Cities 129 (2022) 103831

Contents lists available at ScienceDirect

Cities

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

Urban expansion and the urban–rural income gap: Empirical evidence from China

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ARTICLE INFO

Keywords:
Urban expansion
Urban–rural income gap
Urbanization
Panel quantile regression
China

ABSTRACT

Developing countries tend to exhibit evident urban–rural income divergence as urban areas rapidly expand into adjoining land. However, Western-centric urban theories and studies of spatial inequality have not paid sufficient attention to the connection between income divergence and urban expansion. This paper employed a panel quantile regression model to investigate this relationship in 220 prefecture-level Chinese cities in 2006–2014. To identify potential spatiotemporal effects, we conducted additional robustness checks using the spatial Durbin model and geographical and temporal weighted regression. The results show that a 1 % expansion of urban land decreases the urban–rural income gap by 0.005 % to 0.011 %. This narrowing effect is particularly prominent in the eastern and central regions and in areas that are less urbanized overall. It also varies within regions that have a more pronounced difference between the lowest and highest quantiles in northeastern China and cities with urbanization rates of >50 %. Finally, we find evidence for an inverted U-shaped relationship between urban expansion and the urban–rural income gap. Our results entail suggestions for improved urban–rural development policies aimed toward greater integration and efficiency in urban expansion.

1. Introduction

Urban expansion and spatial inequality are two long-standing themes in an increasingly urbanizing world (Haworth et al., 1978; United Nations, 2020). How can governments cater to the needs of a growing urban population in the face of limited land resources? How can they ensure that no one is left behind as unbalanced urbanization continues? This is not only a major challenge to global urbanization but also a key to sustainable development. Developing countries are currently urbanization hotspots as urban land continues to expand (Sun et al., 2020). Between 1970 and 2000, worldwide, 5800 km^2 of agricultural land was converted into urban land, most of this taking place in Asia and Africa (Seto et al., 2017; Wiesner et al., 2012). As encroachment on agricultural land being the main route of expansion, the geographical boundary between urban and rural areas is becoming increasingly blurred (Chen, Long, et al., 2020; Firman, 2009). However, the urban–rural divide is nevertheless strengthened (Malaeb, 2018). Additionally, the further urbanization of developing countries is predictable (D'Amour et al., 2017). A study investigating urban construction and land expansion is important for reducing urban–rural inequality. Urban land management should also be examined.

Research has noted the importance of urban growth for inequality, but less attention has been paid to land. In theories of urbanization originating in developed countries, land has long fallen out of the neoclassical production function. This tradition has continued in endogenous growth theory, institutional economics, and the new economic geography, in which technology, institutions, and location have been used to explain urban growth, instead of land (Kasarda & Crenshaw, 1991; Sachs, 2007; Schout & North, 1991; Solow, 1956). As inequality grows worldwide, diverging schools represented by neo-Marxism have criticized the growth and convergence theory of neoclassical economics (Wei, 2015). A novel intellectual trend has focused on the relationship between development and inequality. However, when it comes to the uneven development in urbanization, intrinsic agglomeration economies and the intrusion of global neoliberal market forces are the main source, while land is still taken for granted (Lin, 2014).

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https://doi.org/10.1016/j.cities.2022.103831
Received 24 April 2021; Received in revised form 30 May 2022; Accepted 10 June 2022
Available online 27 June 2022

However, owing to the imperfect market and changeable institutions that many developing countries are faced with, prevailing urban theory has obvious limitations for explaining urban development (Lin, 2014; Peck & Zhang, 2013). Empirical evidence shows that land and land-related capital accumulation are often to the support for urban growth in developing countries (Lin, 2014; Pugh, 1995). Thanks to the recent global trend of greater speed in urban expansion than population growth, land scarcity has received further emphasis. Research on urban land expansion and spatial inequality has shown an increase recently (Frenkel & Israel, 2018; Güneralp et al., 2020). However, directed by traditional core-periphery theory, the focus remains on city-centered spatial production and regional inequality, lacking any explanation for the urban–rural divide (Rodríguez-Pose & Hardy, 2015; Wei, 2015). Because of the predictable growth of urbanization in developing countries, the understanding of urban construction and land expansion and of the urban–rural income disparity in this context needs to be strengthened.

China, the world's largest developing country, has undergone the most rapid urbanization in human history. Over the period 1978–2019, China's urbanization rate increased from 17.9 % to 60.6 %, and the urban built-up areas in municipal districts have grown at least eightfold since 1978 (National Bureau of Statistics of China, 2020). However, the ratio of disposable income of urban and rural residents, which increased from 2.57:1 in 1978 to 3.20:1 in 2019, indicates that China's urban–rural income gap has not fallen. In 2013, the urban–rural income gap constituted 34 % of total inequality in China (Jain-Chandra et al., 2018). With its dualistic land system, China's drastic urbanization over the last 40 years can be seen as land-based, such that land plays an essential role in urban growth (Lin, 2014; Liu & Zhang, 2020; Zhu et al., 2020). Simultaneously, the large urban–rural income gap has led to accusations that the urban welfare state is being built on the backs of peasants (Treiman, 2012; Wang et al., 2020). Taking China as an example, this study analyzed the income gap between urban and rural areas in terms of urban expansion to understand the high urban–rural income gap in China's rapid urbanization and provide an empirical reference for other developing countries.

In this paper, we adopted panel quantile regression as the main method. As the urban expansion and the urban–rural income gap are usually complex and uneven processes, heterogeneity cannot be ignored in this study (Bergolo & Carbajal, 2010; Bui & Imai, 2019). This is particularly important in China owing to its obvious regional inequality (Firman, 2009; Jia et al., 2020; Wei et al., 2017). In this context, panel quantile assessment is advantageous in its applicability and robustness than traditional mean regression. First, it can capture the heterogeneous effects of urban expansion on the urban–rural income gap by presenting the full picture of the conditional distribution and thus provide additional information to policy makers. There is no need to strictly satisfy classical econometric assumptions, and this assessment is less sensitive to outliers (Powell, 2016; Yan et al., 2020). Thus, it can provide more robust regression results when classical econometric assumptions fail. In addition, inter-regional heterogeneity was empirically tested using subsample regressions and robustness checks using the spatial Durbin model (SDM) and geographical and temporal weighted regression (GTWR).

This study provides contributions in at least the following aspects. First, unlike the previous core-periphery paradigm of understanding regional inequality, this study focuses on urban–rural inequalities in developing countries, where they are more prominent. Second, unlike Western-centric urban theories that focus on population and technology, we focus on the importance of land in urbanization using the lens of urban expansion. Third, the panel quantile method is employed to examine how urban expansion affects the urban–rural income gap across different quartiles, which provides an incremental contribution to the small literature related to urban expansion and urban–rural income gap nexus.

The key research questions in this paper are as follows: Is there an intrinsic relationship between urban expansion and the urban–rural income gap? If so, has the urban expansion worsened or improved the urban–rural income disparity? Do mechanisms of influence between the two vary across regions and stages of development? In China and other developing countries that are undergoing an urbanization transition, narrowing the urban–rural income gap and eliminating the dual structure between these categories of territory are important policy issues. This approach would also provide a concrete solution to achieving the global development goals of Sustainable Cities (SDG 11) and Reduced Inequalities (SDG 10). Against this backdrop, the remainder of this paper is organized as follows: Section 2 establishes a theoretical background of the urban–rural income gap and urban expansion; Section 3 introduces the models and data; Section 4 presents the empirical results; Section 5 contains a detailed discussion of the results in the broader context; and the conclusion and policy implications are given in Section 6.

2. Literature review and analytical framework

2.1. Perspectives on urban–rural income gap

Previous studies have reached the consensus that an income gap between rural and urban areas is inevitable, but whether it can be eliminated remains controversial. Ricardo described this gap in terms of production methods and product characteristics (Ricardo, 1821). Cline Clark, by contrast, considered it to be inevitable because the ratio of agricultural output value to the proportion of employment is not synchronous (Rothbarth & Clark, 1941). According to Lewis' urban–rural duality theory and Todaro's migration model, the income gap between urban and rural areas also seems inevitable, so long as a division exists between industry and agriculture exists (Chen et al., 2018; Gollin, 2014; Lewis, 1976; Todaro, 1969). However, over longer time scales, a divergence emerges between theoretical predictions. Neoclassical convergence theories hold that the urban–rural income gap is only a temporary product, and the factor mobility and diffusion will gradually eliminate regional inequality (Kuznets, 1955; Wei, 2015). However, scholars who subscribe to divergence and structural models argue that regional inequality is inevitable and tends to intensify under the capitalist system (Harvey, 1975; Soja, 1980).

The urban–rural income gap in developing countries is evidence of regional inequality (Lagakos, 2020). The theory of urban bias, which attributes the urban–rural income gap in developing countries to a systematic bias against agriculture and rural economies, is the most common explanation (Bezemer & Headey, 2008; Lipton, 1977; Yang, 1999). Some find that this is because the urban class has more influence on the policy process than the rural class (Lipton, 1977). Other scholars, however, argue that the difference is dictated by governments' industry-first development strategies (Krueger, 1991). Although urban-biased policies are in line with global trends of radical urbanization and contribute to economic growth, they provide the policy basis for the urban–rural income gap (Scott, 2002). Land, a scarce resource in developing countries, is vulnerable to government distortion and manipulation (Lagakos, 2020; Lin, 2014). Government intervention through land policies is likely to lead to an improper distribution of factors between urban and rural areas and thereby to affect incomes (Glaeser & Ward, 2009; Wang et al., 2019). Further analysis is needed to identify the association of government policy with the urban–rural income gap (Lin, 2014; Wei et al., 2017).

2.2. Urban expansion in China

The rapid expansion of urban land in China has been widely documented, and it features among the highest rate in the world. Between 2000 and 2015, China accounted for 47.5 % of global urban expansion (Sun et al., 2020). The vast majority of urban in China has been converted from agricultural land (Cao et al., 2020; Gong et al., 2019).

However, the urban expansion is obviously unbalanced. Overall, the annual growth rate of urban land in China shows a decreasing trend from the coastal to the western regions, with coastal urban agglomerations such as the Yangtze River Delta and the Pearl River Delta being hotspots (Chen, 2007; Wiesner et al., 2012). Because of factors such as geographic location and administrative hierarchy, similar unevenness can also be identified at provincial and county levels (Wei et al., 2017).

The causes of urban expansion are diverse. Scholars influenced by neoclassical economics have long attributed its prevalence in China to its population and economic growth (Wiesner et al., 2012; Xu et al., 2020). However, an institutional shift in research has been seen lately, with the emergence of explanatory theories such as growth machine theory, regime theory, and urban entrepreneurialism (Bruns-Berentelg et al., 2022; Molotch, 1976; Stone, 2005). The mechanisms of local decentralization, marketization, and globalization have been widely used to explain urban expansion in China (Huang et al., 2015; Lin & Wei, 2002). In empirical studies, the factors of mega projects, urban transportation, and the reorganization of administrative districts have also been found to be closely related to urban land expansion (Zhang & Li, 2020).

In recent years, sustainable development has been emphasized in China's urbanization. A growing body of literature has described the impact of urban expansion in relation to perspective of eco-environmental protection, land development, energy usage, population growth and migration, housing, and policy issues (Tan et al., 2016). In particular, a long-term incongruity between population and land has been identified, as is manifested by the fact that land is urbanized more quickly than the population (Jin et al., 2017; Zhu et al., 2020). The development strategy of urban–rural integration has led to increased studies of income equity between urban and rural residents. Land use conversion and land expropriation have significant effects on urban–rural income disparities (Tang et al., 2012; Wang et al., 2019). The inherent land-related nature of finance and land-centered urban politics has also been shown to be highly correlated with urban–rural inequality (Lin, 2014; Zhu et al., 2019). However, study of the direct correlation between urban expansion and the urban–rural income gap is lacking. Comprehensive analysis should be developed adopting the process perspective.

2.3. Analytical framework

The comprehensive nature of land dictates indicates it is best understood from multiple perspectives and in terms of its connection to incomes among urban and rural residents. First, as identified in classical economics, land is a key element in socioeconomic development. The expansion of urban land is an important factor in inputs and directly contributes to economic growth (Güneralp et al., 2020; Li et al., 2018). Second, owing to the fixed nature of land, transactions in land are in fact transactions in property rights. The property rights reflected in the land price, in turn, have effects on the income of the property owner (Carter, 1990; Galiani & Schargrodsky, 2010). Third, land is the primary source of wealth and power, as stipulated in the growth machine theory (Molotch, 1976). In the growth orientation, land is used as a profit-generating commodity to promote urban growth through an alliance of local interests formed by political and economic elites (Bruns-Berentelg et al., 2022). Fourth, land tends to become a purely financial asset through the urbanization of capital (Harvey, 1978, 1982). This financialization becomes the main channel to raise funds for urban development in most developing countries (Wu, 2022).

It is not difficult to establish that land is a combination of production factors, property rights, power, and capital. This fact, coupled with the interaction between institutions and markets, affects the urban–rural income gap by means of the unbalanced distribution of costs and benefits it produces. To establish the relationship between urban expansion and urban–rural income gap more clearly, we construct the analytical framework depicted in Fig. 1.

From its production factor attributes, the consequent income distribution effect of land becomes the primary concern (Chen, Luo, and Chang, 2020). After the Asian financial crisis of 1998, China's leadership has used land as an important macroeconomic tool (Rithmire, 2017). Following the growth orientation, local growth alliances formed by local governments and developers use land to attract investment and promote urban growth (Lu, 2018; Zhang, 2014). A boom of industrial parks, development zones, and new districts was seen. This provided sufficient development space for urban economic development, leading to faster wage growth among urban residents (Du et al., 2014; Ho, 2017; Wang et al., 2020). Meanwhile, the growth in employment brought by the industrial sector expansion has also helped facilitate the transfer of rural labor and increase their non-farm income (Lagakos, 2020; Lewis, 1976). However, owing to their insufficient education and skills, those migrant workers generally face a significant disadvantage in the job market, which makes them less able to find employment in cities and thus leads to slower wage income growth than is found in urban residents (Cao et al., 2008; He et al., 2009).

Furthermore, in China's dualistic urban–rural land system, urban expansion characterized by land nationalization also affects the income

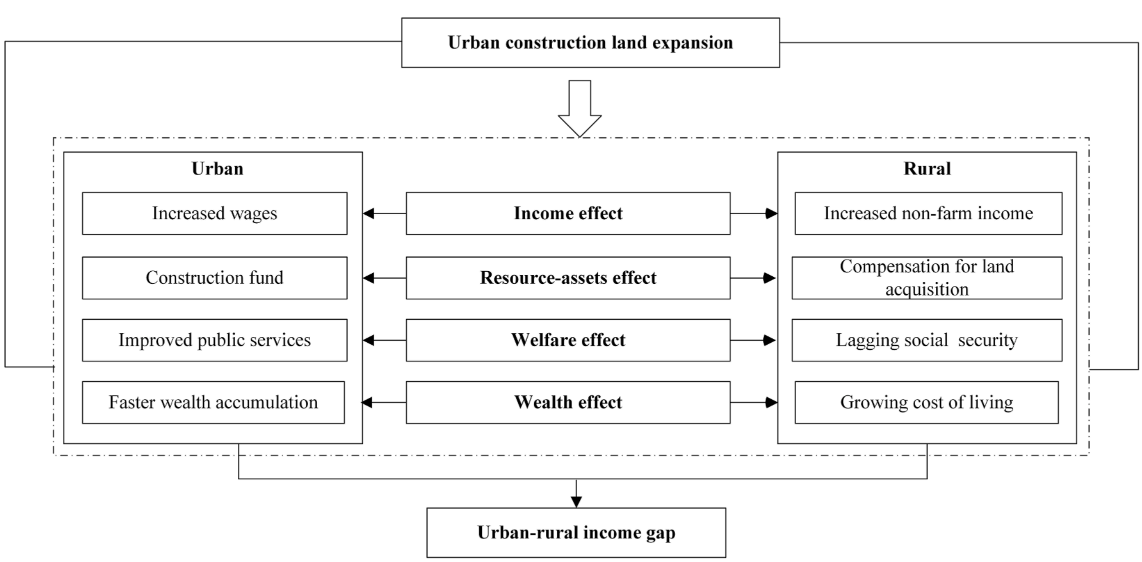

Fig. 1. The theoretical framework between urban construction land expansion and urban-rural income gap.

of urban and rural residents because of the resource-asset effect (Chen, Long, et al., 2020). The Land Administration Law entails that construction land is monopolistically supplied by the state. Rural collective land can only be sold on the land market after it becomes state-owned, in a process widely acknowledged to be land expropriation (Van Westen, 2011; Wang & Tan, 2020). By selling the expropriated collective land at a high price, local governments receive the corresponding rent and obtain the funds they require for urban development (Huang & Du, 2017; Yu et al., 2015). In land-driven urbanization, urban construction is increasing and will lead to income growth among urban residents (Du et al., 2014; Ho, 2017; Wang et al., 2020). For farmers, land expropriation entails the resource-assets effect for collective land, and the compensation they obtain in this process directly increases their property income (Chen, Luo, and Chang, 2020; He et al., 2009). However, compensation for land acquisition usually deviates from the market price. The vast divide between off-market land compensation prices and high land grant premiums has been shown to be one of the primary sources for China's urban–rural disparity (Liu & Zhang, 2020; Wang et al., 2019).

The welfare effect in urban expansion has also been a focus in urban–rural equitable development. Land financing allows the state to capture land value, and most of land revenue is spent on urban and rural infrastructure (Xu, 2019). Because of the urban-biased land development policy, the one-time value-added gains of land acquisition compensation and high-priced concessions captured by local governments go mainly to urban residents through public service improvement (Wang et al., 2019; Zhu et al., 2020). For urban residents, quality public service facilities can increase property values of real estate that they hold and facilitate their capital circulation and wealth accumulation, which helps increase their property income (Du et al., 2014; Wang et al., 2019; Wang et al., 2020). For rural residents, land acquisition is usually followed by deprivation of their livelihood and necessary relocation. Even if farmers do receive a certain amount of compensation and rural construction money, the social welfare that they receive is much less than that of urban residents (He et al., 2009; Huang & Du, 2017).

Last but not least, land-based wealth redistribution cannot be ignored. In 1999, China officially ended the supply of welfare housing, and the era of housing marketization began (Wang et al., 2020). Since that time, the Chinese real estate industry has attracted significant attention in the Chinese economy, and the resulting housing inequality and wealth imbalance between urban and rural have become topics of widespread interest (Logan et al., 2010). Improvements in public services and infrastructure have increased city housing prices, allowing urban residents who already own houses to obtain increased wealth and to accelerate their wealth accumulation through higher capital gains (Du et al., 2014; Wang et al., 2019). However, rural residents, who are limited by friction inherent in transactions within land markets, cannot trade their property or their land as freely as urban residents can trade theirs. Moreover, the growth in urban land prices and the corresponding property prices have increased the cost of living for migrant workers (Liu & Zhang, 2020; Yu et al., 2015). Although the central government has been seeking to promote low-income housing projects, the supply of these in cities is still severely inadequate, which in turn has depleted the wage growth of migrant workers.

To sum up, land is closely related to the income of residents' incomes. Urban expansion entails a redistribution of land resources between urban and rural areas, but because of the combined influence of institutions and markets, its impact on the incomes of these two categories of residents is different, and its role in the urban–rural income gap remains unclear. This study further explores the relationship between urban expansion and the urban–urban income gap based on China's empirical data.

3. Methods

3.1. Data and variables

This study drew on panel data from 220 prefecture-level cities in mainland China from 2006 to 2014 as the regression sample. The selection of regions takes into account the availability of the data of 220 prefecture-level cities, which are relatively complete and continuous.

The study period was chosen for the following reasons. First, the rapid urbanization of China is most visible between 2006 and 2014. As has been documented, this was the period of the fastest urban expansion (Sun et al., 2020; Zhao et al., 2015). Second, this period is consistent with a Chinese government's planning period, and the resulting stable socioeconomic environment is suitable for conducting this study. As a socialist country, China's planning has an important guiding role to play in socio-economic development (Zhou et al., 2017). In this study, 2006 is the beginning of China's third land use planning (2006–2020), and the period 2006–2014 only covers two social and economic development planning periods. Third, the choice of this study period avoids the disruption caused by several important policy reforms and helps ensure model validity. Many policy changes in China were put in place during the economic transition period. For example, in 2006, the agricultural tax was officially abolished, and in September 2014, the former Ministry of Land and Resources issued its *Guidance on Promoting Land Conservation and Intensive Use*.

The descriptions of the variables and data definitions are shown in Table 1. The urban–rural income gap (*ineq*) is the dependent variable, measured as the ratio of per capita disposable income between urban and rural residents (or rural residents' net income), values that are widely adopted and easily calculated (Yuan et al., 2020). The core independent variable is urban expansion (*built*), portrayed by the area of newly added. This value is obtained by subtracting the previous year's urban land areas from those of the following year using national land-use change survey data from 2005 to 2014 (Zhou et al., 2020). Because urban expansion usually occurs on cropland (D'Amour et al., 2017), the area of newly added can picture the urban expansion and reflect the interaction between urban and rural.

To avoid omitted variable bias, six variables that may affect the urban–rural income gap are controlled, as follows:

(1) Economic development (*pgdp*). Lewis' urban–rural dual development model and Rostow's economic development model suggest that the urban–rural divide represented by the urban–rural income gap is an inevitable stage of economic development (Lewis, 1954; Rostow, 1991). On a longer time scale, scholars such as Kuznets and Robinson point out that the urban–rural income gap shows an inverted U-shaped trend, which first expands and then

Table 1
Variable definition and summary statistics.

Variables	Definition	Mean	Std. dev.	Min	Max	VIF
ineq	Urban-rural income gap	0.921	0.202	0.219	1.608	–
built	Urban expansion	6.498	1.578	−1.609	11.509	1.108
pgdp	Economic development	9.752	0.554	8.182	11.303	4.623
expend	Scale of fiscal expenditure	−2.018	0.371	−3.853	−0.860	1.762
urban	Urbanization	−0.746	0.269	−1.589	−0.110	2.911
indus	Industrial structure	−0.143	0.091	−0.480	−0.003	2.897
open	Economic openness	0.883	1.101	−4.372	3.295	1.293
eduexp	Educational inputs	−1.691	0.254	−4.258	−1.006	1.340

decreases with the economic development (Kuznets, 1955; Robinson, 1976). Hence, it is very necessary to include economic development as an essential control variable in the study of the urban–rural income gap. This is measured by GDP per capita and is further processed at constant prices, with 2006 as the base period.

(2) Fiscal expenditure (*expend*). Fiscal policy is a focus of urban-bias theory (Chen & Du, 2010; Wang et al., 2019). To support GDP growth, local governments tend to spend on infrastructure construction, usually within urban territories, thus widening the urban–rural income gap (Chu et al., 2000). Moreover, the urban-biased fiscal expenditure structure prevalent in developing countries has a significant impact on the urban–rural income gap as well because it gives urban residents a substantial advantage over rural residents in obtaining social benefits, such as housing, education, and health care (Kanbur & Rapoport, 2005; Liu & Long, 2021). In this paper, we calculated fiscal expenditures as the ratio of public finance expenditure to regional GDP.

(3) Urbanization (*urban*). Urbanization usually implies a movement of the population between urban and rural areas and labor mobility between the industrial and agricultural sectors. It is closely related to the wage income of urban and rural residents and the general welfare of society (Bryan & Morten, 2019; Lagakos, 2020). Previous studies have verified that urbanization is a key factor affecting the urban–rural income gap and can even Granger-cause it (Su et al., 2015; Yuan et al., 2020). We use the ratio for the urban resident population and total population to represent it.

(4) Industrial structure (*indus*). As an indicator of industrial and agricultural development, industrial structure affects the employment of residents and plays an essential role in urban–rural development (Yuan et al., 2020). In addition, developing countries, facing a distinctly dualistic rural–urban economic structure, usually adopt an industrial- or heavy industry-first development strategy in their early years to transfer resources from rural areas to complete the primary accumulation of capital. Therefore, industrial structures also reflect an urban-biased development strategy in terms of industry, which affects the urban–rural income gap (Chen & Lin, 2014; Lipton, 1977). This study calculates the industrial structure as the added value of secondary and tertiary industries, divided by local GDP.

(5) Economic openness (*open*). Globalization contributes to urban–rural income inequality, usually reflected by economic openness (Wei & Wu, 2013). Rural areas are disconnected from global production chains owing to their geographical disadvantages, while cities receive both foreign investment and technological improvements, thus resulting in income differentiation (Malaeb, 2018; Yuan et al., 2020). Owing to data availability, we concentrate on financial openness, measured by the ratio of the actual amount of foreign capital used and fixed asset investments (Ma et al., 2018).

(6) Educational inputs (*eduexp*). Firms in a competitive market pay factor rewards based on the marginal principle, such that the more educated workers with better skills can receive higher incomes (Lipton, 1977). With increasingly frequent labor mobility between urban and rural areas, educational investments produce an income distribution effect by influencing residents' employment skills and may cause urban–rural income disparities (Cameron, 2000; Li et al., 2014; Sicular et al., 2007). This study uses the ratio of local financial expenditures to education to measure different regions' educational inputs.

Most of the socioeconomic data used here, such as GDP and public expenditures, are taken from the China Urban Statistical Yearbook, and the vacancy data are supplied by each province's statistical yearbook and the statistical bulletin of each city. Urban area is taken from the national land use survey data from 2006 to 2015.

3.2. Model specification

To examine the effects of urban construction expansion on the urban–rural income gap, we take the urban–rural income gap as the dependent variable and urban expansion as the core independent variable in the econometric model. Factors such as economic development (Kuznets, 1955), fiscal expenditures, urbanization rate, industrial structure, openness, and education investment (Chen & Du, 2010; Su et al., 2015; Yuan et al., 2020) may also affect the urban–rural income gap, so they are included in the model as control variables. The specific model is built as Eq. (1):

$$ineq_{it} = \alpha_0 + \alpha_1 built_{it} + \sum\nolimits_{j=1}^{6} \beta_j cons_{it} + \varepsilon_{it} \tag{1}$$

where i ($i = 1, 2, \ldots, 220$) represents the city and t ($t = 1, 2, \ldots, 9$) denotes the year, j ($j = 1, 2, \ldots, 6$) refers to the control variables, $ineq_{it}$ denotes the urban–rural income gap, $built_{it}$ is urban expansion, $cons_{it}$ stands for the remaining control variables, and ε_{it} is a random error term.

3.3. Estimation strategies

First, ordinary least squares (OLS) regression is conducted through Stata15.0 software to estimate the average effect of urban expansion on the urban–rural income gap. To reduce heteroskedasticity, all variables are logarithmically transformed before the regression analysis, and Eq. (1) is transformed into Eq. (2).

$$lnineq_{it} = \alpha_0 + \alpha_1 lnbuilt_{it} + \sum\nolimits_{j=1}^{6} \beta_j lncons_{it} + \varepsilon_{it} \tag{2}$$

Given that the urban expansion and urban–rural income gap vary by development stage and region, this study explores possible nonlinear relationships by adding the quadratic term of the core explanatory variables to the model (Eq. (3)).

$$lnineq_{it} = \alpha_0 + \alpha_1 \mathrm{ln}built_{it} + \alpha_2 lnbuilt_{it}^2 + \sum\nolimits_{j=1}^{6} \beta_j lncons_{it} + \varepsilon_{it} \tag{3}$$

However, the OLS estimator can only provide a partial view of the relationship between urban expansion and the urban–rural income gap, as it is based on mean regression, ignoring the unequal variation in the distribution of the data (Koenker & Bassett, 1978). Owing to the substantial differences among Chinese cities in terms of development, urban expansion is likely to vary with the urban–rural income gap, so we further adopt a quantile regression panel data estimator to check for the heterogeneous effects.

Quantile regression has the following advantages over traditional OLS methods. First, quantile regression does not require random error terms to strictly satisfy classical econometric assumptions, such as zero mean, homoscedasticity, and normal distribution. Furthermore, it is less susceptible to extreme values and thus is more robust in coefficient estimation. More importantly, it can capture heterogeneous effects in urban expansion with respect to different urban–rural income gap quantiles by presenting the complete picture of the conditional distribution (Yan et al., 2020). Quantile regression is widely used to study conditional response distributions in regression (Koenker, 2004).

The quantile regression panel data estimator is a special case of generalized quantile regression, which can take fixed effects into account and is not limited by time length of the panel data (Powell, 2016). Previous analyses show the panel quantile estimates can be specified as Eqs. (4) and (5). This was finally achieved using the adaptive Markov chain Monte Carlo (MCMC) method for five representative quartiles, namely, 10 %, 25 %, 50 %, 75 %, and 90 %, in the Stata15.0 software (Zhang et al., 2018).

$$Qlnineq_{it}\left(\tau/_{\chi_{it}}\right) = \beta_0^{(\tau)} + \beta_1^{(\tau)} lnbuilt_{it} + \sum\nolimits_{j=1}^{6} \beta_j^{(\tau)} lncons_{it} + e_{it} \tag{4}$$

$$Qlnineq_{it}\left(\tau/_{\chi_{it}}\right) = \beta_0^{(\tau)} + \beta_1^{(\tau)}lnbuilt_{it} + \beta_2^{(\tau)}lnbuilt_{it}^2 + \sum_{j=1}^{6}\beta_j^{(\tau)}lncons_{it} + e_{it} \quad (5)$$

where the cities are indexed by i ($i = 1,2, \ldots, 220$), time by t ($t = 1, 2, \ldots, 9$), and τ is the quantile [$\tau \epsilon$ (0, 1)]. χ_{it} stands for the vector of independent variables, and β represents the slopes of the independent variables for quantile τ. The left side of the equation gives the τ^{th} conditional quantile of the dependent variable, $\beta_0^{(\tau)}$ is the individual effect at the τ quantile, and e_{it} is the model perturbation term.

3.4. Descriptive statistics

Moreover, the panel dataset in our study is a balanced short panel, consisting of 220 prefecture-level cities over a period of 9 years; thus, the potential issue of panel autocorrelation can be ignored. Because all variables are in logarithmic form in the final model, Table 1 reports the descriptive statistics in their logarithmic values. The distribution of the variables is more skewed and concentrated than the normal distribution with longer tails, which may lead to a biased estimation in mean regression. In Fig. 2, the uneven distribution of urban–rural income gaps in different quantiles requires attention to be paid to heterogeneity and proves the necessity of a quantile regression analysis.

Meanwhile, no variance inflation factor (VIF) of any variable is >5, indicating that there is no significant multicollinearity in the panel estimation models (Marquaridt, 1970). For panel quantile regression, it is necessary to examine the differences in estimated coefficients across quantiles with the Wald test (Halliru et al., 2020; Koenker & Bassett, 1982). In this paper, the Wald test was performed using the null hypothesis that slope coefficients are homogenous. Because this result rejects the null hypothesis, it is crucial to consider distribution heterogeneity in exploring the relationship between urban expansion and the urban–rural income gap.

3.5. Study area

Because of the current imbalances in regional development in China, this study conducts a regression analysis using four major regions in eastern, northeastern, central, and western China and subsamples of highly urbanized and low-urbanized regions. First, the 220 prefecture-level cities examined in this study are divided by region into eastern, central, western, and northeastern, using the official divisions (National Bureau of Statistics of China, 2011) (Fig. 3a). The average value of GDP per capita from 2006 to 2014 among regions shows the following trend: East (26,033.93 CNY) > Northeast (23,437.51 CNY) > Central

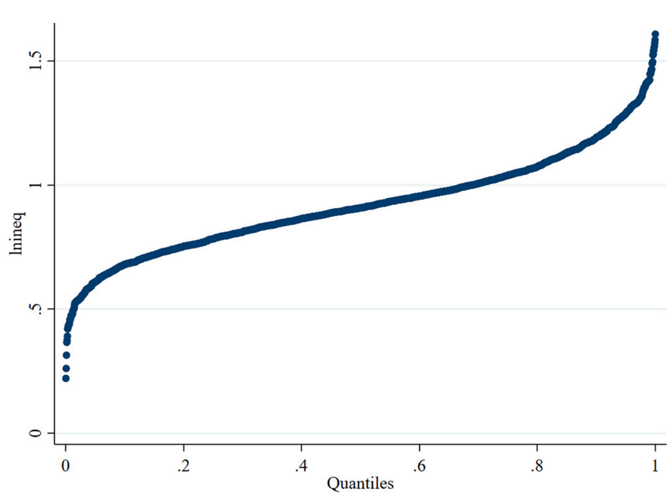

Fig. 2. Distribution of urban-rural income gap (in logarithm).

(15,286.71 CNY) > West (14,943.00 CNY), so this division also symbolizes the regional evolution of economics in China. Second, we further divide these cities into high-urbanization areas and low-urbanization areas, following the S-curve proposed by Northam and the improvements suggested by other scholars (Chen & Zhou, 2005; Northam, 1979; Wang & Wu, 2009) (Fig. 3b). Specifically, the average urbanization rate of 50 % is used as the dividing line.

4. Empirical results

4.1. Panel quantile regression results

4.1.1. Benchmark regression

Table 2 shows the estimated results of Eqs. (2) and (4), where the coefficients of *lnbuilt* are negative and pass the 1 % significance test. Specifically, for every 1 % urban expansion, the ratio of urban to rural incomes decreases by 0.005 % to 0.011 %. This implies that urban expansion during 2006–2014 helped reduce the urban–rural income gap. The role of the related control variables in the model is also worth our attention. As shown in Table 2, improvements in economic development, urbanization rate, and external development will significantly reduce the urban–rural income disparity, while local public expenditures, industrial restructuring, and education expenditures can widen the urban–rural income gap.

A similar conclusion is attained using different subsamples, divided by region and urbanization rate. The summary of the regression results in Table 3 shows that the coefficients of *lnbuilt* remain significantly negative across regions. OLS regression shows that the *lnbuilt* coefficient has the following trend of variation east (−0.021) < central (−0.016) < northeast (−0.015) < west (−0.003) in different regions, and a coefficient of −0.008 in highly urbanized areas is smaller than that of −0.016 in areas with an urbanization rate <50 %. Combining the coefficient of *lnbuilt* at different quantiles (from 0.1 to 0.9), Fig. 4 identifies the heterogeneous effect of urban expansion on the urban–rural income gap. For northeast China and highly urbanized regions, the narrowing effect of urban expansion on the urban–rural income gap is more negligible at the 50th quantile (Q50) and more pronounced at the higher quantile.

4.1.2. Nonlinear regression

To explore the nonlinear relationship between urban expansion and the urban–rural income gap, we further include $lnbuilt^2$ in the regression models (see Eqs. (3) and (5)). From Tables 4 and 5, it is clear that most of the quadratic coefficients are negative, while the primary coefficients are positive at the 1 % significance level. These results highlight the inverted-U relationship between urban expansion and the urban–rural income gap. Put differently, urban expansion first increases the urban–rural income gap and then shows a narrowing effect.

4.2. Robustness checks

Empirical studies show that spatial effects play an important role in forming and developing the urban–rural income gap (Li et al., 2014; Salvati, 2016). By calculating Moran's *I* using an inverse distance spatial weight matrix, we find that the urban–rural income gap in China from 2006 to 2014 has a positive spatial autocorrelation with a significant agglomeration effect (see Table 6 and Fig. 5). To ensure the robustness of our empirical results, we introduce the SDM and GTWR models to capture the spatial effect.

4.2.1. Alternative estimation strategy: estimation by SDM and GTWR

Spatial effects using spatial autocorrelation can be characterized by the spatial lag model (SLM), the spatial error model (SEM), and the SDM. The SDM model adopted here combines the SLM and SEM models and integrates the spatial correlations between the explanatory and explained variables (Halleck Vega & Elhorst, 2015). To ensure the scientific validity of the model, various tests were conducted on the model

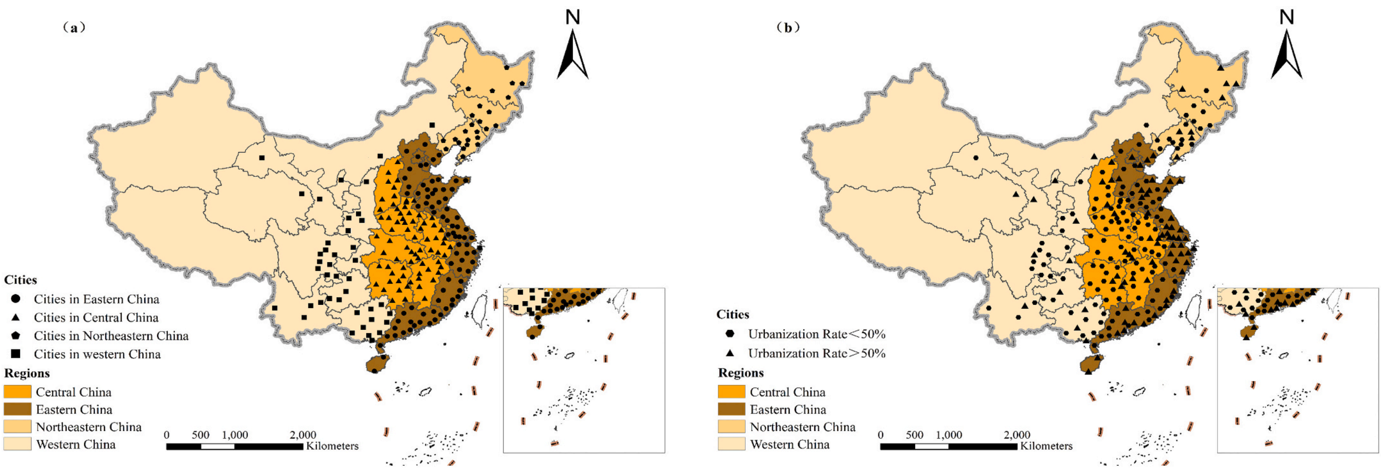

Fig. 3. Study area: (a) Cities based on regions of China; (b) Cities based on urbanization rate.

Table 2
Empirical results of OLS and panel quantile regressions.

lnineq	OLS	Q10	Q25	Q50	Q75	Q90
lnbuilt	−0.009***	−0.011***	−0.005***	−0.006***	−0.008***	−0.010***
	(0.003)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
lnpgdp	−0.156***	−0.138***	−0.133***	−0.159***	−0.186***	−0.170***
	(0.016)	(0.001)	(0.005)	(0.003)	(0.001)	(0.001)
lnexpend	0.031**	0.016***	0.035***	0.019***	0.042***	0.040***
	(0.014)	(0.001)	(0.005)	(0.002)	(0.001)	(0.001)
lnurban	−0.191***	−0.201***	−0.218***	−0.047***	−0.075***	−0.139***
	(0.027)	(0.001)	(0.007)	(0.013)	(0.000)	(0.001)
lnindus	0.881***	0.973***	0.764***	0.538***	0.601***	0.633***
	(0.079)	(0.002)	(0.008)	(0.014)	(0.003)	(0.003)
lnopen	−0.037***	−0.028***	−0.015***	−0.025***	−0.040***	−0.047***
	(0.004)	(0.000)	(0.004)	(0.002)	(0.000)	(0.000)
lneduexp	0.052***	0.070***	0.018***	0.018***	0.029***	−0.042***
	(0.020)	(0.001)	(0.005)	(0.003)	(0.001)	(0.001)
Constant	2.670***	–	–	–	–	–
	(0.159)	–	–	–	–	–

Note: Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. $N = 220$, Obs. = 1980.

Table 3
Estimation results in different regions of China (other variables controlled).

Regions	N	OLS	Q10	Q25	Q50	Q75	Q90
Eastern China	81	−0.021***	−0.018***	−0.011***	−0.016***	−0.024***	−0.026***
		(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Northeast China	25	−0.015**	−0.011*	−0.008***	−0.012***	−0.019***	−0.011***
		(0.007)	(0.001)	(0.000)	(0.000)	(0.005)	(0.001)
Central China	73	−0.016***	−0.019***	−0.013***	−0.020***	−0.019***	−0.000***
		(0.004)	(0.000)	(0.003)	(0.001)	(0.000)	(0.000)
Western China	41	−0.003*	0.002***	−0.008***	−0.004***	−0.014***	0.001***
		(0.007)	(0.001)	(0.000)	(0.006)	(0.008)	(0.000)
Urbanization rate > 50 %	84	−0.008**	−0.015**	−0.000**	−0.000*	−0.004***	−0.010***
		(0.004)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Urbanization rate < 50 %	136	−0.016***	−0.023***	−0.018***	−0.011***	−0.0160***	−0.013***
		(0.003)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)

Note: Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

form selection (Table 7). The results of the LM test and Hausman test indicate that the data are suitable for spatial econometric analysis and had a fixed effect, while the LR test and the Wald test further rejected the null hypothesis that SDM could be simplified to SLM and SEM at a 1 % level of confidence (Elhorst, 2014). Taking into account the goodness-of-fit and variable significance of the model, the time-fixed SDM is selected for the analysis.

The decomposition results of SDM are shown in Table 8. Most of the coefficients of *lnbuilt* maintain consistency with previous results, especially in terms of the nonlinear regression. This provides robust evidence for the role of urban expansion in reducing urban–rural income gap and further affirms the existence of an inverted U-shaped relationship between the two. However, the coefficient of the direct effect of *lnbuilt* in model (1) is significantly positive, indicating that urban expansion may

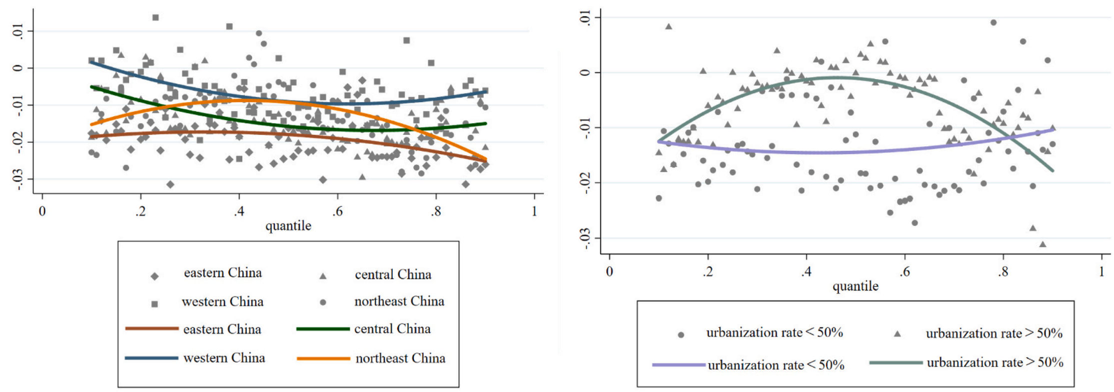

Fig. 4. Coefficient evolution of urban construction land expansion on urban-rural income gap in different regions (all control variables are included).

Table 4
Verification of inverted U-shaped curves at the national level.

Variable	Q10	Q25	Q50	Q75	Q90
lnbuilt^2	−0.002***	−0.002***	−0.002***	−0.002***	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnbuilt	0.006*	0.020***	0.032***	0.009***	−0.011***
	(0.003)	(0.005)	(0.001)	(0.002)	(0.003)
lnpgdp	−0.140***	−0.206***	−0.094***	−0.163***	−0.194***
	(0.015)	(0.027)	(0.006)	(0.004)	(0.005)
lnexpend	0.005	−0.030*	0.053***	0.072***	0.031***
	(0.013)	(0.014)	(0.003)	(0.003)	(0.002)
lnurban	−0.190***	0.004	−0.215***	−0.093***	−0.138***
	(0.023)	(0.079)	(0.006)	(0.004)	(0.005)
lnindus	1.004***	0.645***	0.452***	0.562***	0.664***
	(0.135)	(0.073)	(0.026)	(0.014)	(0.011)
lnopen	−0.020***	−0.021**	−0.022***	−0.037***	−0.047***
	(0.002)	(0.007)	(0.001)	(0.001)	(0.001)
lneduexp	0.053***	0.058***	0.024***	0.047***	−0.054***
	(0.007)	(0.008)	(0.003)	(0.004)	(0.005)

Note: Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. N = 220, Obs. = 1980.

widen the local urban–rural income gap, which is inconsistent with that of the relative strain variable in Table 2. As the direct effects in SDM include intra-regional interactions and feedback effects from affected neighboring regions, we can still assume that the results are robust (Li & Li, 2020).

The GTWR model is introduced in relation to spatial heterogeneity. As shown in Table 9, the R^2 and adjusted R^2 of models (1) and model (2)

Table 6
Global Moran's I statistics of urban-rural income gap from 2006 to 2014.

Year	Moran's *I*	Z_value	P_value
2006	0.102	7.169	0.000
2007	0.099	6.982	0.000
2008	0.133	9.246	0.000
2009	0.153	10.614	0.000
2010	0.176	12.116	0.000
2011	0.162	11.227	0.000
2012	0.139	9.655	0.000
2013	0.095	6.669	0.000
2014	0.120	8.396	0.000

Table 5
Verification of subregional inverted U curves (all other variables are controlled).

Regions	Variable	Q10	Q25	Q50	Q75	Q90
Eastern	*lnbuilt*^{2}	−0.001***	−0.004***	−0.003***	−0.002***	−0.002***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbuilt	−0.007***	0.031***	0.015***	0.004***	−0.010***
		(0.000)	(0.003)	(0.001)	(0.000)	(0.002)
Northeast	*lnbuilt*^{2}	−0.007***	−0.003***	−0.004***	−0.001***	−0.002***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbuilt	0.048***	0.019***	0.035***	−0.005***	−0.000**
		(0.001)	(0.000)	(0.002)	(0.000)	(0.000)
Central	*lnbuilt*^{2}	−0.003***	−0.003***	−0.003***	−0.003***	−0.003***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbuilt	0.006*	0.012***	0.016***	0.021***	0.026***
		(0.002)	(0.002)	(0.000)	(0.001)	(0.000)
Western	*lnbuilt*^{2}	−0.009***	−0.007***	−0.002***	0.001***	−0.002***
		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbuilt	0.100***	0.091***	0.010***	−0.020***	0.024***
		(0.006)	(0.000)	(0.000)	(0.001)	(0.000)
>50 %	*lnbuilt*^{2}	−0.002***	−0.001	−0.001*	−0.002***	−0.001***
		(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
	lnbuilt	0.002***	−0.005	0.009	0.010***	0.001
		(0.001)	(0.005)	(0.007)	(0.003)	(0.002)
<50 %	*lnbuilt*^{2}	−0.007***	−0.005***	−0.004***	−0.004***	0.001***
		(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
	lnbuilt	0.072***	0.038***	0.025***	0.030***	−0.023***
		(0.002)	(0.004)	(0.007)	(0.004)	(0.002)

Note: Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$

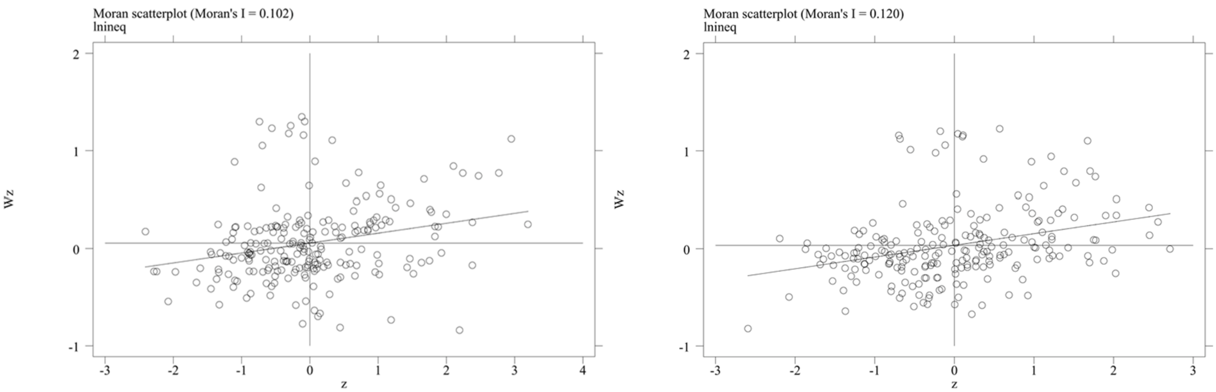

Fig. 5. The Moran scatterplot of the urban-rural income gap in 2006 (left) and 2014 (right).

Table 7
The results of the LM test, LR test and Wald test.

Tests	Statistic	*P*-value
hausman	41.830	0.000
LM_Error	993.340	0.000
Robust LM_Error	347.999	0.000
LM_Lag	761.719	0.000
Robust LM_Lag	116.377	0.000
LR_Lag	149.520	0.000
LR_Error	169.640	0.000
Wald_Lag	11.350	0.004
Wald_Error	27.800	0.000

are above 60 %, which indicates that the GTWR model is suitable for explaining the relationship between urban expansion and the urban–rural income gap. For model (1), the minimum, mean, and median values of the *lnbuilt* coefficient have the same direction as previous results. In model (2), the median and minimum value also satisfy the inverted U-shaped relationship, as before. The results above show the robustness of the model. However, it is still worth noting that the maximum values of the coefficients in model (1) and model (2) are positive; that is, there exists a widening effect for urban expansion on the urban–rural income gap in some regions of China. Furthermore, it is worth further exploring later. The results once again prove the spatial heterogeneity of the impact of urban expansion on the urban–rural income gap, which needs further discussion later.

4.2.2. Re-examining the core explanatory variables

Because there are various ways to characterize urban expansion, we further conducted model regression using the rate of urban expansion (*lnbrate*) as an alternative measurement to obtain robustness results (Gao et al., 2015; Luo et al., 2018; Wei & Ewing, 2018). At the national level, the regression results for both the primary and secondary terms agree well with previous results (as shown in Appendix A Tables A1 and A2). The results for sub-regional regression also support the conclusion derived from the panel quantile regression model, but the difference in coefficients is relatively small, which is worth further discussion (see Appendix B Tables B1 and B2 and Fig. B1).

5. Discussion

Our first main finding indicates that urban expansion has had a narrowing effect on the urban–rural income gap. This is consistent with neoclassical convergence theory, which holds that factor mobility and diffusion can lead to geographical equilibrium (Wei, 2015). As urban expansion is a process of land transfer from the lower-productivity

Table 8
Estimates of direct, indirect, and total effects.

Variable	(1)			(2)		
	Direct	Indirect	Total	Direct	Indirect	Total
lnbuilt	0.015***	−0.040***	−0.025*	0.008*	0.219***	0.227***
	(0.00)	(0.00)	(0.07)	(0.08)	(0.00)	(0.00)
$lnbuilt^2$	–	–	–	−0.001**	−0.017***	−0.018***
	–	–	–	(0.03)	(0.00)	(0.00)
lnpgdp	−0.049***	−0.469***	−0.518***	−0.082***	−0.426***	−0.509***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnexpend	0.180***	−0.101	0.079	−0.013	−0.004	−0.017
	(0.00)	(0.22)	(0.35)	(0.33)	(0.98)	(0.90)
lnurban	−0.155***	−0.432***	−0.587***	−0.018	0.177	0.159
	(0.00)	(0.00)	(0.00)	(0.50)	(0.46)	(0.51)
lnindus	0.771***	1.967***	2.738***	0.408***	−1.271	−0.863
	(0.00)	(0.00)	(0.00)	(0.00)	(0.13)	(0.30)
lnopen	−0.046***	0.084***	0.038***	−0.011***	−0.052**	−0.063**
	(0.00)	(0.00)	(0.01)	(0.00)	(0.04)	(0.02)
lneduexp	0.123***	−0.194**	−0.071	0.049***	0.383***	0.433***
	(0.00)	(0.02)	(0.42)	(0.00)	(0.00)	(0.00)
Observations	1980			1980		
R-squared	0.427			0.274		
Number of cities	220			220		

Note: Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 9
GTWR estimation results.

Variable	(1)				(2)			
	Mean	Median	Min	Max	Mean	Median	Min	Max
inbuilt	−0.007	−0.009	−0.055	0.069	−0.015	0.018	−0.389	0.394
lnbuilt^2	–	–	–	–	0.000	−0.002	−0.030	0.030
lnpgdp	−0.072	−0.096	−0.696	0.596	−0.102	−0.113	−0.654	0.465
lnexpe	0.109	0.093	−0.266	0.480	0.070	0.064	−0.291	0.407
lnurba	−0.140	−0.121	−0.501	0.992	−0.136	−0.121	−0.487	1.050
lnindu	0.651	0.594	−1.738	2.666	0.661	0.603	−1.822	1.974
lnopen	−0.036	−0.034	−0.116	0.043	−0.032	−0.030	−0.104	0.037
lnedue	0.080	0.067	−0.293	0.447	0.059	0.038	−0.315	0.378
Bandwidth	0.115				0.115			
AICc	−2342.750				−2375.950			
R^2	0.630				0.632			
Adjusted R^2	0.629				0.631			
Spatiotemporal Distance Ratio	0.542				0.373			

agricultural sector to the higher-productivity industrial sector (Chen et al., 2018; Liu & Zhang, 2020), it can drive the regional economic growth and increase urban–rural employment (Lu, 2018; Zhang, 2014). In 2006–2014, China achieved rapid urban expansion through the massive conversion of arable land and land acquisition (Zhang et al., 2020). During this period, GDP per capita increased by 25.73 % and the urbanization rate increased by 180.27 %, creating an economic miracle. The incomes of both urban and rural residents increased. For farmers in particular, the growth of wage income from nonfarm employment and urban-to-rural remittances contributed significantly to reducing urban–rural inequality (Khan & Riskin, 2005; Wan et al., 2022).

The shrinkage effect by region shows the following trend: east > central > northeast > west. This is consistent with trends in GDP per capita across these regions in 2006–2014, so it can be concluded that the more developed the economy is, the stronger the shrinkage effect will be. This is closely related to the different types of compensation for land expropriation and employment opportunities available in different regions. Economically developed areas in eastern and central China can generally award more property compensation to rural residents in urban expansion (Li, 2012). For example, in Hangzhou, a mixture of compensation schemes, including monetary compensation, employment substitution, share cooperatives, and collective landholdings has emerged, enabling landless farmers to benefit from urbanization (Qian, 2015). Simultaneously, industries in economically developed areas are also more prosperous; thus, the same urban land can create more jobs and bring additional income growth. In addition, a complete land market is found in the east and in other economically developed areas, through which high land transfer revenue can be used to upgrade infrastructure and thus improve overall social welfare (Liu & Zhang, 2020; Zhang & Wang, 2018).

Also, the shrinkage effect in less urbanized areas is higher than that in highly urbanized areas. According to Northam's view, the demand for urban tends to decline in the later stages of urban development (Northam, 1979). In highly urbanized areas, the demand for urban land is decreasing, and the newly added land is more often made available for public infrastructure and social requirements than to industrial development, thus providing a smaller income promotion effect than that in low urbanization areas (Gao et al., 2015). The problem of high housing prices caused by the scarcity of housing in highly urbanized areas is also more prominent. Urban expansion helps urban residents accelerate their wealth accumulation through capital gains, but migrant workers tend to fall into housing poverty, widening the overall urban–rural income gap (Wang et al., 2020; Wu & Zhang, 2018).

Furthermore, the heterogeneity of the shrinkage effect is reflected across quantiles. It appears obvious that the shrinkage effect in northeast China and high urbanization areas is more significant at the 10th and 90th quantiles. Cities with low urban–rural income gaps are characterized by low-level but balanced economic development or bottom-up rural development. In the former, the gained urban land is mainly used for industrial development and infrastructure construction, bringing more obvious wage growth and welfare effects (Li et al., 2018). For the latter, the bargaining power of the village collective is higher, through which farmers can obtain more reasonable compensation (Guo et al., 2018; Tong et al., 2020). For example, in Nanhai, located in the Pearl River Delta region, industrial land accounts for 57.0 % of the total built-up area, three-quarters of which belong to the collective. Urban expansion in this region will increase the legitimate income of farmers and help legalize their former gray income (He et al., 2009). For regions with a severely differentiated urban–rural income gap, there is usually an explicit function division between urban and rural areas (Chen, Long, et al., 2020). Urban expansion in these areas, on the one hand, can improve the previous one-way export of resources from rural to urban areas through compensation and transfer payment (Barkley et al., 1999; Zhong et al., 2019); However, it can also increase the property income of rural residents and their wage income through the land requisition compensation and employment placement (Huang & Du, 2017; Shi & Cao, 2020).

Another important finding is that of an inverted U curve between urban expansion and the urban–rural income gap. Simon Kuznets' inverted U-curve theory indicates that income distribution inequality tends to grow and then decrease with economic growth (Kuznets, 1955), which may be explained by the evolution of compensation. It is stipulated in Article 47 of the 1998 *Land Management Law* that the total amount of land compensation and resettlement allowance for land expropriation should not exceed 30 times the average annual production value of 3 years before the expropriation, which has proven to be impede any guarantee of the landless farmers' subsequent livelihood. About 50 million peasants had been expropriated in China before 2008 (Bao, 2008), while surveys from Ningxia, Chongqing, and other areas across the country show that a significant proportion of landless peasants face livelihood problems (He et al., 2009). Owing to the increasing conflicts arising from inadequate land acquisition, in 2010, the compensation standard began to be regulated every 2 to 3 years to keep track with the economic development and gradually increase land acquisition compensation levels (Wang et al., 2019). In addition, increased governmental attention to rural development played an important role. Since 2004, the Central Committee has focused on agriculture, countryside, and farmers (*sannong*) for its No. 1 document for nine consecutive years (Li et al., 2014; Zhao, 2017). More than five policy documents were released from 2006 to 2009 requiring local governments to use land transfer revenue to support rural infrastructure investment (Zhong et al., 2019). Combined with all of the regression results in the paper, urban expansion in the country as well as in different regions mainly shows a contraction effect on the urban–rural income gap, indicating that most regions in China have crossed the relevant inflection point, leading to the appearance of positive effects of urban expansion appears.

We also identified some points worthy of further discussion in the robust regression analysis. For example, the expansion of local urban land can help narrow the urban–rural income gap in neighboring regions. We suggest the reason for this is that when cities are economically connected, rural residents in neighboring areas enjoy more employment opportunities brought by the local urban expansion than local rural residents without taking the risk of losing their livelihood (Zhang & Wang, 2018). In addition, in the GTWR, we find that some areas in China are on the left end of the inverted U-shaped curve; that is, urban expansion is still dominated by widening the urban–rural income gap. This can be attributed to the vast size of China and its uneven development. Under existing policy standards, land requisition compensation differs among regions. However, the differentiated degree of financial dependence on land has also led to differences in the share of land revenue for agricultural development (Weldearegay et al., 2021; Zhong et al., 2019). Furthermore, the contraction effect of urban expansion on the urban–rural income gap is less differentiated among regions, taking the growth rate as a measure. This may be because the growth rate of land for use is uniform compared with total land area.

6. Conclusions and implications

Using data from 220 prefecture-level cities in China from 2006 to 2014, this study examines the impact of urban expansion on the urban–rural income gap. The major advance provided by this paper lies in its empirical approach on urban expansion and spatial inequality, presenting a novel perspective on urban–rural income disparity research.

Synthesizing the existing land system and factor characteristics, the relationship between urban expansion and urban–rural income gap is, respectively, analyzed in terms of income, resource assets, welfare, and wealth effects. Furthermore, regional differences and nonlinear relationships are also discussed. Taking into account the complexity of the process and the unevenness of China's regional development, the panel quantile method is applied to capture the differential impact of urban expansion on regions with different urban–rural income gaps. In addition, the SDM model and the GTWR model confirm the robustness of the regression results based on spatiotemporal effects. Observing results from different regions, quantiles, and models can enable us to better understand the relationship between the urban expansion and the urban–rural income gap. As urban expansion is an important indicator of urbanization (Chen, Long, et al., 2020; Skog & Steinnes, 2016), this conclusion provides new empirical experience for urbanization to narrow the urban–rural income gap.

In general, urban expansion has a heterogeneous narrowing effect on the urban–rural income gap. In these economically developed areas in eastern and central China, the contraction effect of urban expansion on the urban–rural income gap is substantial because of the higher level of land acquisition compensation, better developed industrial structure, and mature land market. For highly urbanized areas, the lower land demand and the public service-biased land structure, combined with higher housing prices, make urban expansion less effective in shrinking the urban–rural income gap than that in less urbanized areas. In particular, contraction effects are more pronounced in regions with greater and less urban–rural income differentiation, such as in northeastern China and highly urbanized areas. Furthermore, this can be attributed to regional development paths, the bargaining ability of village collectives, and the functional differentiation between urban and rural areas. Finally, owing to the optimization of the land acquisition compensation policy and the country's continuous attention to the issue of agriculture, rural areas, and farmers, this study also found that the impact of urban expansion on the urban–rural income gap showed an inverted U-shaped trend, with initial expansion followed by narrowing.

The results of quantitative analysis show the differential interaction effects of urban expansion on urban–rural income disparities. These findings have important policy implications for further land management and for urban–rural integration. First, additional attention should be paid to the interaction between space and equity in urbanization. Land is the geographic boundary that divides urban from rural areas, but urban expansion can break this boundary and bring in many other factors, influencing the income of urban and rural residents. Even though urban expansion is useful for narrowing the urban–rural income gap, planning and thinking beyond growth is still required to promote overall income growth while minimizing the damage to farmers' interests. Furthermore, well-defined property rights and equal market dominance are needed to reduce land grabs from rural residents and enhance the resource-asset benefits of collective land. Compensation levels and the differential ability to assetize resources are the main reasons for the different effects between regions and different development stages. Farmers' property compensation and employment training should be supported in regions that show an expanding effect, while welfare and wealth redistribution should be optimized between urban and rural areas in shrinking regions. In addition, previous urban-biased notions should be abandoned, as equitable distribution of public services and infrastructure between urban and rural areas are essential to enhancing rural residents' welfare. Last but not least, deepening housing reform is also greatly necessary. Public rental housing in cities and the withdrawal of residential land in rural areas are necessary to reduce the disparity in housing wealth accumulation between urban and rural residents.

In this paper, we only analyzed data from 2006 to 2014, when China's urban expansion was proceeding at its fastest rate. Taking into account that policies to promote urban–rural integrated development have been launched recently, the relationship between urban expansion and the urban–rural income gap can be further explored in the future. In addition, the spatial analysis is used only as part of a robust analysis in this study. Because of the spatial effects of urban construction, land expansion, and urban–rural income, future work must be carried out to explore the spatial interaction between the two.

Funding

- Science Fund for Creative Research Groups of the National Natural Science Foundation of China (71921003)
- Project of Jiangsu Province, China (BRA2020031)
- Major Program of National Social Science Fund of China (17ZDA061)
- University of Glasgow Reinvigorating Research Funding (201644-20)
- University of Glasgow Research Enabling/Impact Generating Scheme (126438-01)

CRediT authorship contribution statement

Sujuan Zhong: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Mingshu Wang:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Yi Zhu:** Conceptualization, Methodology, Investigation, Writing – original draft. **Zhigang Chen:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Xianjin Huang:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1
Robust regression results of OLS and panel quantile regressions at the national level.

	OLS	Q10	Q25	Q50	Q75	Q90
lnbrate	−0.011***	−0.008**	−0.011***	−0.006***	−0.009***	−0.009***
	(0.003)	(0.003)	(0.001)	(0.002)	(0.000)	(0.000)
lnpgdp	−0.164***	−0.157***	−0.130***	−0.145***	−0.209***	−0.203***
	(0.014)	(0.014)	(0.007)	(0.007)	(0.002)	(0.004)
lnexpend	0.028**	0.012	0.027***	0.054***	0.012**	0.031***
	(0.013)	(0.020)	(0.004)	(0.005)	(0.005)	(0.002)
lnurban	−0.196***	−0.186***	−0.234***	−0.169***	−0.087***	−0.172***
	(0.024)	(0.046)	(0.011)	(0.004)	(0.004)	(0.002)
lnindus	0.895***	0.922***	0.869***	0.763***	0.616***	0.911***
	(0.071)	(0.116)	(0.017)	(0.019)	(0.017)	(0.012)
lnopen	−0.037***	−0.017***	−0.037***	−0.033***	−0.023***	−0.052***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.002)	(0.001)
lneduexp	0.049***	0.066***	0.017***	0.017**	0.046***	−0.016***
	(0.017)	(0.005)	(0.006)	(0.007)	(0.003)	(0.002)
constant	2.642***	–	–	–	–	–
	(0.143)					

Note: Standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1. N = 220, Obs. = 1980.

Table A2
Verification of inverted U-shaped curves at the national level.

Variable	Q10	Q25	Q50	Q75	Q90
$lnbrate^2$	−0.002***	−0.003***	−0.001*	−0.003***	−0.005***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
lnbrate	−0.024***	−0.035***	−0.011	−0.029***	−0.040***
	(0.000)	(0.001)	(0.007)	(0.001)	(0.001)
lnpgdp	−0.150***	−0.193***	−0.238***	−0.172***	−0.209***
	(0.003)	(0.008)	(0.013)	(0.003)	(0.001)
lnexpend	0.030***	0.012**	0.030***	0.082***	0.003**
	(0.004)	(0.005)	(0.001)	(0.003)	(0.001)
lnurban	−0.235***	−0.002	−0.040	−0.150***	−0.111***
	(0.009)	(0.026)	(0.025)	(0.006)	(0.001)
lnindus	1.207***	0.458***	0.497***	0.813***	0.660***
	(0.018)	(0.096)	(0.065)	(0.010)	(0.005)
lnopen	−0.005	−0.030***	−0.006	−0.038***	−0.056***
	(0.003)	(0.002)	(0.004)	(0.000)	(0.000)
lneduexp	0.036***	0.094***	−0.040	0.040***	−0.053***
	(0.004)	(0.012)	(0.024)	(0.003)	(0.002)

Note: Standard errors in parentheses.
*** p < 0.01.
** p < 0.05.
* p < 0.1.

Appendix B

Table B1
Robust regression results in different regions of China (other variables controlled).

Groups		N	Q10	Q25	Q50	Q75	Q90
Regions	Eastern China	81	−0.008*	−0.012***	−0.013***	−0.014***	−0.011***
			(0.004)	(0.001)	(0.000)	(0.000)	(0.000)
	Northeast China	25	−0.020***	−0.003**	−0.017***	−0.032***	−0.038***
			(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
	Central China	73	−0.029***	−0.009***	−0.018***	−0.025***	−0.012***
			(0.002)	(0.002)	(0.001)	(0.000)	(0.000)
	Western China	41	−0.004	−0.007***	−0.005***	−0.013***	−0.021***
			(0.014)	(0.001)	(0.001)	(0.000)	(0.000)
Urbanization level	>50 %	84	−0.008***	−0.002	−0.006***	−0.013***	−0.031***
			(0.001)	(0.004)	(0.002)	(0.002)	(0.000)
	<50 %	136	−0.021***	−0.013***	0.009***	−0.003***	−0.005***
			(0.002)	(0.001)	(0.002)	(0.001)	(0.000)

Note: Standard errors in parentheses.
*** p < 0.01.
** p < 0.05.
* p < 0.1.

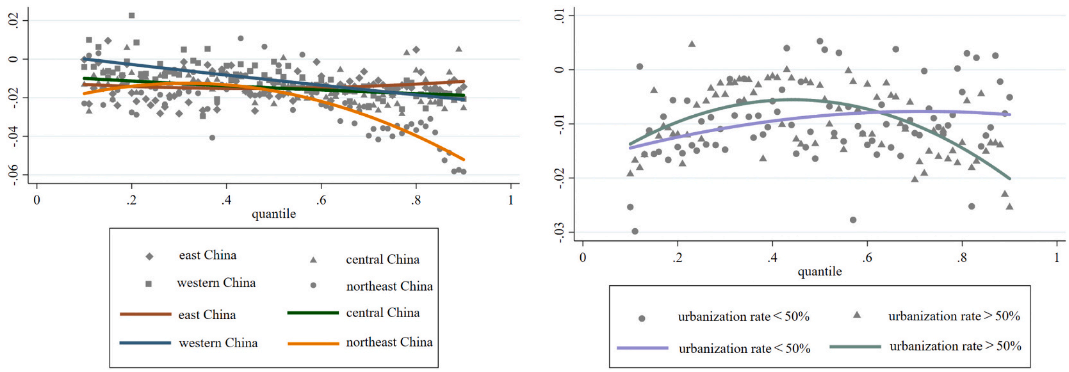

Fig. B1. Coefficient evolution of urban construction land expansion on urban-rural income gap in different regions (all control variables are included).

Table B2
Verification of sub-regional inverted U curves (all other variables are controlled).

Regions	Variable	Q10	Q25	Q50	Q75	Q90
Eastern	*lnbrate*^{2}	−0.005***	−0.003***	−0.003***	−0.002***	−0.004***
		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbrate	−0.053***	−0.039***	−0.035***	−0.031***	−0.034***
		(0.004)	(0.001)	(0.000)	(0.000)	(0.000)
Northeast	*lnbrate*^{2}	−0.008**	−0.007*	−0.006***	−0.002***	−0.003***
		(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbrate	−0.074**	−0.071	−0.052***	−0.049***	−0.060***
		(0.024)	(0.000)	(0.002)	(0.000)	(0.000)
Central	*lnbrate*^{2}	−0.002***	−0.001***	−0.002***	−0.003***	−0.005***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbrate	−0.035***	−0.018***	−0.028***	−0.042***	−0.049***
		(0.002)	(0.003)	(0.001)	(0.000)	(0.000)
Western	*lnbrate*^{2}	−0.011***	−0.008***	−0.007***	−0.011***	−0.007***
		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
	lnbrate	−0.055***	−0.033***	−0.046***	−0.063***	−0.054***
		(0.003)	(0.001)	(0.001)	(0.000)	(0.000)
>50 %	*lnbrate*^{2}	−0.002***	−0.003***	−0.001	−0.003***	−0.002***
		(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
	lnbrate	−0.030***	−0.036***	−0.021***	−0.035***	−0.035***
		(0.000)	(0.007)	(0.004)	(0.002)	(0.000)
<50 %	*lnbrate*^{2}	−0.003***	0.001	−0.000	−0.005***	−0.004***
		(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
	lnbrate	−0.035***	0.005	−0.006	−0.044***	−0.034***
		(0.004)	(0.005)	(0.005)	(0.001)	(0.000)

Note: Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0$.

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