationship measures year-to-year variation, this difference in data trends can cause the lack of a short-run causal effect. In addition, our urban panels consist of cities that have a full range of data and thus exclude cities that have become prefectural level cities after 1990 (in U1 and U3) (for example, there were 31 new prefectural level cities between 1990 and 1997) or 1997 (in U2) and small cities and towns below prefectural level, while the provincial panel naturally includes all cities within the province regardless of their times of emergence. It is likely that these new prefecture level cities and small towns and cities below prefectural level have contributed toward a stronger short-run causal effect at the provincial level.

DISCUSSIONS

The Role of Land in China's Economic Growth. Land is regarded as playing a less and less important role in economic growth.[44−46] Our findings in China suggest otherwise. China's legal system on land ownership and land-use rights might contribute to the significant role of landscape urbanization in economic growth and the positive feedback between them in recent decades. Land is publicly owned in China, and land supply becomes a powerful macro-economy intervention tool for Chinese governments especially since 2003.[47] China has a system of long-term lease of land-use rights, which means government could issue a one-off land lease for a duration of 50−70 years,[48] and raise considerable revenue from the leasing. During the six year period of 1999 to 2006, the total income arising from land-use leasing of state-owned land, which often means converting other land-use types into urban built-up land, grew ∼15 times, reaching 808 billion Yuan,[49] raising its proportion in China's government financial income ∼3.6 times, reaching nearly 21%, its proportion in China's GDP ∼5 times to 3.8%. The income from land leases can account for 30−70% of a city's financial revenue.[35] This income of government has a designated use, with 50% tied to improvement of the leased land such as providing basic infrastructure including water, electricity, Internet, wastewater treatment, gas, roads and heating. The remaining 50% goes to infrastructure investment within the city.[50] These investments directly create jobs in the construction sector, which attracts more people into cities and thus stimulates further urbanization. A better urban infrastructure, in turn, attracts further investment in industries and thus contributes to the economic growth of the city and the region in the long run. Therefore, land acquisition has been used heavily by Chinese local governments to fuel urban development and finance infrastructure provision.[51] Under this circumstance, land plays an active and significant role in economic growth in China.

Policy Implications for China. Our results have significant policy implications for China, revealing a tension between urbanization, environment and economic growth. Landscape urbanization brings economic growth, but at the same time could cause negative environmental impacts[52] leading to serious environmental problems in some Chinese cities.[53] On the one hand, our results confirm that the national policy of promoting urbanization to enhance economic growth does hit the mark. Since by definition built-up area expansion requires infrastructure investment, our results might highlight the importance of infrastructure investment for urbanization to deliver the anticipated economic growth.

On the other hand, the positive feedback suggests that China's policy to arrest the loss of agricultural land might be challenged by its own policy to promote economic growth through urbanization. Urbanization takes up large amounts of arable land which presents a major threat for sustainable agricultural production and food security in China.[43] In 2006, China had 0.09 ha of arable land per capita, which was less than 40% of global average; meanwhile it lost 0.31 million hectares of arable land, of which 84% was changed into construction land.[54] At this rate of urban expansion, the government designated food security "bottom line" of 120 million hectares of arable land,[55] is fast approaching.

The close linkages between urban expansion and economic growth indicate that the current economic growth model in urban China is highly dependent on natural resource input, in this case, land. It is likely that eventually this resource-intensive growth mode will change toward a more service-oriented one and thus require less land input, as experienced in other developed countries. However, it might be very difficult for China to control urban expansion without sacrificing economic growth, at least under its current economic growth model. While the result only reflects the tendency on an aggregated level and therefore does not dictate the behavior of each and every individual city should follow the same pattern, empirical evidence does seem to reinforce our findings. For example, nearly half of the first designated greenbelt in Beijing was already changed into built-up area in 2005,[56] suggesting a strong tendency of urban land-use expansion and the difficulty of preventing it. Empirical evidence in the macro-economic history of China also supports the close linkages between urban expansion and economic growth. In 1999, the Chinese government strived to keep the economic growth rate at 8% after the economic recession caused by the Southeast Asia financial crisis, and found that urbanization was a good instrument for promoting economic growth.[57] In 2004, the State Council subsequently decided to tighten its control over permission for new land development, which has brought about an economic slowdown in some cities and regions.[58]

This challenge is likely to continue into the future. As part of its economic growth strategy, the Chinese government aims to increase demographic urbanization from 43% in 2005 to 47% by 2010, with an economic growth rate of 7.5%.[55] This will inevitably increase demand for built-up areas for infrastructure, industry, and residential use. Given the agricultural land scarcity in the country, there is an urgent need for China to identify an alternative pathway that eases the heavy dependent on land resource input.

While it is not clear to what extent the causal effect between urban expansion and economic growth is applicable to other contexts than China, putting urban expansion under control is a universally challenging task.[59] For example, the greenbelt in Seoul aimed at containing expansion within its ring resulted in leapfrog development.[60] Bad urban planning or poor implementation of such is often blamed for uncontrolled urban growth. Assuming the existence of a feedback between urban expansion and economic growth is a widespread phenomenon, then the driving force is coming from a different dimension and urban planning alone might not be sufficient to achieve the goal.

Implications for Urban Research. Our findings imply that compared to a demographic urbanization indicator, a landscape indicator has the potential to better reveal the complex linkages between urbanization and accompanying economic and environmental processes. Built-up area expansion is a spatial manifestation of population, economic, and environmental dynamics of urbanization. As discussed by Bloom et al., there are different types of urbanization in terms of drivers and economic outcomes,[5] among which demographic indicators alone cannot distinguish. Built-up area might differentiate them to some extent. While urban population growth with built-up area expansion might indicate a direct association with economic activities, urban population growth without built-up area expansion might indicate urbanization without economic growth, especially in low-income countries. In addition to economic aspects, built-up area also reveals strong environmental linkages through concentration of materials,[61] and varying energy use and GHG emissions according to different urban density and transportation system.[62,63]

Our analysis on urban growth pattern shows larger cities gain more per capita GDP growth, and more and faster in terms of total GDP, which endorses Betterncourt et al.'s[44] result. It also shows that richer and larger cities (both in terms of population size and built-up area) are expanding more. These suggest the relationship between city size and wealth creation is not only nonlinear but also bidirectional and complex, which in turn suggests the existence of feedback mechanisms in the growth of cities. The positive feedback between landscape urbanization process and economic growth identified in this study may reveal partly the complex mechanism of such nonlinear, accelerated growth in city size and wealth. Urban land expansion is not only the consequences of economic growth in cities, but also drivers of such growth. While it seems urban land expansion can trigger such feedback within the Chinese contexts, there might be other types of such positive feedback in work in other context, involving other factors. Uncovering these dynamics and mechanisms of the interaction among different components within an urban system is an important step toward understanding the complexity of cities and urbanization processes. This will in turn inform a more coherent urbanization, economic and environmental policy system that reflects the true dynamics of cities.

ASSOCIATED CONTENT

S Supporting Information. Additional information as noted in the text. This material is available free of charge via the Internet at http://pubs.acs.org.

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ACKNOWLEDGMENT

We thank Zinai Li and Christophe Hurlin for technical advice on econometric analysis; Chunyang He for assistance in collecting data; Thomas Graedel, Karen Seto, Tim Baynes, Matt Beaty, David Fisk, Canfei He, Peter Kanowsky, Marcus Lane, Jinshe Liang, Brian Walker, Jingzhe Zheng for helpful comments and suggestions on an earlier version; and three anonymous reviewers for their insightful comments. This research is partly funded by "Urbanization and Environmental Change in Asia" project within CSIRO Climate Adaptation Flagship, Australia, and "Large Scale Risk Governance" cosupported by the National Natural Science Foundation of China (NSFC) (Project No.: 40821140354) and IHDP-IRG Core Science Project (case studies).

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