Is Urban Sprawl Decoupled from the Quality of Economic Growth? Evidence from Chinese Cities

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Abstract: This paper investigates how urban sprawl and the quality of economic growth interact and further studies the spatial-temporal decoupling characteristics of both. To achieve this, a framework was developed to better explain both the different dimensional effects urban sprawl exerts on the quality of economic growth and their reverse feedback relation. A sample of 285 Chinese cities (2003 to 2016) were analyzed, employing both a decoupling model and spatial correlation analysis. The findings indicated that urban sprawl and the quality of economic growth are related via scale, structure, technological efficiency, and technological progress effects. In practice, with increasing quality of economic growth, the urban sprawl index decreases at the national level. At prefecture-city level, the types of decoupling between urban sprawl and the quality of economic growth showed clear periodical and unbalanced characteristics. Furthermore, decoupling showed a significant agglomeration effect in Chinese cities, which is mainly mediated by the types High-High and Low-Low. This study provides a significant contribution to the relevant acknowledge system by providing a comprehensive theoretical framework toward an understanding of how urban expansion interacts with the quality of economic growth. Furthermore, their decoupling types and spatial differences that are critical for the urban sustainable development have been identified, thus providing several important insights for both academics and urban policy makers.

Keywords: urban sprawl; quality of economic growth; decoupling; spatial correlation; sustainable development

1. Introduction

Since the 1990s, China has gradually upgraded its socialist market economy, which boosted advancement of urbanization and industrialization. As a result, a large amount of urban construction land has replaced what was formerly cultivated land, and the pace of urban sprawl has experienced a dramatic acceleration [1]. From 2000 to 2016, the urban built-up areas of China increased from 22,439 to 54,332 km², indicating an average increase of 8.88% (National Bureau of Statistics, 2017). Meanwhile, China’s Gross Domestic Product (GDP) growth rate has exceeded that of major developed countries such as the USA. Since urban land is the carrier of economic growth, the Chinese government increasingly placed greater importance on urban land expansion and its related attributes that contribute to regional economic development [2,3]. Such expansion of urban land is a typical phenomenon of developing countries, especially in China [4]. Moderate sprawl is a central component of “smart growth” due to the presence of population and industry. However, in contrast to GDP growth, land, labor, and
environmental costs have increased to their highest levels in history. Moreover, such a “sprawl for growth” pattern has resulted in housing vacancy, redundant industry facilities, and new urban districts that suffer from inefficient utilization. This raises questions whether the ability and potential of urban sprawl can meet the necessary future improvement of China’s quality of economic growth: a process of production efficiency change that values economic, social, and environmental costs, which enables a higher desirable output level and can positively contribute to regional development.

This situation was officially recognized in the report of the 19th National People’s Congress, which alerted the Chinese nation to the importance of economic growth that integrates quantity with quality. Subsequently, the Central Committee and State Council (CPC) issued a series of management instructions to promote the land use control of provided land and to strictly limit the conversion of agricultural land into urban construction land. These policies were aimed to deter the replacement of agricultural land by urban area, and thus were conducive to high-quality economic growth. In fact, as an obvious result of China’s particularly rapid urbanization, the area of designated urban construction land has sometimes exceeded the planning index [5]. Even more discouraging, despite the average annual increase of built-up districts of 26% in Chinese cities, the GDP growth began to decrease after entering the period of the “new normal”. Moreover, due to a predominant focus on GDP, vast areas of rural land were converted into urban construction land, which had many adverse effects, such as inefficient resource utilization, farmland loss, and environmental deterioration [6]. Clearly, the pattern of “sprawl for GDP” not only aggravates extensive land use in China, but also affects the high-quality development of the Chinese economy [7]. It is thus urgent to appropriately decouple urban sprawl from the quality of economic growth and provide insights for improved urban sprawl policies and land use strategies within the context of high-quality development.

The interaction relationship between urban sprawl and economic growth has been a strongly debated issue for a long time. From the perspective of influencing mechanisms, several studies addressed the effects of urban sprawl on GDP growth and mainly paid attention to the macro panel data [8–11]. Several micro-level studies have examined the effects of land structure, land price, resource input intensity, and industrial clusters at different urbanization stages on GDP growth [12,13]. With regard to the influence of economic growth on urban sprawl, Tu et al. [9] verified the validity of China’s current administrative system and land institution toward obtaining land revenue from land expansion and development. Few studies quantified the intricate connections between both while focusing on their “coupling” [14–16]. One such study was conducted by Ma [14], constructing a Granger causality test model that identified a mutual promotion between urban sprawl and gross GDP growth. However, Altieri et al. [17] stated that although urban sprawl could raise the GDP of a city by 12%, this increase would mainly be the result of capital quantity accumulation rather than of the improvement of the total factor productivity (TFP) or technical progress. Urban sprawl is not necessarily beneficial to the quality of economic growth improvement. Similarly, other studies also investigated the quality of economic growth in the urbanization process [18,19]. In addition, Zhao et al. [20] emphasized that the effects of diversified and specialized economies on urban expansion depend on urban scale. Dadashpoor and Yousefi [21] argued that the pathway of economic growth, which affects urban sprawl, could be summarized by two approaches: centralization effects and decentralization effects.

Although existing studies largely deepen our knowledge of the linkage between urban sprawl and the economy, significant research gaps still exist: (1) From the theoretical view, an integrated analytical framework is required to understand the mutual interaction pathways between urban sprawl and the quality of economic growth. (2) At the methodological level, the measurements of economic growth, for studying the association between urban sprawl and the quality of economic growth, mostly focused on the GDP indicator, while ignoring its quality aspects. (3) From a policy evaluation perspective, while the decoupling of both is conducive to sustainable development, research that attempts to link their relationship from a decoupling perspective is not available to date. Moreover, few studies quantitatively examined the heterogeneous relationship between urban sprawl and the quality of economic growth.
Consequently, this paper studied the decoupled relationship between urban sprawl and the quality of economic growth in China by focusing on (1) How urban sprawl and the quality of economic growth interact? and (2) What is the spatial-temporal decoupling characteristics of both. This is also the innovation and contribution of this paper. Theoretically, an analytical framework is developed from a literature review based on a discussion of the complex effect between urban sprawl and the quality of economic growth. Empirically, the study is based on data of 285 Chinese cities, and the urban sprawl index and total factor productivity were calculated for the period of 2003–2016. Based on these calculations, a decoupling index was developed to investigate and study the decoupled relationship between urban sprawl and the quality of economic growth. Then, a spatial autocorrelation model was adopted to identify the spatial differences and cluster types in this decoupling relationship. This research can help government sectors make more effective measures and instructions to control urban sprawl, toward improving the quality of urban growth in China. The remainder of this paper is structured as follows: After the introduction, Section 2 summarizes existing literature and develops an interaction analytical framework. Section 3 explains both the data and methodology, which consist of city identification, the methods used to calculate urban sprawl, the quality of economic growth, the decoupling index, and the spatial autocorrelation model. Section 4 presents the empirical related results and discussion. Section 5 provides the conclusions and potential policy implications.

2. Theoretical Framework

2.1. Literature Review

2.1.1. Conceptualizations

The definition and measurement of urban sprawl is historically debatable. However, a common consensus is that urban sprawl refers to the low-density development of urban areas characterized by a rapid expansion of urban land, resulting in inefficient use of land resources and scale growth [22]. Urban sprawl is also featured by an uneven pattern of growth between an urban area and urban population, which is now widely applied to describe urban sprawl process among different urban scales [23–25]. In this context, several measurement indexes have emerged. For instance, the urban built-up area has been used as a proxy indicator to quantitatively show how sprawl has evolved [3,17,26]. Sprawl has also been quantified by the ratio of the growth rate of urban land to the growth rate of the urban population and the changing rate of the per capita urban land (PCUL) [27,28]. On the other hand, considering the relatively vague connotation of “growth”, scholars were not yet able to reach a consensus on the definition and measurement of the quality of economic growth. Several scholars have emphasized its meaning of “gross growth” and established a single indicator, represented by the output of both secondary and tertiary industries [16]. Moreover, another single indicator, represented by per capita GDP/GDP, has also been widely used, especially in cases where the different influential factors of economic growth are discussed. Other studies addressed economic growth from the opinion of “input–output productivity”. In this case, TFP and Malmquist index (GI) calculated by data envelopment analysis (DEA) and its extension form, were widely adopted [29–31]. These indexes measure production efficiency while considering various production costs.

2.1.2. Potential Interaction Pathways for Urban Sprawl and the Quality of Economic Growth

According to the Cobb–Douglas function, land, capital, and labor are the three foundational factors of production. Among these factors, land supplies a specific place for the production. When changing to a viewpoint from the quality of economic growth, it is natural to recognize land input and its productivity as direct determinants of the quality of economic growth, which have been verified previously [15,19,32]. By expanding the previous research [33,34], labor market pooling, knowledge spillovers, and better service inputs have been considered to offer significant advantages for urban sprawl. Agglomeration theory explains why the labor market is more efficient in urban sprawl, since
a large-scale local labor pool allows industries to spend less time on employee training and labor force seeking. This in turn attracts more labor force to the cities, which increases economic efficiency. Moreover, due to further accumulation of the labor force, large cities can provide better public facilities, more efficient financial and information services, and centralized markets, and thus yield increasing returns on scale [35]. Moreover, due to the further accumulation of the labor force, large cities can provide better public facilities, more efficient financial services, and centralized markets, and thus yield increasing returns on scale. Also, high geographic proximity and economic contact make firms more easily benefit from knowledge communication, advanced technology, and management experience, thus improving their quality of economic production. However, due to possible impact factors, such as externality effects and space control policies, the urban scale typically deviates from the theoretically optimal state [33,36,37]. At this time, the congestion effect is introduced, diseconomies of scale form, and economic growth efficiency decreases.

In addition to the afore-mentioned direct determinants of the quality of economic growth, several other factors related to urban sprawl have been generally believed to exert an indirect influence on the quality of economic growth in previous studies. First, both policymakers and scholars regarded land use structure as a core influencing factor of the quality of economic growth. Theoretically, urban land use structure optimization affects urban sprawl when land production is ‘spatially efficient’ and achieves a greater economic combination of various production elements [20,26,38]. In this context, a greater land use structure would promote a city’s ability to absorb investment and, as a result, both multiplier effect and selection effect of new investments can take effect. With the aim to improve the quality of economic growth and adjust land use structure, an urban development policy, and a later study [39], verified the policy effect for improving the urban land allocation efficiency. Second, industrial activities as a result of urban sprawl, have been found to be strongly associated with the quality of economic growth. Considerable empirical studies have pointed out that industrial structure rationalization and industrial structure supererogation exert a significantly positive impact on the quality of economic growth since industrial development is protected by law [15,19]. The former promotes the flowing of production factors from a marginal and inefficient sector to a sector with higher productivity. The latter coordinates the balance of professional labor division and resource distribution, and thus improves the economic development efficiency. Third, the industrial cluster in the urban sprawl process is a further factor that is related to the quality of economic growth. This factor is helpful to generate strong positive externalities due to the contribution of an agglomeration economy [11,33].

Urban sprawl, especially in big cities, is restrained by technological efficiency as a result of economic growth [5,10,15]. Technological efficiency in a variety of industries or different cities directly affects the future city growth by causing industrial agglomeration, reducing factor costs, and improving the urban management level [32,40]. Increasing technological efficiency indicates that more economic output can be achieved with less land input and environmental cost. Moreover, according to factor substitution, when the technological efficiency decreases, the input of the land factor will further increase to maintain the same level of output. Empirical studies have shown that technological efficiency is negatively correlated to urban land expansion [18].

Moreover, Zhao et al. [19] reported a negative correlation between technological progress and urban scale. As large-scale factors enter the city, the elasticity of factor substitution, as well as land use intensity, change due to technological progress. Due to technology advancement, the forms of capital are richer, and the relative price of non-land factors decreases [12,41]. In reference to both land rent-seeking theory and real practice, when the relative price of land is high, less land factors are required, since they are replaced by other non-land factors. Moreover, technological progress can offset fixed land scale limitation and other resource endowment constraints for economic growth. Intensifying urban land use in response to replacing the technical factor by the land factor decreases the demand for newly added urban areas and slows the speed of urban sprawl.
2.2. Theoretical Framework: Decoupling or Coupling

Taking the presented literature review as basic, this study proposes an integrated conceptual framework that summarizes the interacting influential mechanisms of urban sprawl and the quality of economic growth (Figures 1 and 2). Overall, the quality of economic growth is determined by the input scale and intensity of production factors, as well as the comprehensive economic, social, and environmental costs. Urban sprawl and the quality of economic growth either directly or indirectly interact by the following three pathways: scale effect, structure effect, and technological effect. This results in different levels of decoupling or coupling between urban sprawl and the quality of economic growth improvement. Two forces in particular affect the relationship between urban sprawl and the quality of economic growth: the first is centripetal force, and the second is centrifugal force. The centripetal force is rooted in scale effect and structural effect, and results in a coupling relationship, akin to a “snowball effect”. In contrast, the centrifugal force (e.g., technological efficiency and technological progress effect) may lead to a decoupling relationship. Moreover, the impact of the scale effect remains unclear. It may be either a coupling force or a decoupling force. In addition, due to a discrepancy in the resource endowment, administrative level, industrial planning, and economic development stages of China’s eastern, central, and western regions, the decoupling relationship between urban sprawl and the quality of economic growth in different regions is not exactly the same with regard to its degree and intensity.

![Figure 1. Positive feedback of urban sprawl on the quality of economic growth.](image1)

![Figure 2. Negative feedback of the quality of economic growth on urban sprawl.](image2)
Thus, clarifying whether urban sprawl and quality of economic growth follow a coupling or decoupling relationship, as well as identifying the regional differences in light of this relationship, is required to formulate effective regional development policy.

3. Methodology and Data

3.1. Study Area Identification

China was used as an example to test whether urban sprawl is decoupled from the quality of economic development. China is the largest developing country in the world with a vast territory, covering 9.6 million square kilometers total land area. However, because of the large population, China’s per capita land resources are extremely small. There is a severe shortage of space for newly increased construction land. With the in-depth advancement of new-type urbanization, this contradiction between population and available land has increased to a severe constraint on social and economic development of China. Therefore, it is necessary to decouple urban sprawl from the quality of economic growth. Additionally, city-level governments are essential bodies of urban sprawl implementation. Thus, 285 prefecture-level Chinese cities were chosen as the research sample (Figure 3).

![Figure 3](http://www.resdc.cn/)

Figure 3. The 285 sample cities in China. Note: Data for basic geographic elements were obtained from the Resource and Environmental Science Data Center (http://www.resdc.cn/).

3.2. Measurements of Variables

3.2.1. Measuring Urban Sprawl

According to prior studies, the urban built-up area, the ratio of the growth rate of urban land to the growth rate of the urban population, and the changing rate of the per capita urban land (PCUL) have been the most commonly used indicators to measure how sprawl has evolved [17,22,28,42]. While the former two methods are feasible and meaningful, it may be difficult to make comparisons regarding sprawl and its degree among cities of various sizes. Furthermore, extremely high sprawl values would be obtained when the denominator of the latter indicators is very small. By comparison, PCUL can largely overcome the shortcomings of the above-mentioned measurement methods. Here,
the changing rate of PCUL was used as a proxy indicator of urban sprawl in this study. It can be calculated as follows:

\[
PCUL = \frac{UL}{UIP} \\
R_{PCUL} = \frac{(PCUL_{t+1} - PCUL_t)}{PCUL_t}
\]

(1)

where \(i\) represents the \(i\)-th year, \(UL\) represents the amount of the urban built-up area, \(U\) represents the urban population number, and \(R_{PCUL}\) represents the changing rate of the PCUL.

### 3.2.2. Measuring the Quality of Economic Growth

Following most conceptualizations, this study used the TFP to assess the quality of economic growth. In reference to prior studies, the evaluation of the quality of economic growth must consider undesirable outputs such as environmental pollution. Since the radial DEA takes the lack of slack in variables and poor outputs into account, a slack-based measure (SBM) model proposed by Tone [43] was chosen for TFP measurement. And the SBM model is as follows:

\[
\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

\[
\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
\]

\[
\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

\[
\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
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\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

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\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
\]

\[
\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

\[
\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
\]

\[
\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

\[
\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
\]

\[
\text{Min} \quad \frac{1}{m} \sum_{i=1}^{m} \frac{1}{x_i}
\]

\[
\frac{1}{r_1 + r_2} \left\{ \sum_{j=1}^{n} \left( \frac{y_{ij}}{x_i} \right) \right\}^{\frac{1}{r_1 + r_2}}
\]

(3)

where \(p\) represents the TFP. Supposing there are \(m\) DMUs, then each DMU consists of \(n\) inputs, \(r_1\) desirable outputs, and \(r_2\) undesirable outputs; \(x, y^d, y^u\) are the elements of the corresponding input matrix, desirable output matrix, and undesirable output matrix, respectively; and \(\gamma\) is a weight vector.

To avoid overestimating the efficiency and to avoid the issue of a missing feasible solution, the global Malmquist–Luenberger index (GML) was used. Based on the general production possibility set, the construction of the GML index is outlined below:

\[
GML_t = \frac{x^t + y^d + b^t}{x^{t+1} + y^{d+1} + b^{t+1}}
\]

(4)

where \(x\) represents the input factors, \(y\) represents desirable outputs, \(b\) represents undesirable outputs, and \(D_g\) represents the directional distance function. To obtain a static TFP value, the TFP values of each city in 2003 were set to 1. Furthermore, the cumulative method was used to compute the dynamic and comparable TFP on an annual basis, based on the GML index.

In particular, following Lin and Chen [44], the utilized inputs include capital, labor, and land: (a) Capital. Similar to existing studies, the perpetual inventory method is adopted to measure capital stock in this study. The formula is \(K_t = K_{t-1} (1 - \delta_t) + I_t\). Where \(K_t\) and \(K_{t-1}\) represent the capital stock of city \(i\) in years \(t\) and \(t - 1\), respectively, \(\delta_t\) represents the depreciation rate of city \(i\) in year \(t\), and \(I_t\) represents the total volume of investment in fixed assets. (b) Labor. The total employment in both secondary and tertiary industries was used as proxy for the labor input. (c) Land. The urban built-up area was adopted as proxy for land. Furthermore, desirable output was measured via GDP using constant prices at 2003. To imply undesirable output, three variables were selected due to data unavailability. These include the volume of discharged industrial waste water, \(SO_2\) emissions, and industrial soot emissions.
3.2.3. Data Sources

The data were collected from the following sources: The China Statistical Yearbook and the China City Statistical Yearbook. Due to data availability, the years of 2003–2016 were chosen as the study period. To eliminate the impact of price factors and inflation, 2003 was used as the base period price.

3.3. Methods

3.3.1. Decoupling Model

In recent years, the decoupling model has been widely utilized to study how to delink the consumption of land, water, and other resources from economic development [19,45,46]. Similarly, in this study, an explicit decoupling model is used that relates the trend of urban sprawl to the trend of the quality of economic growth change. Since the problems caused by selecting the most ideal period can be avoided by using Tapio’s elastic decoupling model, this model was adopted to distinguish specific degrees and the boundary of coupling and decoupling between urban sprawl and the quality of economic growth. The decoupling index was computed as follows:

$$DI_{i+1} = \frac{\Delta R_{PCUL}}{\Delta TFP} = \frac{(R_{PCUL_{i+1}} - R_{PCUL_i})/R_{PCUL_i}}{(TFP_{i+1} - TFP_i)/TFP_i}.$$  (5)

Furthermore, drawing lessons from physics, Tapio’s model is divided into three decoupling groups, including negative decoupling, decoupling, and coupling. According to Taipo, these types can be divided into eight sub-types as shown in Figure 4.

3.3.2. Spatial Autocorrelation Analysis

A further purpose of this study is to analyze the spatial association characteristics of the decoupling degree between the urban sprawl and quality of economic growth improvement. If the decoupling index is regarded as a particular attribute of a city, using spatial autocorrelation analysis enables a
A better understanding of this context [47]. Global Moran’s I was utilized to estimate the spatial correlation of an attribute and explore the spatial distribution of its values. It can be calculated with Equation (6):

\[
\text{Global Moran’s } I = \frac{\sum_{i=1}^{n} \sum_{j \neq i} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \frac{1}{n} \sum_{i=1}^{n} x_i)^2} \frac{1}{\sum_{i=1}^{n} \sum_{j \neq i} w_{ij}}. \tag{6}
\]

Global Moran’s I could be tested based on the assumption of a spatially uniform distribution. However, it was not suited to catch such a significant local nonstationary distribution as decoupling index data. Thus, in this study, the significance of the local spatial correlation was tested by a local Moran’s test, as shown in Equation (7):

\[
\text{Local Moran’s } I = \frac{n(x_i - \bar{x}) \sum_{j=i} w_{ij} (x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}. \tag{7}
\]

To visualize the local agglomeration of this decoupling in space, local indicators of spatial association (LISA) cluster maps can be drawn according to the Local Moran’s I index. According to visual analysis of Moran scatter plots, the four quadrants were divided into four types, including High-High cluster (the first quadrant), Low-High cluster (the second quadrant), Low-Low cluster (the third quadrant), and High-Low cluster (the fourth quadrant).

4. Results and Discussion

4.1. Changes of PCUL and TFP

To investigate the relationship (either coupling or decoupling) between urban sprawl and the quality of economic growth, first, a statistical analysis was conducted. As shown in Table 1, among the 285 investigated cities, the max value, the min value, the average value, and the standard deviation of PCUL for 2003 were 10.6772, −0.5145, 0.1559, and 2.1324, respectively. Of the total of 285 cities, 188 cities experienced a growth of PCUL in 2003. Compared with 2003, in 2016, the number of cities with a PCUL above 0 remained steady (183) with values ranging from 0.0001 to 1.7280. The max value, the min value, the average value, and the standard deviation of TFP among all 285 cities were 3.5241, 0.3087, 1.2164, and 0.4375, respectively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>PCUL</th>
<th>TFP</th>
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<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>2003</td>
<td>10.6772</td>
<td>−0.5145</td>
</tr>
<tr>
<td>2007</td>
<td>1.7855</td>
<td>−0.5261</td>
</tr>
<tr>
<td>2011</td>
<td>1.3643</td>
<td>−0.3741</td>
</tr>
<tr>
<td>2016</td>
<td>3.5241</td>
<td>0.3087</td>
</tr>
</tbody>
</table>

Note: Due to space limitations, only main-year results of PCUL and TFP are presented.

At the national level, PUCL decreased from 0.1063 in 2003 to 0.0005 in 2016 at an average annual rate of −7.30%. During the same time, TFP increased from 1.0 to 1.5015 at an average annual growth rate of 3.86%. Descriptive comparisons were also supplied among different cities of the eastern, central, and western regions. With the passage of time, these three regions followed a trend toward a
PUCL decrease. Central cities faced faster urban sprawl compared to both eastern and western cities (Figure 5a). Unlike the change of PUCL, the change of TFP increased. Cities in the eastern region showed the highest average change of TFP, followed by central cities and western cities (Figure 5b). This pattern suggests a decoupling of correlations between urban sprawl and the quality of economic growth in response to urban development. Notably, PCUL and TFP values and their changing trends vary between different cities.

4.2. Decoupling Analysis between PCUL and TFP

Before decoupling analysis, it can be found that the correlation coefficient of PCUL and TFP variables was 0.4410, and this coefficient is significant at the 5% level. This result indicated that a positive relationship existed between both in the whole. However, on the premise of considering regional differences, the coupling or decoupling relationship between urban sprawl and the quality of economic growth still needs further exploration.

Two years was used as the constant period to calculate the decoupling index. Figure 6 shows the decoupling states of different cities at different stages. In general, with increasing quality of economic growth, the demand for urban expansion increases as a result of both the structural effect and the scale effect. This is indicated by the number of cities with expansive negative decoupling that experienced a fast growth from 30 to 62 during 2003–2016. Furthermore, the number of cities with strong decoupling fluctuated from 109 to 149, and 21 cities had finally achieved weak decoupling. These two decoupling states are satisfactory, which indicates that the TFP value increased, while PCUL decreased. This indicates that the decoupling force plays a major role under the substitution effect from technological factors. Due to the negative scale effect, urban sprawl adversely impacts the quality of economic growth. Thus, several of the other cities begin to witness a clear tendency toward strong negative decoupling.

The decoupling states appear with an obvious periodical and unbalanced characteristic. During the first period, strong and recessive decoupling takes the leading role, which is mainly distributed in cities of southeast and central of China, especially cities in Zhejiang, Fujian, Guangdong, and Guangxi, including cities like Beijing, Hangzhou, Nanning, and Nanjing. The second period is China’s most popular era of real estate investment, and also a stage of strong dependence on land finance. As a consequence, the amount of expansive negative decoupling increased remarkably, especially in central cities. This indicates that the existence of the scale effect and structure effect as part of the coupling process may improve the quality of economic growth. During 2009–2011, the development mode of urbanization in China began to change as a result of land institution reforms and land mortgage operation. During this time, land sprawl showed great spatial gaps, was stronger in the east, and both...
strong decoupling and extensive negative decoupling increased to 76.84% during this period. Cities with extensive negative decoupling clearly gathered in the coastal provinces. Strong decoupling was mainly distributed in the Beijing–Tianjin–Hebei region, Heilongjiang, and Henan. This phenomenon may be explained by interactions between factor substitution effect, scale effect, and structure effect in different regions and cities. After 2011, China issued a series of policies that promoted the construction of an intensive land use system, which emphasized land use control, land market management, and urban growth evaluation. These proposals advanced the marginal decline of the scale effect and the rapid growth of the substitution effect of non-land factors during 2011–2016. As a result, an increasing number of cities experienced a stronger “decoupling” than “coupling” force.

Figure 6. Spatial distribution of decoupling status at different stages. Note: The data comes from measurement by decoupling model.
4.3. Spatial Heterogeneity of Decoupling

The Global Moran’s I index, shown in Table 2, describes the spatial correlation of the decoupling index between urban expansion and the quality of economic growth. The estimated global Moran I values all exceed 0, the general trend follows a decrease, and values vary from 0.0425 to 0.2913, except for 2011–2013; the p-values were all equal to 0.000 (i.e., <0.05). This indicates that the decoupling degree of 285 cities was positively correlated in space. Furthermore, a more obvious agglomeration effect of a decoupling relationship was found from 2003 to 2007, 2007–2009, and 2009–2011, with Global Moran’s I values of 0.2913, 0.1883, and 0.1846, respectively.

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<tbody>
<tr>
<td>Moran’s I</td>
<td>0.1883***</td>
<td>0.2913***</td>
<td>0.1440**</td>
<td>0.1846**</td>
<td>0.0425</td>
<td>0.1462**</td>
</tr>
<tr>
<td>Z value</td>
<td>2.8076</td>
<td>6.7381</td>
<td>2.2047</td>
<td>2.9005</td>
<td>0.6531</td>
<td>2.4642</td>
</tr>
</tbody>
</table>

Note: **, and *** represent 5%, and 10% significant levels, respectively.

This study uses ArcGIS 10.2 software to calculate the Local Moran’s I index of 285 cities in China. According to the Moran scatter plots and its corresponding quadrant, the agglomeration types of each city are summarized into four categories. Consequently, the visual analysis of local indicators of spatial association (LISA) cluster maps could be obtained. A LISA cluster map includes four types of spatial autocorrelations. As illustrated in Figure 7, an obvious polarization phenomenon of decoupling degree was found for Chinese cities. During the studied period, the cluster types only remained unchanged for 70 cities. At the beginning of 2003–2005, the High-High type clearly agglomerated in the Beijing–Tianjin–Hebei region (Beijing, Tianjin, Shijiazhuang, Tangshan, Baoding, Langfang, Qinhuangdao, Zhangjiakou, Chengde, and Cangzhou), the Shandong Peninsula region (Jinan, Qingdao, Yantai, Weihai, Rizhao, Weifang, Zibo, and Dongying), and the Yangtze River Delta (Shanghai, Nanjing, Suzhou, Wuxi, Changzhou, Yangzhou, Zhenjiang, Nantong, Taizhou, Hangzhou, Ningbo, Jiaxing, Shaoxing, Huzhou, and Zhoushan). Over time, this gradually expanded to the Pearl River Delta (Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, Zhaoqing, and Huizhou), Fujian, Shaanxi, and Henan. The High-Low pattern was found in few cities, and the entire western region was almost completely devoid of this type. The type Low-High was mainly found in Inner Mongolia, Hebei, and Anhui provinces, and over time, gradually expanded to Fujian, Guangxi, and Yunnan provinces. During the whole period, the Low-Low type was mainly located in western China, and included four urban clusters in Ningxia, Guangxi, Yunnan, and Fujian province. This clustering pattern changed during the spread to the center and east. In comparison to non-cluster cities, the decoupling relationship in urban clusters had a greater agglomeration effect.

Overall, the spatial decoupling differentiation is mainly composed of the types High-High and Low-Low, while the effects of High-Low and Low-High types are not obvious and less notable. Over time, the agglomeration centers of High-High type changed and the agglomeration centers of Low-Low remained nearly unchanged. In comparison, the aggregation centers of High-Low and Low-High continued to move southward. Furthermore, at the country level, urban clusters of the High-High type mostly agglomerated in eastern cities, which act as a driving force and promote the decoupling between urban sprawl and the quality of economic growth. This may be because China’s coastal cities have already surpassed the rapid-urbanization stage, and urban land demand has decreased. In addition, due to the increased application of favorable economic policies, these areas experienced investments of both significant domestic fixed assets and foreign capital. Therefore, urban sprawl is not the most important factor to affect economic growth. The existence of Low-Low clustering in the central and western cities slowed the overall decoupling process. These cities are geographically disadvantaged and lack factors that attract non-land factors. Consequently, for the foreseeable future, the economic development of these cities will largely rely on urban sprawl.
5.1. Conclusions

Previous studies that investigated the uni-directional association between urban sprawl and the quantitative economic growth were typically based on metrological technology. These studies identified the difficulty in evaluating how urban sprawl and the quality of economic growth interact and neglected the division into decoupling or coupling types. From the point of academic accumulation, this is the first study to respond to the call for the decoupling of urban sprawl and quality economic growth. This may be because China’s coastal cities have already surpassed the rapid-urbanization stage, and urban land demand has experienced investments of both significant domestic fixed assets and foreign capital. Therefore, the economic development of these cities will largely rely on urban sprawl. Geographically disadvantaged and lack factors that attract non-land factors. Consequently, for the foreseeable future, the economic development of these cities will largely rely on urban sprawl. The existence of Low-Low, while the effects of High-Low and Low-High types are not obvious and less notable. Over time, this gradually expanded to the center and east. In comparison to non-cluster cities, the decoupling relationship in urban clusters had a greater agglomeration effect.

Local indicators of spatial association (LISA) cluster maps for decoupling between urban sprawl and the quality of economic growth. Note: The data comes from Local Moran’s I index, measured by spatial autocorrelation analysis method.

5. Conclusions and Policy Implications

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growth. Specifically, this study introduced a theoretical mechanism to undertake and explore the interaction framework between urban sprawl and the quality of economic growth. Furthermore, 285 prefecture cities were used as research areas for the spatial-temporal analysis of the decoupling relationship between urban sprawl and the quality of economic growth. This study also implemented the decoupling model and spatial correlation analysis.

From the temporal perspective, this study showed that the overall PUCL followed a decreasing tendency, while TFP followed an increasing tendency over the entire study period. With regard to the decoupling analysis, the decoupling types between urban sprawl and the quality of economic growth showed a clear periodical and unbalanced characteristic. Three decoupling statuses were mainly identified: strong decoupling, recessive negative decoupling, and expansive negative decoupling. During the entire study period, more and more cities experienced a stronger “decoupling” than “coupling” force. From the viewpoint of spatial analysis, the spatial autocorrelation of the decoupling degree was positively correlated with the significant agglomeration effect. In summary, the spatial agglomeration of decoupling is mainly composed of the two homogenous types of High-High cluster and Low-Low cluster, while the agglomeration trends of the other two are less obvious.

5.2. Policy Implications for the Decoupling of Urban Sprawl and the Quality of Economic Growth in China

According to the above-mentioned empirical results, we can indicate several policy implications, even beyond the local case. Firstly, urban sprawl may pose different effects on the quality of economic growth at different stages of regional economic development. Undue stress should not be focused on strong decoupling and extensive negative coupling should not be underestimated. A sustainable urban development can be achieved by classified regulation. Before a city with a low level of economic development reaches its optimum size, to maximize both the scale effect and structural effect, the local government should encourage moderate urban expansion as a tool to drive economic growth. For cities during the higher economic stage, more attention should be focused on the redevelopment of inefficient land, the vigorous readjustment of the industrial structure, and a scientific delimitation of urban growth boundaries, thus promoting vertical growth of the urban space. In addition, the government should restrain from land expansion and should instead seek innovation-driven development.

Secondly, a one-size-fits-all solution that solves all problems related to urban sprawl does not exist. How the land supply and the land allocation mode in cities at different scales can be readjusted to adopt this change is an inevitable question. Policymakers should abandon traditional development ideas, and relax the urban scale control in the “shrinking eastern cities”. In areas where urban sprawl is more positive and influential, such as Shenzhen, Shaoxing, and Nancang, land use regulations could be drafted to encourage more efficient and healthier bottom-up urban land expansion. In areas where few reserved land resources are available, municipal governments should assume the leading role in directing future sustainable economic growth. Furthermore, both small and medium-sized cities in the central and western regions with recession decoupling, are encouraged to enlarge their urban scale to achieve better economic benefits. Several of these cities faced resource depletion, industrial transfer, and administrative division adjustment. These cities are more willing to increase the scale effect via further land expansion, followed by the launch of parallel supporting policies and measures, which include attracting labor back-flow, enhancing consumption motivation, and stimulating industrial investment.

Finally, this study has clarified the importance of spatial autocorrelation of decoupling between urban sprawl and the quality of economic growth. According to the actual situation, which differs from the four decoupling types, targeted policies are needed for future regional development. The High-High type clearly accumulated in several urban agglomerations. Consequently, the government needs to fully utilize the leading role of spatial spillover, optimize the mechanism of regional cooperation, and expand the distribution of these agglomeration areas. The Low-Low type mainly accumulated in central and western China. For these cities, reasonable measures should interrupt the spatial connection and avoid the trap of unsustainable decoupling. With regard to cities with Low-High or High-Low
types, their conduction function should be further optimized to promote factor flow and enhance the spatial synergy of decoupling.

This study also has several potential limitations. First, the undesirable outputs of quality of economic growth were only evaluated based on three independent eco-environment indicators. In addition, it was beyond our scope to identify the specific factors that improved or decreased the decoupling force, or to quantify their impact factors. In future studies, it is necessary to further calculate a compound of the environmental pollution index using entropy weight method based either on the three above-mentioned or on further types of environmental indicators. This is helpful to identify cities with poor environmental performance that require special attention from policy makers. It is also of great importance to further quantity and distinguish the interacted relationships between socio-economic factors and decoupling types by using either a structural decomposition analysis or econometric model. Above these will further help policy makers to adjust relevant strategies and plans toward achieving regional sustainable development.

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References


21. Dadashpoor, H.; Yousefi, Z. Centralization or decentralization? A review on the effects of information and communication technology on urban spatial structure. *Cities* 2018, 78, 194–205. [CrossRef]


34. Huang, Z.; Wei, Y.D.; He, C.; Li, H. Urban land expansion under economic transition in China: A multi-level modeling analysis. *Habitat Int.* 2015, 47, 69–82. [CrossRef]

35. Ciscel, D.H.; Tuckman, H.P. Plant scale and multiplant production as determinants of industrial concentration. *J. Behav. Econ.* 1983, 12, 1–16. [CrossRef]


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