



# Exploring impacts of the *Grain for Green* program on Chinese economic growth

Jingjing Liu<sup>1</sup> · Jing Wang<sup>1</sup> · Zehui Li<sup>1</sup> · Yingkun Du<sup>1</sup>

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## Abstract

Research on effects of ecological restoration and afforestation and their links to land conservation and regional development have received global attention. The Chinese government has successively invested a substantial amount of funds in the *Grain for Green* Program (GGP) since the mid-1990s. The economic effects of the GGP on macroeconomic growth could be attributed to an increase in agricultural production and off-farm employment and follow-up industry development. Few studies have focused on economic effects of the GGP at the national level using long-term series of panel data in 31 provinces and cities across the country. This study analyzed the regional differentiation and temporal-spatial changes in the GGP and investigated economic impacts of the GGP at different scales. Results showed that the scale of the GGP varied significantly in the eastern, central and western regions and regional changes were characterized by temporal differentiation from 2000 to 2016. The GGP had a slightly negative impact on China's economic growth, which presented an overall U-shape, changed with an increase in economic growth. Significant regional heterogeneities in economic growth and impacts of the GGP were observed in the eastern, central and western regions. In the current situation in China, the technical progress, adjustment of industrial structure and focus on human capital to promote the development of follow-up industries and farmers' labor skills have demonstrated the role for improving economic growth and optimizing the GGP arrangement. It is crucial to achieve a synergy between ecosystem conservation and regional economic in China.

**Keywords** *Grain for Green* program (GGP) · Economic growth · Regional differences · Panel quantile regression · Effective implementation · China

## 1 Introduction

Climate change, which is the greatest global challenge of our time, has various implications for socioeconomic conditions and environment (Ali 2018). Sustainable development has been threatened by not only the impacts of climate change but also the problematic relationship between land for ecological protection and economic development and

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✉ Jing Wang  
wjing0162@126.com

<sup>1</sup> School of Resource and Environmental Sciences, Wuhan University, Wuhan 430079, China

agricultural production under the macro-background of urbanization and ecological civilization. Environmental innovations and a decrease in ecological degradation have gained increasing attention due to their important roles in the global and regional sustainable development of the economy (Aldieri et al. 2019c; Ali et al. 2017). Many ecological restoration programs and public incentives, which are aimed to preserve the natural ecosystem and create environmental innovations, have been introduced by governments around the world and received global attention, since the innovative scenario of economic development is the environmental scenario (Wang et al. 2018; Aldieri et al. 2019a). Whether economic growth can be achieved without environmental degradation has prompted several discussions (Sepehrdoust and Zamani 2017; Ali et al. 2017). The contradiction between environmental degradation and economic growth has become increasingly prominent due to the continuous and rapid growth of economic aggregate, especially in China, which is the largest developing country with complex natural conditions and an imbalanced economy (Wang et al. 2015, 2018). Scholars and policy makers are seeking novel ways to address ecological degradation while achieving the divergent goals of conservation and production in terms of increasing sustainable ecosystems and food security and reducing poverty (Li et al. 2018). Since the mid-1990s, the Chinese government has successively initiated and invested a large amount of financial resources in *national natural forest protection projects*, the *Grain for Green Program* (GGP) and other payments for environmental services (PES) projects, particularly in the central and western regions.

As one of the typical programs of PES in China, the GGP was implemented due to the massive floods in 1998. The GGP included not only the conversion of cultivated land on steep slopes to forest or grassland in the western, central and northeastern regions but also the conversion of cultivated land on important wetlands to lake or wetland in the eastern region (Xiong et al. 2004; Zhang et al. 2016). Since 2005, the police of “Notice of the General Office of the State Council of the People’s Republic of China on Effectively Strengthening the ‘Five Combinations’ to Further Consolidate the Achievements of Grain for Green Program” has begun to pay attention to poverty alleviation and increasing farmers’ incomes. In 2015, the “Notice on Expanding the Scale of Grain for Green Program” was promulgated; it indicated that accelerating the new round of the GGP not only could improve the eco-environment and liberate the rural labor force but also increase the incomes of farmers. The new round of the GGP (2014–2020) provides an important opportunity for farmers to adjust their livelihood strategies (Zhang 2018). In the 20 years since the start of the two-round GGP, China has converted more than 33 million ha of cultivated land into forests and grassland, and the total investment has exceeded 500 billion yuan (Wang 2019). Objectively assessing the effect of the GGP on China’s economic growth on the national and regional scale is to provide a theoretical basis for the implementation of a new round of the GGP and support policy-making for optimizing the GGP arrangement and promoting sustainable economic development.

Many studies focused on the ecological effects of the GGP implementation caused by the large-scale ecological restoration, including increasing vegetation coverage and carbon sequestration, reducing soil erosion and restoring regional ecosystems (Persson et al. 2013; Zhang et al. 2010, 2016). The GGP was one of the important ways to adjust the structure and function of terrestrial ecosystems to address excessive land use disturbances (Du et al. 2017) and had positive effects on improving the cultivated land quality and agricultural productivity in China (Wang et al. 2012a). Several studies focused on the socioeconomic effects of the GGP and showed that the adequate and sustainable implementation of the GGP could address some of the socioeconomic challenges of China and other countries in the world (Liu et al. 2008; Wang and Yue 2017;

Kelly and Huo 2013). The economic impact of the GGP was mainly due to the issuance of subsidies, transformation of rural surplus labor and development of the industry following the GGP (Wang and Deng 2016; Xu et al. 2018). Some studies have discussed the GGP's response and impact on economic growth and farmers' incomes on a typical region scale. For instance, Li et al. (2015) analyzed the relationship between the GGP and the regional economic growth in Shaanxi and concluded that greater was the amount of cultivated land that was retired, the greater was the amount of labor that was freed from farming for higher-paying off-farm employment, which generated a larger gain in off-farm income. The research of Zhu et al. (2014) and Peng et al. (2007) indicated that the implementation of GGP in Ansai and Zhangye counties could promote the upgrading of industrial structure, economic growth and farmers' incomes. Wang and Yue (2017) also considered that the GGP in the impoverished counties of the central and western regions affects farmers' production fields and generates an increase in farmers' income, promotes non-agricultural employment and adjusts rural production structures. Xie et al. (2010) and Chen et al. (2007) concluded that the project had minimal positive impacts on farmers' income and even reduced the incomes of farmers, especially in western China. These studies reflected individual situations, and the long-term impact remains controversial. On the other hand, several studies at the national level have attempted to analyze the socioeconomic effects of the GGP using short-term parcel data and cross section data and concluded that the GGP had a slight positive effect on the off-farm employment and increase in farmers' incomes (Kelly and Huo 2013; Xie et al. 2011). However, few empirical studies focused on the national economic effects of the GGP using long-term and reliable data from national land surveys. This paper aims to investigate the regional differentiation and temporal-spatial changes in the *Grain for Green* program and the effects on China's economic growth using panel data from 2000 to 2016 in 31 provinces and cities across the country. In particular, the aim was to explore the trends in the impacts of the GGP on China's economic growth on different scales and provide evidence for decision-making to ensure effective implementation of the GGP and rational land development.

The paper is organized as follows: Sect. 2 reports the methodology, dataset and descriptive statistics. Section 3 presents the results, and Sect. 4 provides discussions of the mechanism analysis and effective implementation of the GGP and similar programs. Section 5 concludes this study and outlines some suggestions.

## 2 Data and methodologies

In this study, to examine the impacts of the GGP on the distribution of economic growth and the marginal effects on economic growth, a panel quantile regression was employed to estimate the coefficients in different quantiles. Since the natural and socio-economic conditions in different regions vary significantly, to determine the regional differences of the economic effects of the GGP, 31 provinces and cities were classified into three zoning regions—eastern, central and western regions—according to the level of economic development (Feng et al. 2008). The impacts of the GGP on the regional economic growth in these regions were analyzed using fixed-effect panel regression models according to the results of the Hausman test.

## 2.1 Data and model variables

According to the economic growth theory and classical literature research, technology, capital, natural resources and human resources are four factors that promote economy development (Romer 2006). Natural resources include land elements that could directly provide environmental production factors, such as soil and water (Li and Shi 2017). Human capital is identified as one of the main determinant factors for economic growth and has an important role in a country's technological progress (Teixeira and Queirós 2016). In this study, natural resources were divided into two factors: the GGP variable and the increase in cultivated land, which were considered in the regression model. The GGP provides environmental production factors for the production sector and ecosystem services for consumers, and the ecological compensation and off-farm income generated by the GGP may impact economic growth. The increase (replenishment) in cultivated land is the compensation for the reduction of cultivated land caused by urban development and the GGP. In the process of analyzing the economic impact of the GGP, the physical capital, labor, human capital and increase in cultivated land were incorporated into the regression model as explanatory variables.

The *Grain for Green* Program converted cultivated land in the western, central and the parts of the eastern provinces into forests and grassland and converted cultivated land in most of the eastern region into lakes and wetland. In this study, considering that the compensation funds to farmers by the Chinese government are compensated in accordance with the conversion areas of farmland to forests, grassland and lakes owned by farmers (Li et al. 2015), the GGP variable could be reflected by the conversion areas of cultivated land to forests, grassland and lakes (Li and Shi 2017). Considering that the economic effects of the GGP on macroeconomic growth could be attributed to an increase in agricultural production and off-farm employment and follow-up industry development, the economic output was represented by the gross domestic product (GDP) in this study and data obtained for 31 provinces and cities in China for the period 2000–2016. To eliminate the drastic fluctuations caused by price factors, the data in each year were converted to a constant price in 2000. Capital stock was measured by using the perpetual inventory method proposed by Goldsmith (Goldsmith 1951). The depreciation rate of the capital stock was 9.6%, and the physical capital stock data were calculated from the constant price of 1990. The labor input variable was applied in the analysis model using the number of employees.

Data on the annual conversion areas of farmland to forests, grassland and lakes, and the increased area in cultivated land from 2000 to 2016 were obtained from Chinese several detailed land surveys of the former Ministry of Land and Resources (MLR). The official nationwide land surveys provided data on land use and land use changes from locations and areas of various land use types in each county (Wang et al. 2012b). Data on fixed assets investment and GDP were obtained from the “China Statistics Yearbook,” which was published by the “China State Statistics Bureau” (CSSB 2001–2017), and data on the number of employees were cited from the “Provincial Statistical Yearbook,” which was published by the Provincial Statistics Bureau. Additionally, human capital data were obtained from the China Human Capital Index Report of China Center for Human Capital and Labor Market Research (CHLR). The variables descriptions and data sources are listed in Table 1. All variables were transformed with natural logarithms to eliminate the heteroscedasticity.

Table 2 presents the statistical descriptions for all variables and indicates that the variables are asymmetric since the skewness coefficient is not equal to 0. The distributions of

**Table 1** Data sources and variable descriptions

Variable	Definition	Data source
<i>R</i>	GDP variable (Cumulative conversion area of cultivated land to forests, grassland and lakes by the GGP)	Detailed nationwide land surveys in China conducted by the former Ministry of Land and Resources (MLR)
<i>K</i>	Physical capital (Physical capital stock constant RMB at 1990 prices)	China Statistics Yearbook published by the 'China State Statistics Bureau' (CSSB, 2001–2017)
<i>L</i>	Labor force (Number of employees)	Provincial Statistical Yearbook published by Provincial Statistics Bureau.
<i>H</i>	Human capital (Human capital index)	China Human Capital Index Report of China Center for Human Capital and Labor Market Research (CHLR)
<i>I</i>	Increase in cultivated land (Increased area of cultivated land)	Detailed nationwide land surveys of the former Ministry of Land and Resources (MLR)
GDP	Economic growth (Real GDP constant RMB at 2000 prices)	China Statistics Yearbook published by the 'China State Statistics Bureau' (CSSB, 2001–2017)

**Table 2** Summary of variables and statistics

Variable	Mean	Minimum	Maximum	Stdev	Skewness	Kurtosis	Jarque–Bera	Probability
lnGDP	8.4236	4.7661	10.8573	1.2190	−0.6253	3.2106	35.31	0
lnR	11.0590	4.3962	10.7915	1.8891	−1.1696	4.6522	180.1	0
lnK	8.8588	5.3042	11.3474	1.1571	−0.4302	3.0846	16.41	0
lnL	6.8965	3.5026	8.5998	0.9832	−0.8516	3.5401	70.11	0
lnH	8.4923	3.6938	8.5691	1.0018	−1.0450	3.8580	112.1	0
lnI	8.7452	5.1051	10.0951	1.2409	−1.3240	9.7327	1149	0

these six variables are skewed and have fatter tails due to the positive kurtosis values. In addition, the Jarque–Bera tests show that the unconditional distribution of variables is non-normal. Figure 1 visualizes the general trends of the impacts of the GGP, physical capital, labor force and human capital and the increase in cultivated land variables on economic growth in different provinces and autonomous regions. The links between the effect factors and the GDP, which includes numerous linear and nonlinear relationships, were described. Therefore, adoption of the quantile regression technique to estimate the impact of the GGP on economic growth is reasonable.

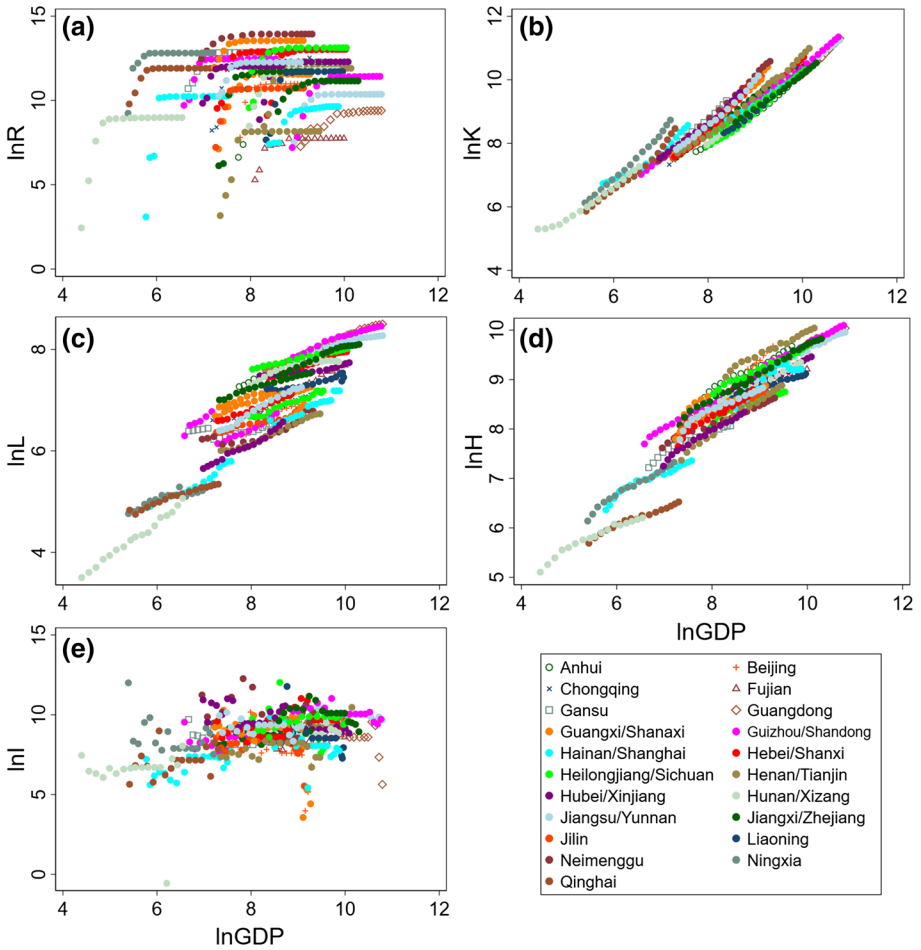
Before conducting a rigorous empirical study with the panel quantile regression model, root tests of the panel unit were employed to test the stationarity of the variables considered in the study. Therefore, we first performed unit root tests of the panel data with common unit roots, including Levine–Lin–Chu (LLC) and Breitung tests, and different roots, including Fisher-ADF and Im–Pesaran–Skin (IPS) tests. The results of the unit root tests are presented in Table 3, which indicates that the null hypothesis of the existence of a unit root could be rejected for all variables at the 5% significance level. Therefore, we can conclude that all the variables are stationary and the selected level will be applied in the following empirical analysis.

## 2.2 Panel quantile regression model

Considering that traditional regression techniques focus on the mean effects, which may cause under- or over-estimation of the relevant coefficients or hide some important features of underlying relationships (Bassett and Koenker 1978), a quantile regression technique was employed to obtain a complete assessment of the effects of the GGP on economic growth for different economic levels (Agovino et al. 2018). Quantile regression models allow researchers to explain unobserved heterogeneous covariates effects (Canay 2011), while panel data enable a reasonable effect on special heterogeneities indicated by non-observables and region-specific and time-invariant intercepts. The intersection of these two factors could help us explore the relationship among variables more comprehensively and determine whether the estimation results are more effective than the ordinary least squares (OLS) regression and are robust to observations of the explained variable (Zhu et al. 2016).

The panel quantile regression model is expressed as follows:

$$Q_{y_{it}}(\tau_k | \alpha_i, x_{it}) = \alpha_i + x'_{it} \beta(\tau_k) \quad (1)$$



**Fig. 1** Scatter plots of the links between GDP and **a** GGP, **b** physical capital, **c** labor force, **d** human capital, and **e** increase in cultivated land

**Table 3** Panel unit root tests

Variable	lnGDP	lnR	lnK	lnL	lnH	lnI
LLC	-17.430***	-240.000***	-13.6132***	-10.1598***	-10.6224***	-8.7956***
Breitung	-8.0474***	-1.7400**	-7.9444***	-1.7905**	-2.7600**	-4.5494***
IPS	-7.3574***	-190.000***	-3.1087***	-2.3538***	-3.3079***	-7.0955***
Fisher-ADF	220.122***	1552.519***	167.752***	132.389***	115.475***	230.217***

\*, \*\*, \*\*\* denote that the significant at 10%, 5% and 1%, respectively

The variable of fixed effect ( $\alpha_i$ ) was estimated using the method proposed by Koenker (2004) to address the inclusion of a considerable variable of fixed effect, which was subject to the incidental parameters (Lancaster 2000).

Furthermore, the conditional quantiles function for quantile  $\tau$  was built based on the specifications of previous studies (Chen and Lei 2018) as

$$\ln Q_{yit}(\tau_k | \alpha_i, \varepsilon_t, x_{it}) = \alpha_i + \varepsilon_t + \beta_{1\tau} \ln k_{it} + \beta_{2\tau} \ln L_{it} + \beta_{3\tau} \ln H_{it} + \beta_{4\tau} \ln R_{it} + \beta_{5\tau} \ln I_{it} \tag{2}$$

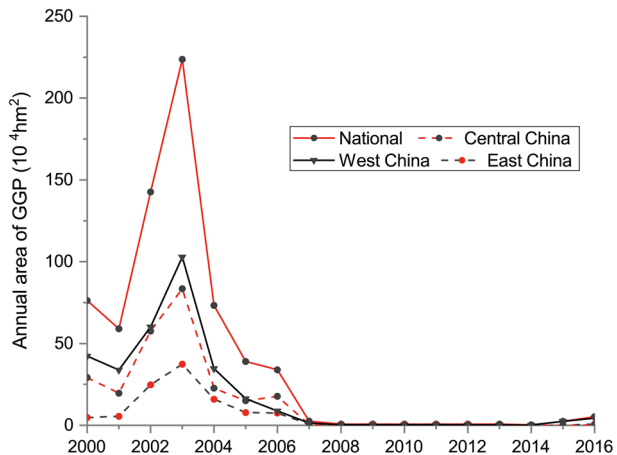
where  $Q_{yit}$  is the GDP, which indicates the economic growth in province  $i$  at period  $t$ ;  $K_{it}$  is the physical capital in province  $i$  at period  $t$ ;  $L_{it}$  is the labor force in province  $i$  at period  $t$ ;  $H_{it}$  is the human capital in province  $i$  at period  $t$ ;  $R_{it}$  is the GGP area in province  $i$  at period  $t$ ; and  $I_{it}$  is the increase in cultivated land in province  $i$  at period  $t$ .  $\beta_{1\tau}$ ,  $\beta_{2\tau}$ ,  $\beta_{3\tau}$ ,  $\beta_{4\tau}$ , and  $\beta_{5\tau}$  are the elastic coefficients of  $K_{it}$ ,  $L_{it}$ ,  $H_{it}$ ,  $R_{it}$ , and  $I_{it}$ , respectively, for the given quantile conditions.

### 3 Results

#### 3.1 Temporal changes and regional differences in the Grain for Green program

The Grain for Green Program, which was officially proposed by *Several Opinions on Further Improving the Pilot Project of Grain for Green* in 2000, caused the large-scale ecological restoration for forests, grassland and lakes, particularly in the western and central regions. Figure 2 shows the changing trends of cultivated land converted to forests, grassland and lakes by the GGP in China and different regions from 2000 to 2016. Significant temporal differences were observed from 2000 to 2016 with similar changing trends in different regions. The area of ecological restoration increased from 2000 to 2008, with the peak of cultivated land converted to forests, grassland and lakes by the implementation of the GGP from 2000 to 2004 in China and different regions. The growth in the area of ecological restoration began to decline after 2004 and stopped increasing between 2007 and 2015, and increased slightly after a new round of the GGP was implemented in 2015. The conversion area accounted for 64% of the total reduction in cultivated land before 2004, according to a study by Wang et al. (2018). In the same period, China’s cultivated land protection policy gradually changed from lenient to strict, and a strict cultivated land protection system was formed in response to a sharp

**Fig. 2** Changing areas of cultivated land converted to forests, grassland and lakes by the GGP in China from 2000 to 2016





decrease in the area of cultivated land and total output of grain caused by the GGP and increase in construction land. Therefore, the annual area of returning cultivated land restored to forests, grassland and lakes under the GGP had begun to decrease, and eventually the GGP stagnated in 2007. The implementation of the GGP and protection of cultivated land are mutually influential with long-term equilibrium between the cultivated land quantity and China's economic development (Chen and Long 2007). In 2015, a new round of the GGP was restarted as the cultivated land protection was gradually balanced.

Figure 3 describes the total area of cultivated land that was converted to forests, grassland and lakes under the GGP by province in the 2000–2016 period, which varied from 0.23 to 113.00 ten thousand ha in different regions. The area of cultivated land that was converted to forests, grassland and lakes by the GGP was concentrated in most provinces in central and western China, such as the Inner Mongolia Autonomous Region and Shaanxi province, whereas the regions with fewer areas were concentrated in the eastern region, such as Fujian, Tianjin, Guangdong, Shanghai, Hainan, Jiangsu, Beijing and Zhejiang provinces. These findings may be attributed to the notion that the eco-environment of the western and central regions is more fragile than that of the eastern region, and the central and western regions have more poverty-stricken areas. Lucid waters and lush mountains are invaluable assets, and the existence of human race and social economy depends on the eco-environment (Sinha Babu and Datta 2014). Areas with the advantage of natural resource endowment tend to have better economic conditions, and their economic development is often more sustainable.



**Fig. 3** Total areas of cultivated land converted to forests, grassland and lakes by the GGP in provinces from 2000 to 2016

### 3.2 Effects of the *Grain for Green* program on national economic growth

Table 4 lists the OLS and panel quantile regression results, including the estimation results by the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th and 90th quantiles using the investigated quantile regression models. The GGP had a slight negative impact on China's economic growth. At the 10th quantile, the elastic coefficient of the GGP was  $-0.0169$ . As the economic growth increased, the negative impact of the GGP on economic growth continuously increased. Until the 50th quantile, which implied a GDP between 390 and 530 billion yuan, the negative impact of the GGP on economic growth reached the highest level by  $-0.0504$ , after which it began to decrease. In China, the temporal differences in different provinces to achieve the economic goals of GDP exceeded 390 billion yuan. Fujian, Beijing, Shandong, Hebei and Shanghai in the eastern region had achieved their economic goals before 2005, while most of the western and central provinces achieved this goal after 2008. At the 90th quantile, the GGP area increased by 1 unit, and the level of economic growth decreased by 0.0214 units. If the area of the GGP increases by one ha, the GDP will decrease by 248 yuan for a GDP greater than 1273 billion yuan (at the 90th quantile) and will decrease by 504 yuan at a GDP between 390 and 530 billion yuan. Most provinces in the eastern region had achieved this level before 2016, while other regions lagged.

As shown in Fig. 4, the changing trend of each variable in the panel quantile regression model and the economic effect of each variable changed with an increase in economic growth. The impact of the GGP on economic growth, which shows a U-shape, decreased with economic growth and then gradually increased after the economy reached an appropriate level of economic growth. This finding implied that the GGP has different effects on economic growth at different economic levels, and the negative impact in the central and western regions could last for a longer time than in the eastern region. According to its U-shaped changing trend, the negative impact would gradually decrease in the eastern region with rapid economic growth and may even exhibit a positive impact if an appropriate degree of economic growth occurs. The fixed capital has a major role in promoting economic growth and a relatively stable impact on economic growth. The contribution of human capital and labor factor to economic growth fluctuated with the economic development. However, the change in human capital increased, and the labor factor declined. The increase in cultivated land has minimal impact on economic growth, and the coefficients were only significant near the 10th and 70th–90th quantile of the distribution. Further discussion of other variables was omitted in this paper because our focus is the regression results of the GGP.

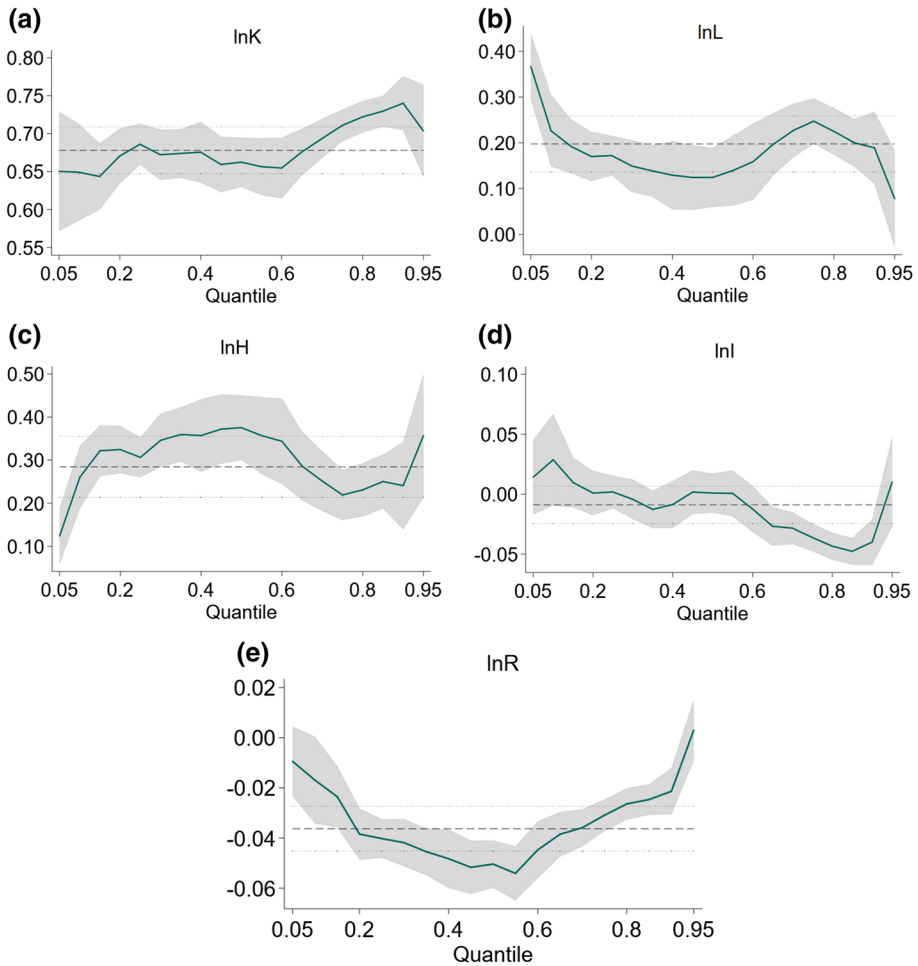
### 3.3 Regional differences in effects of the *Grain for Green* program on economic growth

Table 5 describes the results of the fixed-effect regression for eastern, central and western China. The results indicated the regional heterogeneities in the impacts of the GGP on the economic growth in the three regions. The determination coefficient  $R^2$  of the models in each region was relatively large—greater than 0.9—and the negative elastic coefficients of the GGP were relatively low, which indicates that the GGP had a slight negative effect on the regional economic growth. The negative impact in central China was more pronounced than that in other regions because the central region was in a period of rapid economic development and the land element provided important support for undertaking the industry

**Table 4** Elasticity coefficients of the GGP, physical capital, labor force, human capital and increase in cultivated land variables using panel quantile regression estimates in China

Independent variables	Quantile								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	-0.882*** (-9.82)	-1.164*** (-9.96)	-1.096*** (-12.34)	-0.934*** (-8.27)	-0.950*** (-7.29)	-0.739*** (-5.37)	-0.669*** (-6.08)	-0.665*** (-8.31)	-0.693*** (-3.21)
lnR	-0.0363*** (-8.00)	-0.0384*** (-6.51)	-0.0418*** (-9.33)	-0.0483*** (-8.46)	-0.0504*** (-7.66)	-0.0447*** (-6.44)	-0.0359*** (-6.46)	-0.0264*** (-6.53)	-0.0214* (-1.96)
lnK	0.678*** (43.26)	0.649*** (20.20)	0.672*** (43.38)	0.676*** (34.27)	0.662*** (29.15)	0.655*** (27.28)	0.694*** (36.17)	0.722*** (51.76)	0.740*** (19.67)
lnL	0.198*** (6.33)	0.170*** (4.19)	0.149*** (4.84)	0.129*** (3.30)	0.124*** (2.75)	0.159*** (3.33)	0.227*** (5.95)	0.225*** (8.10)	0.189** (2.52)
lnH	0.284*** (7.87)	0.260*** (3.51)	0.346*** (9.69)	0.357*** (7.86)	0.375*** (7.17)	0.344*** (6.21)	0.251*** (5.68)	0.231*** (7.18)	0.241*** (2.77)
lnI	-0.00892 (-1.13)	0.000928 (0.09)	-0.00438 (-12.34)	-0.00859 (-8.27)	0.000943 (-7.29)	-0.0123 (-5.37)	-0.0284*** (-6.08)	-0.0434*** (-8.31)	-0.0400** (-3.21)

\*, \*\*, and \*\*\* denote that the significance at 10%, 5% and 1%, respectively. The figures in parentheses are t statistics



**Fig. 4** Changing elasticity coefficients of **a** physical capital, **b** labor force, **c** human capital, **d** the increase in cultivated land, and **e** the GGP at different quantiles in panel quantile regression model. The horizontal black line represents the OLS estimates, and the gray “shadow” represents the 95% confidence intervals

of the eastern region (Wang and Gu 2015). For example, a decrease in the area of the GGP by one-ha could decrease the GDP by approximately 719 yuan. This result was consistent with the analysis in Sect. 3.2. Moreover, the economy of the western region remains at a low level, and the negative impact of the GGP in the region has not reached its maximum.

Based on Table 5, we also determined that the elastic coefficients of physical capital and human capital were significantly higher than those of labor force by 0.01 at the significance level. This finding indicated that the physical capital and human capital are the main source of economic growth and implied that the effect of human capital on economic growth was much greater than that of labor input. With economic development, the influence of the labor force number on economic growth was gradually weakening, and the human capital was becoming even more important to China’s economic growth (Li and Xia 2013), especially in the eastern region. This result could be attributed to the notion that the contributions of technological advances, capital, and other factors have surpassed the role of the

**Table 5** Coefficient of elasticity of the GDP, physical capital, labor force, human capital and increase in cultivated land using fixed-effect regression estimates in different regions

Region	lnK	lnL	lnH	lnR	lnI	R <sup>2</sup>	F-statistic
National scale	0.6229*** (0.024)	0.2617*** (0.036)	0.2549*** (0.032)	-0.0571*** (0.006)	0.0081 (0.009)	0.9734	3693.02
East China	0.4802*** (0.052)	0.1587** (0.061)	0.4755*** (0.057)	-0.0369*** (0.009)	0.0340** (0.016)	0.9656	1115.50
Central China	0.5521*** (0.043)	0.8325*** (0.084)	0.2322*** (0.101)	-0.0718*** (0.018)	0.0173 (0.015)	0.9000	205.25
West China	0.6904*** (0.055)	0.4394*** (0.048)	0.0177 (0.052)	-0.0690*** (0.012)	0.0092 (0.013)	0.9838	1803.16

\*, \*\*, and \*\*\* denote the significance at 10%, 5% and 1%, respectively. The figures in parentheses are standard errors

labor force on the regional economic growth. The physical capital and human capital have an essential role in the economic development of different regions. The low investment in human capital and extensive utilization of physical capital were the main reasons for the slow economic development in the western region. Consistent with the results of Sect. 3.2, the impact of increasing the amount of cultivated land on economic growth was not obvious. Because the quality of the cultivated land in eastern China was significantly higher than that of other regions, the increase in cultivated land had a more significant impact than that in other regions. Compared with other regions, the increase in cultivated land had no significant impact on economic growth due to a large area of cultivated land with low quality in western China.

## 4 Discussion

In the last few decades, the effects of the GGP on ecological restoration and ecosystem health in China have been positive, and the effects on water resources conservation and water quality have made a strong positive contribution to SDG 6 (Clean water and sanitation) (Bryan et al. 2018). The achievement of economic benefits during implementation is one of the major goals of the GGP. According to the results of our study, the GGP had a slight negative impact on the current economic growth in China; the negative impact changed with an increase in economic growth; the negative impact of the GGP on economic growth in the eastern region reached the right side of the U-shaped curve; and the western region remains on the left side of the U-shaped curve.

The changing trends of the relationship between the GGP and economic development is consistent with the environmental Kuznets curve (EKC) hypothesis. Kaika and Zervas (2013) concluded that the equity of income distribution, structural change and technical progress, institutional framework and governance, consumers' preferences etc. are the major driving forces of the EKC. The possible causes of the negative effect of the GGP on economic growth in China is somewhat similar to the EKC relationship. In the current situation in China, a substantial economic imbalance between the east and the west and the industrial structure and production techniques, especially in the western region, are incomplete and backward. The greatest threat to the future in China includes social divisions caused by uneven economic development (Zhou 2010). The low investment in human capital and extensive utilization of physical capital caused the slow economic development in the western region. The GGP could serve as a stimulus measure that encouraged the transformation of farmer households in non-agricultural industries (Zhang et al. 2018). The development of follow-up industries in most of the GGP villages was constrained by the industrial structure, technical progress and farmers' self-development abilities, such as the poor participation in the labor market, weak ability to respond to market changes (Liu 2018), and low investment in human capital, which were significant factors that affect farmers' attitudes toward the GGP (Neycheva 2013). The farmers in the central and western areas have a greater awareness of traditional petty peasant ideology and regard cultivated land as the only source of survival. Therefore, many farmers will not be willing to implement the GGP if it hinders their economic benefits, and ecological restoration interventions may risk reconversion as farmers return to farming to supplement incomes when payments cease. Moreover, the GGP created financial burdens for numerous local governments due to a loss of tax revenues (Xu et al. 2006). Therefore, to some extent, in the presence of

China's current circumstance, the slight negative impact of the GGP on economic growth might be reasonable.

The ecological and economic impacts of the coupling between humans and nature may not appear immediately because of time lags in their effects (Huang et al. 2012). Although its current impact on economic growth is negative, the changing trend of the GGP indicated that its impact is likely to become positive. Economic growth and ecological preservation are probable if the productivity effect is significant enough to more than offset the crowding out effect (Ansuategi and Marsiglio 2017). The dynamic effects of technological change and a changing economic structure could increase the output by increasing productivity (Aldieri et al. 2019b). With a change in the industrial structure and technical progress, the high tendency of citizens to demand a clean environment and the improvement in education level, the negative impact may gradually disappear; thus, the poverty–environmental degradation trap may be avoided and economic growth thereby improved. With improvement in the implementation of the GGP and economic growth, the GGP will probably contribute toward SDG 2 (Zero hunger) and SDG 1 (No poverty). This analysis is significant for a rapid quantitative analysis on the effect of the GGP on economic growth for policy-making from a national and local viewpoint.

Noting that this analysis of the effects of the GGP on macroeconomics indicated only the relative trends, enabled rapid interpretation of the macroeconomic impacts of the GGP from the contribution of physical capital, labor force and human capital using inter-provincial panel data for 31 provinces. The analysis was less time consuming than numerous socioeconomic surveys and questionnaire investigations, which could be significant for rapid analysis of the effects of the GGP and PES programs on economic growth for policy-making from a national and local viewpoint. The impacts of the PES programs will be greater in the future as ecosystems recover and continue (Liu et al. 2008). Therefore, an exploration of whether further impact of the GGP and PES on economic growth is positive when the economic output reaches a higher level will be explored in future research. Nevertheless, some issues need to be identified. Considering the lack of data for areas of the ecological restoration of cultivated land to forests and grassland in each county and city in China, each province as an analysis unit was chosen and inter-provincial panel data for 31 provinces were employed for the analysis in this study. Because some scale variances or geographical differences were observed among different counties in one province, our analysis may lose some detail and targeted information. The implementation of the GGP in different counties may have negative (Cao et al. 2009) or positive (Peng et al. 2007) effects on farmers' income and economic growth. Therefore, further studies should be carried out to explore the relationship between the GGP and the economic growth on county and township scales. To ensure a more scientific and rational analysis, the economic theory and research methods in the study need to be continuously enriched, and the theoretical knowledge of other related disciplines should be gradually supplemented and improved.

## 5 Conclusions and suggestions

For Chinese ecological civilization construction and social-economic development with high quality, increasing investment in human capital, promoting the upgrading and transformation of agricultural structure and off-farm employment are significant for the GGP, which could also promote the upgrading of industrial structure and economic growth. The study results indicated that the areas of the *Grain for Green* program in most provinces in

central and western China were larger than those in the eastern developed regions, which varied from 0.23 to 113.00 ten thousand ha in different provinces from 2000 to 2016. The results of the panel quantile regression reveal that the GGP had a slight negative impact on China's national economic growth in the current situation in China, and the negative impact changed with an increase in economic growth. Until the 50th quantile, which implied the GDP from 390 to 530 billion yuan, the negative impact of the GGP began to decrease. A U-shaped curve expressed their relationship. With an increase in the economic growth, the physical capital has been the main driving force of economic growth, and the contribution of the labor force factors was gradually surpassed by human capital and science and technology. According to the results of fixed-effect regression for eastern, central and western China, significant regional heterogeneities were identified in the economic impacts of the GGP. The negative impact of the GGP on economic growth in the central region was more pronounced than that in other regions, while the eastern region has reached the right side of the U-shaped curve and the western region remains on the left side. The negative impact in the central and western regions could last for a longer time than in the eastern region due to the substantial imbalance in China's economic development. Moreover, the low investment in human capital and extensive utilization of physical capital were the main reasons for the slow economic development in the western region. Adjusting the industrial structure, increasing the investment in education and solving the uneven development are important for realizing the economic development and effective implementation of the GGP in the western region.

Long-term durability of the GGP should be enhanced by better planning to minimize trade-offs and capture win-win environmental and economic opportunities. To achieve effective implementation of the *Grain for Green* program and promoting economic growth, policy makers could support employment by developing the follow-up industries that conform to regional characteristics and appropriately extending the subsidy period in the western and central regions. In the long term, the adjustment of industrial structure and focus on human capital has significance to achieving a synergy between ecological protection and economic growth, taking into account the different levels of economic development and improving the sources of economic growth in the central and eastern regions.

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