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Original Paper

Effects of green energy development on population growth and employment: Evidence from shale gas exploitation in Chongqing, China

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A B S T R A C T

With the maturity of horizontal drilling and hydraulic fracturing technologies, countries rich in shale gas have begun to promote the development of the shale gas industry. The impact of the booming shale gas industry on the regional economy has also become a main focus. Shale gas' exploration and extraction may have positive spillover effects on other sectors, resulting in population growth and job creation. However, negative spillover effects can occur through rising local goods prices and its adverse effects on the local quality of life, which in turn could harm population growth and employment. By using the synthetic control method, we investigates the shale gas fields in Chongqing to reveal the relationship between population growth, employment and shale gas development in Fuling, Nanchuan and Wulong districts. Our results indicate that due to the development of the shale gas industry, the number of urban non-private sector employees in three districts and counties has decreased. From 2017 to 2018, this decline had gradually weakened and the population growth had been negatively affected.

1. Introduction

Shale gas, known as an efficient clean green energy, refers to unconventional natural gas that is trapped within shale formations (Ma et al. 2017). Natural gas produces less carbon dioxide emissions than coal and oil. Developing shale gas would reduce greenhouse gas emissions (Xie et al., 2021). According to the National Bureau of Statistics of China (2020), China's annual energy consumption in 2019 totaled 4.86 billion tons of coal, of which coal consumption accounted for 57.7%. The thermal efficiency of coal is between 40% and 60%, and the thermal efficiency of natural gas is higher than 75%. Therefore, Shale gas development can increase the proportion of natural gas in China's energy structure, thereby improving energy efficiency.

Shale gas, with the penetrability less than 1μD (micro-Darcy), can be extracted through horizontal drilling and staged fracturing (Zhang et al. 2019). These extraction technologies have created an expansion of production in China (Sun et al., 2021). The U.S. shale gas revolution had transformed its energy structure. The U.S. Energy Information Administration (EIA) indicated that shale gas production had a high growth rate of over 35% between 2008 and 2011. The shale gas production increased from 1.99 Trillion Cubic Feet (Tcf) in 2007 to 19 Tcf in 2017, with an annual growth rate of 25.32%, accounting for 8.07% of the country's total natural gas production in 2007 to 57.01% in 2017. Shale gas development has eased energy pressures in the U.S. The revolution has increased global gas supplies and transformed the U.S. from a gas importer to an exporter (Wang and Jiang, 2019).

Meanwhile, as China's external dependence on natural gas continues to improve, the contradiction between supply and demand is highlighted. According to the National Development and Reform Commission's data, in 2017, China's natural gas consumption reached 237.3 billion cubic meters and natural gas production totaled 148 billion cubic meters, with a year-on-year growth rate of 15.3% and 6.9%, respectively. Therefore, the external dependence hit 39% in 2017. According to the BP Energy Outlook, China's share of natural gas consumption will double by 2035 and will exceed

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400 billion cubic meters each year.

Considering the escalating trade frictions between China and the U.S., China calls for increasing domestic shale gas development. China highlights the shale gas development for its low proportion in natural gas production, which is only 6.05% in 2017. On September 30, 2016, the National Energy Administration released the Shale Gas Development Plan (2016–2020), positioning shale gas as a major clean energy industry. China planned to achieve 30 billion cubic meters of shale gas production by 2020 and 80 to 100 billion cubic meters of shale gas production by 2030. Thus, the annual growth rate of shale gas production from 2018 to 2020 and from 2020 to 2030 should be 48.8% and 10.3%, respectively.

China has abundant shale gas resources, mostly distributed in the southwest region. Chongqing pioneers the shale gas exploration of China. Key shale gas fields are located in Fuling, Yongchuan, Fushun and Qianjiang districts. The Fuling shale gas field is the largest in China (Liu et al., 2019; Li et al. 2020). Considering the Fuling Jiaoshiba shale gas development project, the first-stage project of reaching an annual production capacity of 5 billion cubic meters was completed. Sinopec leads the exploration of the Fuling shale gas field. As of December 31, 2018, the Fuling shale gas field ranked the first in China with an annual production of 6.02 billion cubic meters' shale gas.

Energy exploration would increase employment in the energy sector, but little is known about the impact on other sectors of the local economies. The positive spillover effect on other sectors could result in population growth and job creation, but it may also lead to higher local wage prices and harm the environment, which in turn may negatively affect the population growth and employment.

The paper is organized as follows. After the introduction, Section two provides a review of related studies and motivations. Section three introduces the empirical approach. Section four presents the empirical analysis based on the Synthetic control method. Section five includes the conclusions with several implications.

2. Theoretical background

Exploration and extraction of shale gas are associated with a direct increase in employment and income in an area. Theoretical studies on the relationship between shale gas extraction and population growth find evidence for some potential risks. For example, the extraction of shale gas has adverse effects on the local ecological environment and the quality of life of the residents, including contamination of groundwater, waste of water, spills of the chemical, reduction in air quality, increase of noise and earthquake (Rahm, 2011; Sun, 2020; Huangfu et al., 2020). These risks may further affect agriculture and tourism, leading to population migration (Lipscomb et al., 2012; Wang et al., 2021). In China, the shale gas fields, like the Fuling shale gas field, feature deep-buried depth and low permeability of shale gas. The shale gas development may bring about the destruction of cultivated land and vegetation, water pollution, noise pollution and air pollution, which have negative impacts on the local quality of life (Hu et al., 2018; Zhen et al. 2020; Munasib and Rickman, 2015).

Evidence of the adverse economic effects of shale gas extraction can be found in housing values near shale gas producing sites. By using contingent valuation surveys in Texas and Florida, a reduction in value of houses located proximate to fracking scenarios, also referred to as "fracking" sites, was found, thus proving that the shale gas extraction would affect human settlements (Throupe et al., 2013). However, the effects depend on the intensity of shale gas extraction activities, with a greater negative impact on households that are close to highways and dependent on groundwater (Gopalakrishnan and Klaiber, 2014).

Studies on the relationship between the exploration and extraction of shale gas and employment have provided support for positive employment effects (IHS,2013; Li et al. 2020). During the shale boom period, employment in both boom counties and non-boom counties was higher than expected (Lee, 2015). Using data from 2001 to 2011, it is estimated that shale gas-related activities have generated employment opportunities in Texas, with between 25,000 and 125,000 new jobs added in Texas in 2011 alone (Paredes et al., 2015). However, estimates of the employment impact may vary depending on the different estimation approaches and measurements. Specifically, the ordinary least squares estimates are larger than that of the case in which an instrument variable is used (Weber, 2012). In addition, the positive employment effects are greater in the early stage of the shale boom, which seems to wane over time, usually short-lived (Komarek, 2016).

A "resource curse" has been documented in the literature on the effects of energy extraction in different sectors. The extraction of the natural resource may negatively affect other economic sectors, causing damage to the local employment (Corden and Neary, 1982). In the case of a fixed labor force, increased economic activity in the tradable energy sector leads to an increase in demand for labor and wage. As local incomes rise, so do the prices of local non-traded goods. Employment in tradable sectors, such as manufacturing, has also been affected by higher wages, which have reduced the profits of local businesses. This effect, also known as the "Dutch disease", refers to the negative economic impact of the development of natural gas discoveries in the Netherlands in 1960s.

Some literature investigates the long-term spillover effects of energy extraction on other industrial sectors to determine whether there is a "resource curse" or "Dutch disease". On the one hand, some studies have found no resource curse, and changes in employment growth in manufacturing are not significant, or have a small impact (Marchand, 2012). The employment in the tradable sector has increased more than that in the non-tradable sector (Weinstein, 2014). On the other hand, evidence has been found for the resource curse, with 1.8 jobs lost in the agricultural sector for every additional job in Australia's coal-mining industry (Fleming and Measham, 2015). The operation of the Peruvian gold mine has increased real income in and around the city but the price of housing and locally produced food has risen (Aragon and Rud, 2013).

In China, most studies on the economic effects of shale gas development focus on the following aspects: the existing situation of shale gas development policy in China and the United States, the problems and challenges facing the commercialization of shale gas in China and analysis on the social and environmental benefits of shale gas development (Wang and Jiang, 2019). However, there is little literature on the impact of the shale gas industry on the local economy.

This paper, first, chooses Chongqing Fuling shale gas field featuring rapid shale gas industry development as sample for several reasons. Fuling shale gas field covers the Fuling District, Nanchuan District and Wulong District. In these districts, the extraction of other fossil fuels remained limited before the shale gas extraction. In addition, the districts do not belong to the metropolitan area. Hence, compared with a metropolis, shale gas accounting for a larger proportion of the energy sector, these districts make it easier to measure the treatment effect. Second, the synthetic control method (SCM) is used to construct their corresponding counterfactual control groups in three districts. The influence of shale gas industry on local population and employment is evaluated by comparing the differences between the two groups after the intervention. Then the robustness checks have been conducted. An advantage of SCM is the transparency in constructing the counterfactual. In SCM, no single match with all the comparable characteristics to the shale gas is required as it is in case studies or some matching approaches. The pre- and post-treatment trends that are not related to shale gas extraction have been controlled for.

3. Empirical method

In the study, the Synthetic Control Method is adopted to estimate the counterfactual of the districts in treatment group. Synthetic control method is to evaluate the effect of a policy or event. Instead of seeking a realistic control group to match with the treatment group, SCM aims to construct a counterfactual that can be referred to as a weighted average of the available control units, based on various economic characteristics (predictor variables), by putting weight on each potential control units. It displays the same trend as the treatment group before the intervention of a policy or event. After the policy or event intervention, the difference between the treatment group and the synthetic control group measures the impact (Zhang et al. 2019). The analysis therefore focuses on how to get a synthetic control group that is similar to the treatment group before the intervention, i.e. the most eligible treatment group weights are sought through observable economic characteristics (Lee, 2015).

SCM can avoid subjectivity in selecting control groups. Compared with the Difference-in-Difference (DID) that assumes the same time trend for all units, the SCM allows each unit to react differently to a shock, i.e. different units can have different time trends. Because there is a long enough period before intervention, the matching of pre-intervention observable characteristics and the results of SCM can match the non-observable characteristics that change over time. Since the mathematical derivation of SCM is in previous literature (Abadie et al., 2010), we focus on its application.

When selecting potential control units to construct a synthetic control group, we exclude other samples that are also affected by the same event. Samples that are subject to significant special shocks during treatment period should be excluded from potential control groups. The samples that make up the synthetic control group should be similar to the treatment groups in terms of various economic characteristics. The longer the time before the intervention of policy or event, the better, and if the period is short, the fits is not good enough to be compared.

A placebo test is performed on each district. It is assumed that each district that constitutes the control group is also affected by shale gas extraction. Other districts, including treatment group under the real influence of shale gas extraction, together form the new control group. Assuming that other conditions are the same, since the districts in the synthetic control group are not affected by the shale gas extraction, the population, employment and income of the districts are expected to be smaller than that of the treatment group. The higher ranking of the placebo effect in the treatment group is, compared with that in other districts, the more significant the placebo effect is.

4. Empirical analysis

4.1. Data

4.1.1. Variables

Data. The data are from the Chongqing Statistical Yearbook from 2007 to 2018. Therefore, the data of 2012, when the exploration and extraction of the Fuling shale gas field began in Chongqing, is included.

Outcome variables. There are two outcome variables, namely, the year-end total population (10,000 people), and the number of non-private sector employees in urban areas (10,000).

Predictor variables. Several variables are used as Predictor variables to construct the synthetic control for each group of shale gas districts, namely, natural growth rate (‰), urbanization rate (%), regional gross domestic product (10,000 RMB), the proportion of the primary industry (%), proportion of the secondary industry (%), mileage of graded highways (km), and the ratio of the number of urban residents with minimum subsistence allowances to the total population. The number of social service agencies providing accommodation services, the number of beds in social welfare institutes, the ratio of ordinary secondary school students to the total population (%), the ratio of primary school students to the total population (%), and the number of health agencies. Among them, population-related variables are measured as ratios to avoid issues associated with differences in sizes of city economies.

4.1.2. Sample

Considering that the Fuling shale gas field is located in Fuling District, Nanchuan District and Wulong District, these three districts are selected as treatment groups. Potential control groups are selected in Chongqing's districts, excluding the three districts. Among them, because the urbanization rate of Yuzhong District, Dadukou District, Jiangbei District, Shapingba District, Jiulongpo District, Nanan District, Beibei District, Yubei District and Banan District is generally more than 80%, it can be speculated that these districts belong to the metropolitan area of Chongqing. Moreover, the energy sector accounts for a smaller proportion of the economy of these districts. To make the effect of synthetic control more significant, we take the other 26 districts as potential control groups instead of these districts (see Fig. 1).

4.2. Empirical results

This study ran the SCM twice, using the Stata package synth. First, including all 12 Predictor variables mentioned above, together with the 2007 outcome variable, the 2012 outcome variable, and the 2018 outcome variable, synthetic control was conducted in Fuling district, Nanchuan district and Wulong district respectively. By giving weights to the other 26 districts in Chongqing, we made Fuling District, Nanchuan district and Wulong District, which have not yet developed shale gas before 2012, as similar as possible to the control group obtained by SCM. Second, by comparing the estimators of the synthetic control group obtained from the first analysis with the real value of the treatment group, then omitting the Predictor variables with poor synthetic effect, we re-ran the SCM on the three treatment groups respectively. To offer a clear picture, the chart presented in this article shows the result of the second synthesis control.

Tables 1, 3 and 5 respectively shows the comparison of each Predictor variables for the treatment group and the synthetic control group. The results of the synthetic control can be found in Tables 2, 4 and 6, each of which contains the weights that the donor district non-metropolitan portions contribute to the construction of the synthetic control. Figs. 2, 4 and 6 plots the changes of outcome variables of the real and synthetic treatment group. Figs. 3, 5 and 7 show the results of robustness checks.

4.2.1. Fuling District

In Table 1, the comparison of the predictor variables between the synthetic control estimate and the actual values of the Fuling District can be found. Based on the results of the first SCM, the regional gross domestic product (10,000 RMB), the proportion of the secondary industry (%), the mileage of grade highways (km), the ratio of the number of urban residents with minimum subsistence allowances to the total population (%), and the social service institutions providing accommodation services were omitted. With the remaining 7 predictor variables, we performed the second SCM.

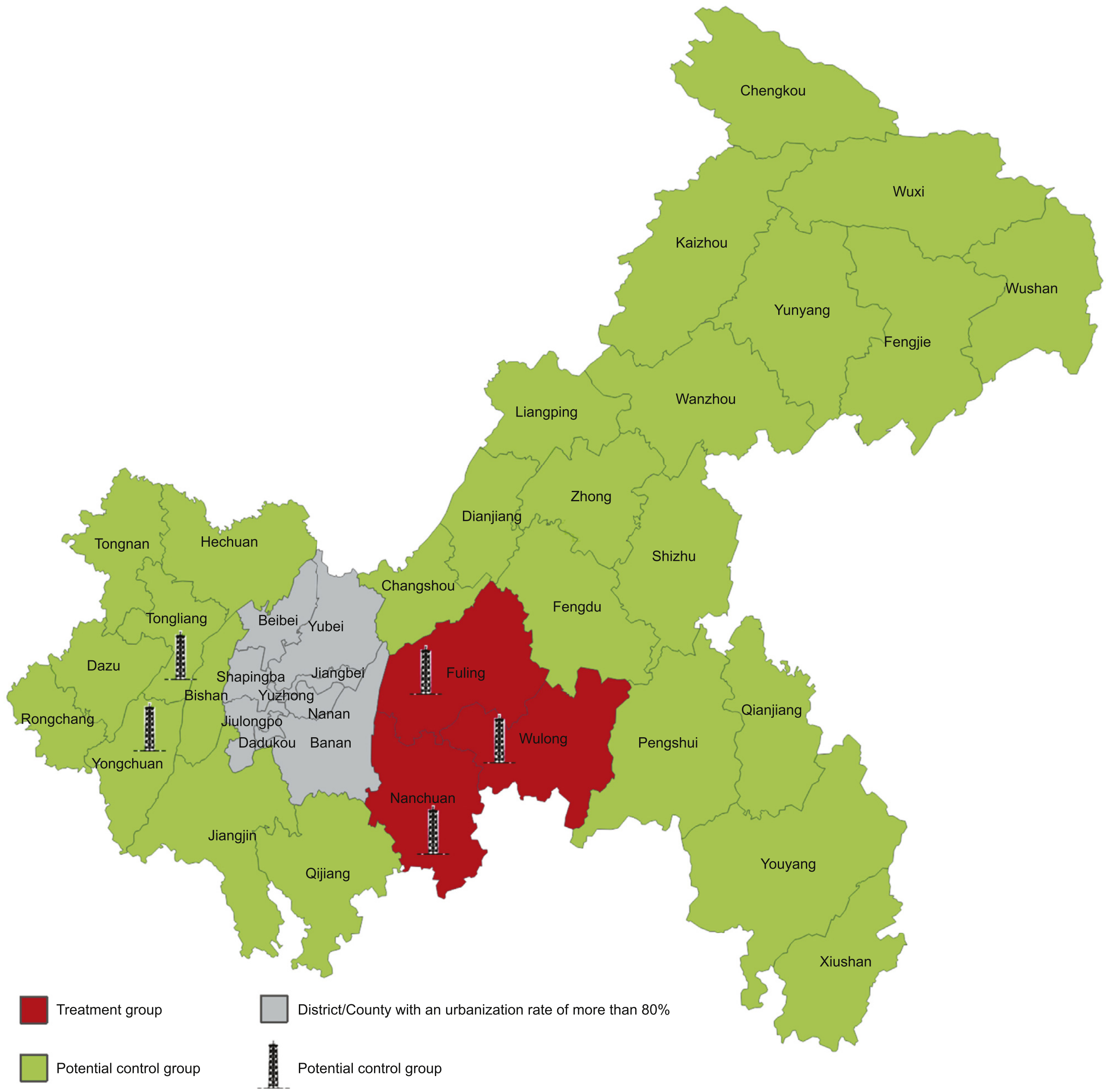


Fig. 1. Districts, countries and shale gas fields in Chongqing.

All 12 predictor variables are included to estimate the number of employees in urban non-private sectors. From Table 1, it can be found that the difference between the treatment group and the synthetic control group of each predictor variable is small, which indicates that the synthetic control produces a good fit for the real Fuling District.

According to Table 2, the districts and counties that contributed to the synthetic control of the year-end total population (10,000 people) in Fuling were Changshou District, Yongchuan District, Qijiang District, Dazu District, Wanzhou District, Kaizhou District and Qianjiang District, of which Yongchuan District contributed the most, with a weight of 0.315. The main contributors to the synthetic control for the number of employees (10,000) of non-private sectors in urban areas were Yongchuan and Wanzhou Districts, of which Wanzhou District had the largest weight, at 0.756. In Fig. 2, we can see the changing trend of outcome variables. Throupe et al., 2013 as the year of invention, the changing trend of the year-end total population and the number of non-private sector employees in synthetic Fuling District before 2012 is similar to that of real Fuling District. But since 2012, the solid line and the dashed line no longer coincide.

The real year-end total population began to show a fluctuating downward trend in 2012, while the synthetic year-end total population began to show a trend of fluctuating upward in 2012. In general, after the shale gas industry began to flourish, the total population of the real Fuling District fell compared with the synthetic Fuling District, with a wider gap between the two values. Therefore, shale gas development does not appear to have positively affected the local population growth but has inhibited the growth of the population. The results of robustness checks shown in Fig. 3 indicate that the gap between the actual value and the synthetic control estimate of Fuling District is greater than that of

Table 1
Comparison of predictor variables for Fuling district.

Predictor variable	The comparison of predictor variables for year-end total population, 10,000 people		The comparison of predictor variables for number of non-private sector employees in urban areas, 10,000	
	The treatment group	Synthesis control group	The treatment group	Synthesis control group
Natural growth rate, ‰	4.730833	5.694544	4.730833	3.437403
Urbanization rate, %	60.33	57.2238	60.33	59.32026
Regional Gross Domestic Product, 10,000 RMB	–	–	6168419	5940374
The proportion of the primary industry, %	452817.6	363669.9	452817.6	466195.6
The proportion of the secondary industry, %	–	–	3692303	2951916
Mileage of graded highways, km	–	–	3552.218	3835.338
The ratio of the number of urban residents with minimum subsistence allowances to the total population, %	–	–	22903.58	50090.27
Social service agencies providing accommodation services	–	–	35.75	91.59367
Number of beds in social welfare institutes	3064.167	3223.83	3064.167	6049.124
The ratio of ordinary secondary school students to the total population, %	61001.33	60796.83	61001.33	85456.4
The ratio of ordinary primary school students to the total population, %	66751.33	74398.82	66751.33	88053.71
Number of health agencies	493.5833	467.9657	493.5833	921.9527
Outcome variable (2007)	113.45	113.5286	10.18	9.748
Outcome variable (2012)	116.66	116.7401	15.85	16.61696
Outcome variable (2018)	115.13	117.691	15.04	15.6148

Table 2
Synthetic weights for Fuling district.

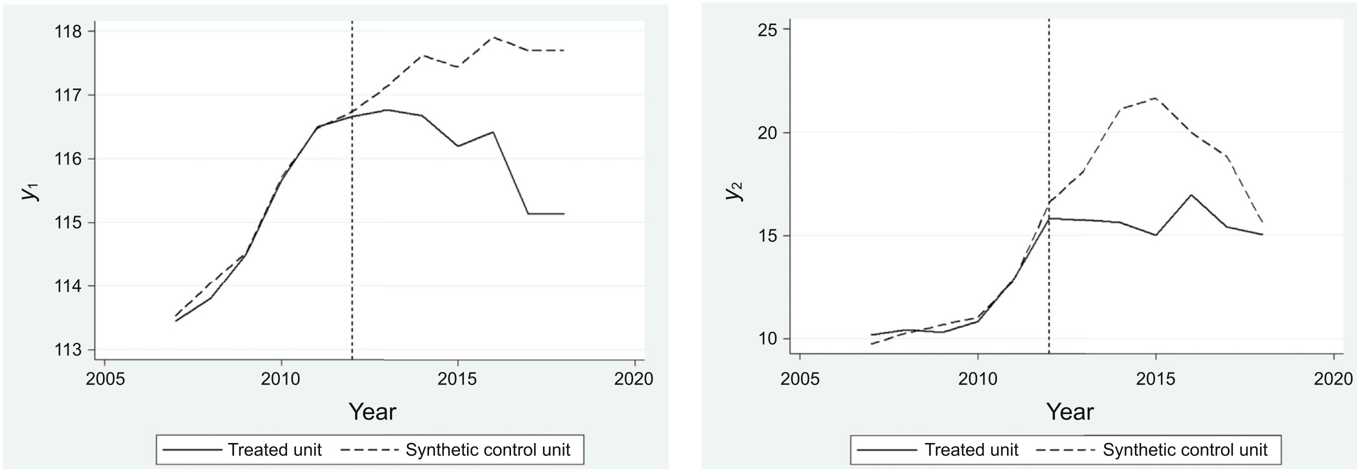
District	Synthetic weights for year-end total population, 10,000 people	Synthetic weights for number of non-private sector employees in urban areas, 10,000
Changshou District	0.043	0
Jiangjin District	0	0
Hechuan District	0	0
Yongchuan District	0.315	0.244
Qijiang District	0.124	0
Dazu District	0.085	0
Tongnan District	0	0
Tongliang District	0	0
Rongchang District	0	0
Bishan District	0	0
Wanzhou District	0.107	0.756
Liangping District	0	0
Kaizhou District	0.152	0
Qianjiang District	0.175	0
Chengkou County	0	0
Fengdu County	0	0
Dianjiang County	0	0
Zhong County	0	0
Yunyang County	0	0
Fengjie County	0	0
Wushan County	0	0
Wuxi County	0	0
Shizhu County	0	0
Xiushan County	0	0
Youyang County	0	0
Pengshui District	0	0

most of the districts, but the ranking is not high enough to prove the significance of the results.

The trend of change in the real number of non-private sector employees in urban areas since 2012 has been generally stable. However, the number of non-private sector employees obtained by SCM has increased first, falling to the level of 2012 since 2015, with synthetic control estimate getting close to the actual value. As shown in Fig. 2, it can be found that the development of the shale gas industry has not brought about an increase in the number of non-private sector employees in the urban areas of Fuling District. Moreover, the shale gas boom even negatively affects employment, and the negative impact seems to wane over time. Given the results of robustness checks, this negative impact is highly significant around 2015.

4.2.2. Nanchuan District

The comparison of predictor variables between the actual values and synthetic control of Nanchuan District can be found in Table 3. Taking all the 12 predictor variables into account, we estimate the year-end total population (10,000 people) and the number of employees in urban non-private sectors (10,000). In Table 3, there is a small difference of the predictor variables between the treatment group and synthesis control group for the two Outcome variables, with a certain implication that the synthetic control has produced a very good fit for the real Nanchuan District. In Table 4, the districts and counties that made up the synthetic control estimate of the year-end total population are Yongchuan District, Dazu District, Liangping District, and Chengkou County, of which the Chengkou County was the dominant contributor, with the weight of 0.464.



(a) Trend of year-end population

(b) Trend of non-private sector employees

Fig. 2. Trends of outcome variables for Fuling district.

(a) Rankings of year-end population

(b) Rankings of non-private sector employees

Fig. 3. Robustness checks for Fuling district.
Note: In Fig. 2–7, y1 is the Year-end total population (10,000 people) and y2 is the number of non-private sector employees in urban areas (10,000). The solid lines and dashed lines in the figure show the time trend of outcome variables of the real Fuling District and synthetic Fuling District. We identified 2012 as the year of intervention. In 2012, Sinopec made a breakthrough in exploration, drilling and extraction in the Fuling shale gas field area, and large-scale production has been fully up and running since then.

The districts and counties that contributed to the number of non-private employees (10,000) in synthetic control estimate were Changshou District, Dazu District, Tongnan District, Rongchang District, Chengkou County, Wuxi County, Shizhu County, of which Wuxi County's contribution to synthetic control reached a weight of 0.393, followed by Shizhu County, with a weight of 0.292.

Fig. 4 presents the changing trend of each Outcome variable in the real Nanchuan District and the synthetic Nanchuan District, with 2012 as the year of intervention. Throughout pre-intervention, the trend of the year-end total population and the number of urban non-private sector employees of synthetic Nanchuan District were similar to that of the real Nanchuan District. Since 2012, the gap between solid lines and curves became significant.

Both the actual values and synthetic control estimates of the year-end total population had continued the previous upward trend since 2012. Furthermore, the population growth rate had gradually decreased, with the actual value lying below the synthetic control estimate, showing a wider gap and a lower growth rate. This suggests that shale gas extraction was not conducive to population growth, while the negative impacts are increasing over time. However, the results of robustness checks in Fig. 5 are not significant.

The number of non-private sector employees in real Districts began to fluctuate about 2012 and was generally stable, with a slightly rising trend. By contrast, the number of non-private sector employees obtained by SCM rose first and then fell. The synthetic control estimate appeared to be the same as the actual value between 2017 and 2018. This sheds light on the conclusion that the development of the shale gas industry had led to a decline in the number of urban non-private sector employees. However, from 2017 to 2018, this negative impact gradually faded away. Considering the robustness checks, the negative effects in Nanchuan District rank high, showing that the result is significant.

4.2.3. *Wulong District*

Table 5 shows the comparison of the predictor variables

Table 3
Comparison of predictor variables for Nanchuan district.

Predictor variable	The comparison of predictor variables for year-end total population, 10,000 people		The comparison of predictor variables for number of non-private sector employees in urban areas, 10,000	
	The treatment group	Synthesis control group	The treatment group	Synthesis control group
Natural growth rate, ‰	5.203333	8.075052	5.203333	6.465044
Urbanization rate, %	52.01833	49.51792	52.01833	38.16428
Regional Gross Domestic Product, 10,000 RMB	1650182	1877474	1650182	1254761
The proportion of the primary industry, %	324771.5	209783.8	324771.5	189330.5
The proportion of the secondary industry, %	630525	1039010	630525	630914.6
Level road mileage, km	2493.478	2221.756	2493.478	3065.225
The ratio of the number of urban residents with minimum subsistence allowances to the total population, %	4440.75	6335.011	4440.75	8406.078
Social service agencies providing accommodation services	48.08333	46.90042	48.08333	37.40333
Number of beds in social welfare institutes	1420.333	1873.989	1420.333	1432.081
The ratio of ordinary secondary school students to the total population, %	32592.67	32420.13	32592.67	32588.44
The ratio of ordinary primary school students to the total population, %	42221	44743.54	42221	40099.34
Number of health agencies	254.75	276.0267	254.75	265.0731
Outcome variable (2007)	65.75	65.70495	2.35	2.31314
Outcome variable (2012)	68.16	68.20902	3.3	3.47503
Outcome variable (2018)	68.68	69.55653	3.45	3.48995

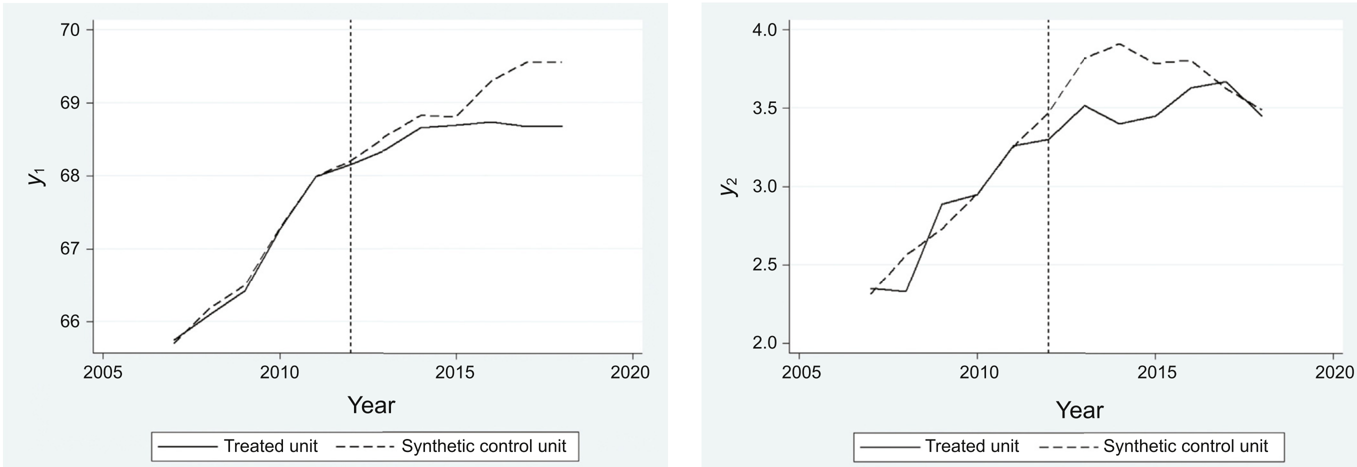
Table 4
Synthetic weight for Nanchuan district.

District	Synthetic weights for year-end total population (10,000 people)	Synthetic weights for number of non-private sector employees in urban areas (10,000)
Changshou District	0	0.066
Jiangjin District	0	0
Hechuan District	0	0
Yongchuan District	0.185	0
Qijiang District	0	0
Dazu District	0.293	0.096
Tongnan District	0	0.032
Tongliang District	0	0
Rongchang District	0	0.05
Bishan District	0	0
Wanzhou District	0	0
Liangping District	0.058	0
Kaizhou District	0	0
Qianjiang District	0	0
Chengkou County	0.464	0.071
Fengdu County	0	0
Dianjiang County	0	0
Zhong County	0	0
Yunyang County	0	0
Fengjie County	0	0
Wushan County	0	0
Wuxi County	0	0.393
Shizhu County	0	0.292
Xiushan County	0	0
Youyang County	0	0
Pengshui District	0	0

between the real and synthetic Wulong District. All 12 predictor variables are included to estimate the year-end total population (10,000). According to the results of the first SCM, the natural growth rate (‰), the proportion of the secondary industry (%), and the social service agencies providing accommodation services were omitted when predicting the number of employees in urban non-private sectors (10,000). With the remaining 9 predictor variables included, we performed the second SCM. From Table 5, it can be found that the difference of each predictor variables between the treatment group and the synthetic control group for the two Outcome variables is small, which indicates that the synthetic Wulong District serves as a very good fit for the real Wulong District.

According to Table 6, the districts and counties that contributed to the year-end total population for synthetic Wulong District were Qijiang District and Chengkou County, where the Chengkou County was the top contributor, with weight as high as 0.828. The main contributors to the synthetic control estimate for urban non-private sector employees were Jiangjin District, Qijiang District, Tongnan District, Rongchang District, Chengkou County, Zhong County, Wushan County, of which the Chengkou County contributed most, with a weight of 0.645.

As can be seen from the trend of the year-end total population, the synthetic control estimate of Wulong District before 2012 fitted



(a) Trend of year-end population

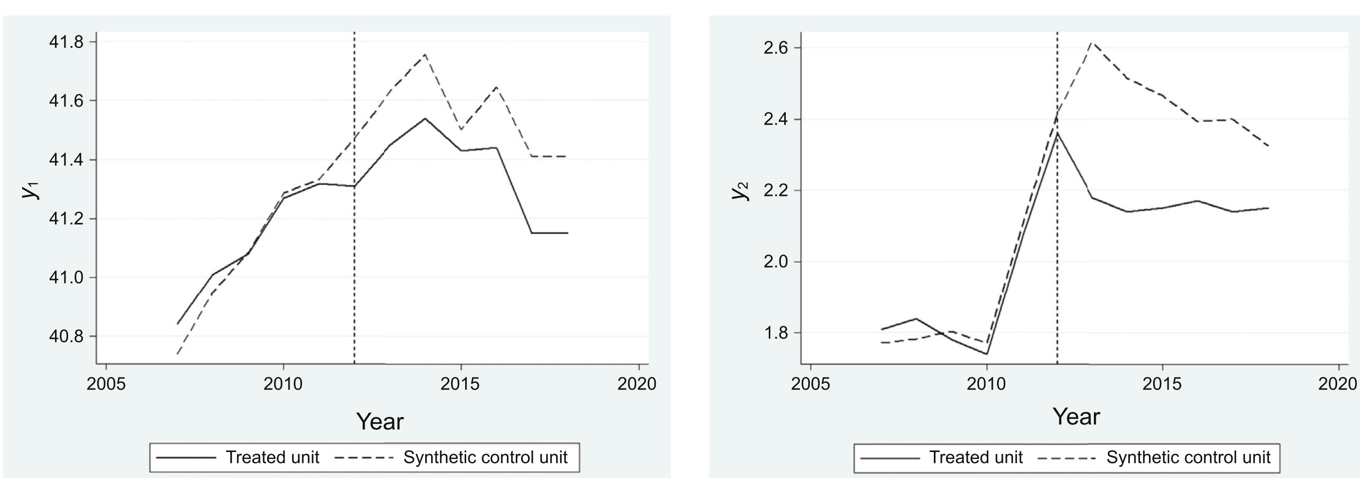
(b) Trend of non-private sector employees

Fig. 4. Trends of outcome variables for Nanchuan district.

(a) Rankings of year-end population

(b) Rankings of non-private sector employees

Fig. 5. Robustness checks for Nanchuan district.



(a) Trend of year-end population

(b) Trend of non-private sector employees

Fig. 6. Trends of outcome variables for Wulong district.

Table 5
Comparison of predictor variables for Wulong district.

Predictor variable	The comparison of predictor variables for year-end total population, 10,000 people		The comparison of predictor variables for number of non-private sector employees in urban areas, 10,000	
	The treatment group	Synthesis control group	The treatment group	Synthesis control group
Natural growth rate, ‰	3.598333	7.508677	–	–
Urbanization rate, %	36.59333	36.35156	36.59333	34.13994
Regional gross domestic product, 10,000 RMB	1037091	822888.2	1037091	1059178
The proportion of the primary industry, %	155221.7	120483.5	155221.7	150090.4
The proportion of the secondary industry, %	410576.7	418409.6	–	–
Level road mileage, km	2921.825	2853.086	2921.825	2580.718
The ratio of the number of urban residents with minimum subsistence allowances to the total population, %	6702.583	7111.98	6702.583	6679.707
Social service agencies providing accommodation services	18.08333	24.685	–	–
Number of beds in social welfare institutes	1000.417	1026.454	1000.417	1255.805
The ratio of ordinary secondary school students to the total population, %	20613.33	20244.19	20613.33	22305.16
The ratio of ordinary primary school students to the total population, %	27214.75	27796.02	27214.75	31475.18
Number of health agencies	243.5833	227.069	243.5833	242.3807
Outcome variable (2007)	40.84	40.73912	1.81	1.7823
Outcome variable (2012)	41.31	41.47404	2.36	2.38488
Outcome variable (2018)	41.15	41.41088	2.15	2.19355

Table 6
Synthetic weights for Wulong district.

District	Synthetic weights for year-end total population (10,000 people)	Synthetic weights for number of non-private sector employees in urban areas (10,000)
Changshou District	0	0
Jiangjin District	0	0.011
Hechuan District	0	0
Yongchuan District	0	0
Qijiang District	0.172	0.03
Dazu District	0	0
Tongnan District	0	0.001
Tongliang District	0	0
Rongchang District	0	0.191
Bishan District	0	0
Wanzhou District	0	0
Liangping District	0	0
Kaizhou District	0	0
Qianjiang District	0	0
Chengkou County	0.828	0.645
Fengdu County	0	0
Dianjiang County	0	0
Zhong County	0	0.023
Yunyang County	0	0
Fengjie County	0	0
Wushan County	0	0.099
Wuxi County	0	0
Shizhu County	0	0
Xiushan County	0	0
Youyang County	0	0
Pengshui District	0	0

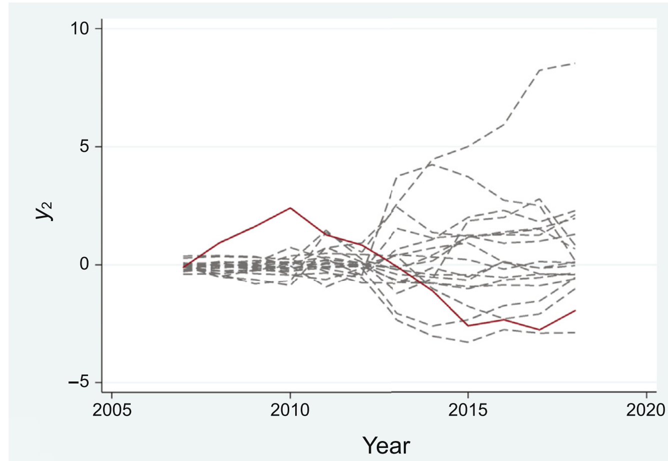
well for the actual value. Since 2012, the actual value appeared to lie below the synthetic control estimate, indicating that the development of shale gas led to a decline in the population. Judging from the results of robustness checks in Fig. 7, the results are significant.

Before 2012, the synthetic control estimate produced a good fit for the actual value of the non-private sector employees in urban areas. Since 2012, the actual value had declined sharply, displaying a stable trend since 2014. By comparison, the synthetic control estimate went up first and then went down, showing a narrowing gap between the synthetic control estimate and the actual value. In conclusion, the development of the shale gas industry has led to a decline in the number of non-private sector employees in urban areas, but the negative impacts weakened gradually from 2017 to 2018. The robustness checks in Fig. 7 prove the results are significant.

5. Conclusions

The exploration and extraction of shale gas, which is a kind of emerging clean green energy, have a profound impact on regional population growth and employment. Shale gas extraction may lead to the destruction of the local ecological environment, as well as the decline in the quality of life of residents. The occupation of cultivated land and air pollution may harm local agriculture and

(a) Rankings of year-end population



(b) Rankings of non-private sector employees

Fig. 7. Robustness checks for Wulong district.

tourism, which further leads to population migration. However, different scholars have different ideas about the relationship between exploration and extraction of shale gas and regional employment. On the one hand, some scholars hold the view that the total employment rate will be higher. On the other hand, some scholars find evidence for "resource curse" and "Dutch disease", which refers to the indirect adverse effects of natural resource booms on the manufacturing and agriculture industry.

According to the robustness checks, our main findings remain robust to different estimation approaches and measurements. Since the large-scale exploration of shale gas began in 2012, the year-end total population and the number of non-private sector employees in urban areas of the shale gas fields both show similar changing trends. The development of the shale gas industry has curbed the total population growth of Fuling, Nanchuan and Wulong districts, although the robustness check results in Nanchuan district is not significant enough. Similarly, the development of shale gas industry has led to a decline in the number of employees in urban non-private sector, but the negative effects seemed to wane over time from 2017 to 2018.

Our study lends support for the theoretical argument that shale gas extraction has no positive or even negative effect on population growth and employment, for the following reasons: First, there may be a "resource curse". Though this study does not include industrial analyses, the development of the shale gas industry leads to higher wages, resulting in the decline of non-shale gas industry profits and employment. Second, shale gas extraction takes up a small share of the local economy, which may account for the less significant result. Third, the oil and gas industry, as a capital-intensive industry, with low demand for labor, has lowered the expected impact on the labor market. In addition, after well drilling and hydraulic fracturing, the number of employees required to continue production at each well was significantly reduced compared to the initial construction phases (Kelsey et al., 2016). The less sanguine findings for the regional economic benefits of shale gas development indicate that it may not be the panacea for what ails many local economies. Residents and policymakers should weigh the balance of the potential benefits and costs in the exploration and extraction of shale gas. Whether the shale gas development would improve regional overall economic well-being should also be taken into account.

Due to the short history of the shale gas industry in China, annual data are only available from 2012 to 2018. With the development of the shale gas industry, the energy sector accounts for an increasing proportion of the total economy, a longer-term data may yield more significant results in the future.

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