ENERGY STRUCTURE, ECONOMIC GROWTH, AND CARBON EMISSIONS: EVIDENCE FROM SHAANXI PROVINCE OF CHINA (1990-2012)

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ABSTRACT
Can different economic development levels cause different carbon emissions, which being accordance to Environmental Kuznets Curve Hypothesis? This paper says 'yes' and utilizes a vector autoregression (VAR) model which focuses on different energy types, economic growth and carbon emissions, based on empirical data. The results show that when area's growth suffers a positive impulse, the trend of carbon emissions will rise firstly and then decline, and the relationship of them is an inverted "U" type of Kuznets curve.

KEY WORDS
carbon emissions, energy structure, economic growth.

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Introduction

With the deepening of the industrialization process, China has become the largest energy consumer in the world. The energy consumption structure featuring high carbon emissions has caused annual increases in carbon dioxide emissions, a situation which has placed growing international pressure on China to bring about reductions. Shaanxi province, as the core of economic development in the western region and because of its special geographical environment and natural resources, has an economic development model that depends heavily on the energy industry. As a result, coal and oil resources production and use make up a high proportion of the national accounts. The question of how to alleviate the contradiction between economic development and environmental protection and to improve the quality of the local environment has become one of the problems to be solved in the social development of Shaanxi province. Therefore, there is important theoretical and practical significance in studying the relationship between the energy struc-

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ture, economic growth, and carbon emissions. This paper establishes a vector autoregression (VAR) analysis framework to analyze the degree of influence that coal, petroleum, and natural gas consumption has on the level of carbon emissions in Shaanxi province. In addition, we analyze the significance of optimizing the energy structure to reduce emissions in order to provide theoretical guidance for the formulation of relevant policies.

1. Literature review

Studies of the relationship between the environment and the economy began near the end of the 20th century. In 1991, the American economists introduced the environmental Kuznets curve (EKC) which describes the relationship between environmental pollution and economic growth (Grossman, Krueger 1991). Later, other scholars proved the existence of a Kuznets curve from the global scope and the population perspective, and they proposed that the relationship between environmental pollution and economic growth is satisfied with the inverted "U" type curve, namely having the upper limit of environmental pollution (Shafik, Bandyopadhyay 1992). Some used a simplified econometric model to estimate global carbon emissions using panel data from 1995 to 2005, and found that the majority of IPCC use of the emission growth plan is inconsistent with the experiential plan, and that the inverted "U" type curve clearly describes the relationship between per capita income and per capita carbon emissions (Schmalensee et al. 1998). Some used a comparative analysis method to compare the main technical measures of emission reduction (carbon capture and carbon sequestration) with basic policies (carbon tariffs, fossil fuel tax, and renewable energy subsidies) (Reyer, Bob 2006). They argue that standard of carbon combination is the most cost-effective way to address global climate issues, and carbon capture and sequestration technologies can reduce the cost of reducing emissions, but they cannot meet the needs of large scale renewable energy sources. Others have researched the relationship between carbon dioxide and economic growth based on hierarchical structure methods, such as the minimal spanning tree (MST) and hierarchical tree (HT), and they have found that high income countries are closely connected to each other and are isolated from the upper middle and lower middle income countries both for the CO_2 emissions and economic growth (Deviren, Deviren 2016). Recent research used the vector error correction model (VECM) and the autoregressive distributed lag (ARDL) to analyze the relationship between carbon dioxide emissions, GDP, energy use, and population growth in Ghana from 1971 to 2013. They found that 21% of future shocks in carbon dioxide emissions are due to fluctuations in energy use, 8% of future shocks are due to fluctuations in GDP, and 6% of future shocks are due to fluctuations in population (Asumadu – Sarkodie, Owusu 2016). Some studied the relationship between energy-resource depletion, climate change, health resources and the environmental Kuznets curve, and found the EKC hypothesis in the energy-resource depletion model has been tested (Khan et al. 2016). Some scholars examined the relationship between environmental pollutants, population growth, energy use, trade openness, and per capita food production using the panel data of 34 high-income OECD, high-income non-OECD, and European and Central Asian countries from 1995-2014 and found that there is a need to establish an interactive environmental model to improve the process of sustainable development (Ramakrishnan et al. 2016). The GMM panel estimator has been used to research the relationship between national culture, carbon dioxide emissions, and economic growth in the framework of the environmental Kuznets curve (EKC) based on 69 developed and developing countries, and scholars proved the existence of the EKC (Disli, Askari 2016). According to tests on an environmental Kuznets curve (EKC) hypothesis between 16 individual industry sectors and total industrial sectors among 39 countries from 1995 to 2009, results proved at least ten individual industries do not have an EKC relationship in eight air pollutants. Meanwhile, the EKC turning point and the relationship between economic development and the trends of air pollutant emissions differ among industries according to pollution substances (Fujii, Managi 2016). Some dynamic simultaneous-equation panel data models were used to research 58 countries between 1990-2012 to examine the causal relationship between energy consumption, CO_2 emissions and economic growth. They found the same conclusions, a bidirectional causality relationship between energy consumption and CO_2 emissions, and a unidirectional causality between CO_2 emissions and economic growth (Saidi, Hammami 2016). The relationship between energy consumption and carbon dioxide emissions in the causal framework using the maximum entropy bootstrap approach for Malaysia in 1975-2013,found that unidirectional causality exists between energy consumption and carbon emissions in the bivariate model and multivariate framework, and the results show that Malaysia is an energy-dependent country (Gul et al. 2015). Research on the relationship between energy consumption, carbon emissions, economic growth, and trade openness in Sri Lanka in 1971-2006 using the long-run Granger causality method found that it exists not only in this relationship but there is also a unidirectional causality relationship between carbon emissions, energy consumption, and economic growth (Uddin et al. 2016). Some adopted a new method to research the relationship between environment degradation, economic growth (EG) and energy consumption (EC), namely wavelet windowed cross correlation. They aimed at the six oil-exporting countries from the GCC (Gulf Cooperation Council) region from1980 to 2012 and found that a bidirectional causal relationship between EC and EG exists, a relationship which applies equally to EG and CO_2 emissions, and there is unidirectional causality between EC and CO_2 emissions (Jammazi, Aloui 2015). Some researched the relationship between economic growth, carbon dioxide (CO_2) emissions, and energy consumption to test the validity of the environmental Kuznets curve (EKC) hypothesis in five ASEAN (Association of South East Asian Nations) countries by using the panel smooth transition regression (PSTR) model. They found the results rejects the null hypothesis of linearity, and the research supports the validity of the environmental Kuznets curve (EKC) (Heidari et al. 2015). The relationship between carbon dioxide (CO_2) emissions and per capita income in 20 high-income OECD countries from 1961 to 2004 shows a positive relation between GDP and CO_2 in most countries (Ucak et al. 2015).Some scholars examined whether developing countries have the latecomer's advantage or suffer the latecomer's disadvantage in the framework of the environmental Kuznets curve, they aimed at researching SO_2 and CO_2, and found the former meets the inverted U-shape pattern of the EKC and the latecomer's advantage, but the latter does not (Taguchi, Murofushi 2011). Others analyzed the role of energy in developing countries based on energy use patterns, and they found more than three-quarters of the reduction in carbon emissions are achieved through efficiency improvement (Sathaye, Ketoff 1991). One scholar researched the relationship between economic development and environmental quality, and found some indicators, like carbon emissions and so on, worsen steadily with rising incomes (Shafik 1994).

Research on the relationship between environmental pollution and economic growth in China started late, but it has achieved fruitful results. Based on the traditional model of Kuznets and carbon dioxide emissions predictions, some use two methods to test for the existence of the EKC in China. The results show that the first research method indicates that the EKC exists in China, and the turning point is at 37,170 yuan per capita income. Analysis of carbon dioxide demand found that the EKC does not exist, but the shapes of the curves under various energy and economic policies are different (Lin, Jiang 2009). And some used a non-parametric model and treated carbon as an indicator of environmental pollution. The results show that there is no inverted "U" curve relationship between per capita GDP and per capita carbon dioxide emissions (Hu et al. 2013). Some found that the EKC exists in the eastern and central regions, but not in the western region (Xu, Song 2010). Others used the Copeland model and found that the EKC exists only in some provinces and cities in China (Song, Wang 2011). Some confirmed the existence of the inverted "U" type EKC from microcosmic department perspective (Chen 2002; Tang, Sun 2012). Based on the VAR model an analysis of the influence of the coal, petroleum, and natural gas on economic development showed that energy consumption had a significant influence and different energy types had different cost reductions in achieving the same equivalent emission reduction effect (Xu, Dong 2011). Kuznets curve of per capita carbon emissions in Shaanxi province existed a inflection point, and the carbon emissions reached the inflection point about 32.5 years, namely 2040 years or so, after that carbon emissions would be reduced as per capita income increases. At the same time, the curve fit the characteristics of an "inverted U" type curve and the environmental Kuznets curve hypothesis. The study also found that technological progress reduced carbon emissions when economic development, energy intensity and institutional factors increased carbon emissions (Shao et al. 2012). Others chose data from 30 provinces for 2000 to 2009, and found that China had an inverted u-shaped relationship between carbon emissions and economic growth. In this research, the proportion of industrial structure had a negative effect on carbon emissions reduction, and technological progress, FDI had significant positive effects on carbon emissions (Chen, Zhang 2012). Using heterogeneous panel cointegration test to research the relationship between urbanization and carbon emissions in BRICS countries from 1985 to 2014, it was found that urbanization and carbon emissions exist in a long-run equilibrium cointegration relationship. In addition, urbanization causes carbon emission (Wang et al. 2016 a). Some examined the causal relationships among economic growth, energy consumption, and CO_2 emission in China during 1978-2012 with linear and nonlinear causality tests, and the results show that there is a unidirectional causality from CO_2 emissions to GDP, and a bi-directional causality between energy consumption and CO_2 emission (Wang et al. 2016 b). Regarding the relationship between urbanization, energy consumption, and CO_2 emissions in different provinces of China, some believed that urbanization can increase energy consumption and CO_2 emissions, and with different results between provinces (Wang et al. 2016 c). The assumptions for environmental Kuznets curve (EKC) theory models have never received strict verification with a large set of available data, so some used a novel symbolic regression method to research 67 countries from 1971 to 2010 and it can be regarded as a reasonable models for a specific country or region (Yang et al. 2015). Regarding the relationship between economic growth and environmental emissions in the frame of the environmental Kuznets curve in China, some found that the inverted "U"- shaped relationship between economic growth and carbon dioxide emissions does not exist, but it meets the relationship between economic growth and sulfur dioxide emissions (Li et al. 2016). Others used cointegration tests and a vector error-correction model (VECM) to analyze the relationship between urbanization, economic growth ,and energy consumption in China during 1980-2012, and they found a marginal impact from the energy consumption shock on urbanization and the impact of urbanization on economic growth They also obtained the bi-directional Granger causal relationship between energy consumption and economic growth, and found unidirectional causality running from urbanization to energy consumption and economic growth to urbanization (Zhao, Wang 2015). Some analyzed the impact of regional development on carbon emissions, they believed it has some influencing factors including population size, income level, and technical progress in affecting carbon emissions. The origins of growing global carbon emissions included the increasing influence of the elasticity of the population size and the declining negative effect of technical progress were studies by a using multivariate nonlinear regression (Li, Yuan 2014). Using an improved C-D production function model to research the relationship between energy consumption, economic growth, and carbon emissions based on Chinese panel data from 1991 to 2009, they found energy consumption and economic growth exist in a long-term equilibrium and a one-way causality relationship., and they predict China's carbon dioxide emissions will be reduced by 34.53% in 2020 compared with in 2005 (Yang et al. 2014). Others used the Logarithmic Mean Divisia Index (LMDI) method to analyze the change in energy-related CO_2 emissions in China during 1991 to 2010. They found that while energy intensity is the major contributor to the decrease of CO_2 emissions, energy mix and carbon intensity of energy use have negative effects on the increase of CO_2 emissions (Ouyang, Lin 2015). Some used the LMDI method to decompose the changes in China's carbon emissions and carbon emission intensity from 1996 to 2010, and found economic growth is a main driver in increasing carbon emissions in past decades based on a decoupling index (Zhang, Da 2015).

The current domestic and foreign research on carbon emissions mainly concentrated on the verification of the EKC, and the scope of the research was also more concentrated at the national or regional level. Relevant literature on the relationship between the energy consumption structure and carbon emissions is relatively rare. In research methods, econometric models mainly uses Kuznets's tradition or the forms of deformation, and the dynamic mechanism between carbon emissions and its influence factors still need to be further studied. Based on the statistical data for Shaanxi province from 1990 to 2012, we use the VAR model to get the dynamic relationship between carbon emissions, the energy consumption structure, and economic growth, allowing us to provide a reference for alleviating the contradiction between economic development and environmental protection.

2. Variable selection and model construction

2.1. Construction of the VAR model

By constructing a VAR model which includes per capita output Y, total energy consumption E (or the type of energy consumption, E_{coal}, E_{oil}, E_{gas}, as a proportion of total energy consumption), urbanization level U, per capita carbon emissions C, we can quantitatively find the effects of the energy consumption structure on per capita carbon emissions. This method can reflect the dynamic feedback mechanism between variables, and can measure the direct and indirect effects of energy consumption on per capita carbon emissions. In this paper, we develop four VAR models, each of which includes per capita output, per capita carbon emissions, and the urbanization level. The energy variables of the four models are the total energy consumption and the three types of energy consumption as a proportion of total energy consumption.

The models are as follows:

$$\ln C_{1t}=(\ln Y,\ln E,\ln U),\ \ln C_{2t}=(\ln Y,\ln E_{coal},\ln U),$$
$$\ln C_{3t}=(\ln Y,\ln E_{oil},\ln U)$$

$$\ln C_{4t}=(\ln Y,\ln E_{gas},\ln U),$$
$$\ln C_{kt}=A_k \ln C_{kt-1}+E_t \quad (t=1,2,3,4) \quad E_t\sim iid\,(0,\Omega)$$

C is carbon emissions per capita; E is the total consumption of the three types of energy; E_{coal}, E_{oil}, and E_{gas} represent the various types of energy consumption as a proportion of total energy consumption; U stands for the level of urbanization; A_k is a 4 * 4 order coefficient matrix; E_t is a random error column vector of 4 * 1; and E_t is the white noise sequence, which is the mean value for 0, the variance for Ω.

2.2. Variable descriptions and data sources

Based on the data availability and research needs, the research period of this paper is from 1990 to 2012, the energy data are derived from the *China Energy Statistical Yearbook* and the *Shaanxi Statistical Yearbook*, and per capita output and urbanization data are derived from the *Statistical Yearbook of China*. The per capita output in Shaanxi province can be substituted by the ratio of year of the value to the total population, The level of urbanization is described by proportion of urban population to the total population.

In the past, carbon measurement methods both at home and abroad were not standardized, and China had released provincial carbon emissions data. In this paper, carbon emissions data are calculated by using the method provided by the Intergovernmental Panel on Climate Change (IPCC) in the second volume of the "Guidelines for the national greenhouse gas inventory guidelines" released in 2006. In the following formula:

$$C_i=\sum_{i=1}^{3} E_i * F_i$$

C_i represents the carbon emissions generated by the full combustion of i energy, E_i represents the total amount of energy consumption of i, and F_i represents the carbon emission coefficient of i. This paper revises the emission factors provided by the IPCC through the value of the standard coal coefficient according to energy[1]. The emission coefficients of the three kinds of energy are obtained as follows: $\text{coal} = 0.9159\text{kgC/kg}$, $\text{oil} = 0.8360\text{kgC/kg}$, and natural $\text{gas} = 0.5957\text{kgC/kg}$. The carbon emissions in Shaanxi province were calculated as shown in Table 1.

Table 1. Carbon emission statistics for Shaanxi province; 1990 to 2012. Unit: million tons

Year	Total carbon emissions	Carbon emissions(coal)	Carbon emissions (oil)	Carbon emissions (natural gas)
1990	1876.84	1753.03	116.44	7.37
1991	1991.67	1828.14	135.09	28.44
1992	2058.18	1885.84	142.87	29.47
1993	2250.84	2071.77	154.04	25.04
1994	2358.18	2159.69	177.33	21.15
1995	3555.90	3461.19	91.70	3.01
1996	3872.02	3753.36	117.48	1.19
1997	3466.47	3288.08	173.48	4.91
1998	3432.95	3213.89	203.85	15.21
1999	3039.06	2745.87	265.70	27.49
2000	2896.95	2533.38	310.72	52.85
2001	3323.70	2869.51	368.30	85.88
2002	3691.29	3160.77	419.52	111.00
2003	4290.79	3627.88	518.24	144.67
2004	5439.84	4541.03	639.17	259.63
2005	6429.02	5540.28	740.11	148.63
2006	8071.22	6959.01	886.96	225.25
2007	8688.22	7402.30	958.39	327.53
2008	9649.13	8189.06	1051.25	408.82
2009	10208.54	8698.30	1114.02	396.22
2010	12382.83	10660.2	1253.72	468.95
2011	13941.44	12197.9	1248.39	495.10
2012	16321.10	14447.4	1351.02	522.67

Source: own elaboration.

3. Empirical analysis

3.1. Unit root test

Due to some economic variables in real economic life belonging to the nonstationary sequence, namely variables showed a trend of increase or decrease over time. And most of the econometric analysis methods require a smooth sequence to continue the empirical analysis, so it is necessary to test the stability of economic variables before modeling. The unit root (ADF) test method is used to determine the single integration order of each economic variable. Test results are shown in Table 2.The statistics value of the two order difference ADF of lnC, lny, lnE, lnEcoal, lnEoil, lnEgas, and lnU are less than the critical value, so we reject the original assumption that the variable has the unit root. It shows that the Second-order difference of these 7 variables is a stationary sequence, that is, these variables are all Second-order single integration.

[1] Correction method (taking oil as an example): The default factor for oil provided by the inventory guide of national greenhouse gas is 73300KG/TJ. The average low calorific value of oil is 41816KJ/KG. 1TJ/41816 represents heat produced by 1TJ requires the quality of the burning oil, namely 23914KG. 73300/23914=3.065KGCO_2/KG shows full combustion of one kilogram oil releases the amount of carbon dioxide, finally 3.065*12/44=0.8360KGC/KG.

Table 2. Statistical results of ADF test

Variable	Statistical results at 5% significant level	Critical value	P-value
lnC	-3.232896	1.154649	0.8952
dlnC	-3.690814	-2.768524	0.2550
d(lnC,2)	-3.658446	-6.009413	0.0005
lnE	-3.632896	-1.187145	0.8883
d(lnE)	-3.644963	-3.332106	0.0884
d(lnE,2)	-3.658446	-6.115650	0.0004
lny	-3.644963	0.953146	0.9296
dlny	-3.644963	-2.993483	0.1568
d(lny,2)	-3.658446	-6.389810	0.0002
lnEcoal	-3.632896	-1.066429	0.9122
d(lnEcoal)	-3.644963	-3.371889	0.0824
d(lnEcoal,2)	-3.673616	-4.664490	0.0078
lnEoil	-3.632896	-1.866279	0.6374
d(lnEoil)	-3.690814	-2.393103	0.3701
d(lnEoil,2)	-3.710482	-6.093176	0.0007
lnEgas	-3.658446	-3.223804	0.1080
d(lnEgas)	-3.644963	-3.584087	0.0560
d(lnEgas,2)	-3.658446	-5.815704	0.0007
lnU	-3.632896	-0.782606	0.9521
d(lnU)	-3.644963	-2.578411	0.2921
D(lnU,2)	-3.658446	-4.537942	0.0092

Source: Eviews software calculation results.

3.2. Cointegration test

For non-stationary series, the different methods are usually adopted to eliminate the non-stationary trend in the practical measurement, but this method also has its disadvantages, which means that the difference of the variables often does not have realistic economic significance. In 1978, Engle and Granger put forward the cointegration theory, which provided a new research method for the modeling of non-stationary series, and the Johansen test was used to test the cointegration relationship between variables in this paper. Before this, we determined the optimal VAR model lag order through the AIC and SC standards, which is 1. The results of the Johansen cointegration test for the four models show that the maximum eigenvalue and trace characteristic value were significantly rejected the original hypothesis that there was no cointegration relationship. In the original hypothesis, at least one cointegration relationship existed, so the original hypothesis cannot be rejected. We can conclude that the original sequence at least has a cointegration relationship.

Table 3. Unrestricted cointegration rank test (Trace)

Hypothesized No.of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.**
None*	0.732688	36.72804	24.27596	0.0008
At most 1	0.316989	9.021898	12.32090	0.1678
At most 2	0.047219	1.015773	4.129906	0.3640

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Source: Eviews software calculation results.

Table 4. Unrestricted cointegration rank test (Maximum Eigenvalue)

Hypothesized No.of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.732688	27.70614	17.79730	0.0012
At most 1	0.316989	8.006125	11.22480	0.1740
At most 2	0.047219	1.015773	4.129906	0.3640

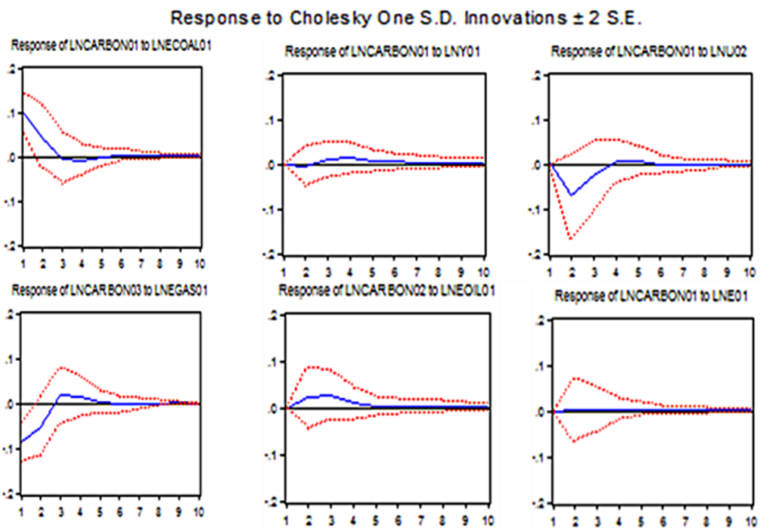
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

Source: Eviews software calculation results.

3.3. Impulse response function analysis

The impulse response function often analyzes whether an error term is changed or the model is affected by some kind of impacts which produces a dynamic influence on the system. So the impulse response function is an effective tool to analyze the dynamic relationship between variables. In this paper, the stability of the VAR model is tested by the method of AR root estimation. Results show the four models' reciprocal roots are less than 1, which indicate that the model is stable. The result of the impulse response analysis for this model is credible, and the results of the impulse response analysis are shown in Figure 1. At the top row of Figure 1, from left to right, it shows the impulse response diagrams of the proportion of coal consumption, per capita income, and urbanization, and the bottom row shows the proportion of natural gas consumption, oil consumption, and energy consumption to the carbon emissions. The horizontal axis represents the lag periods of impact, the vertical axis represents the response of the carbon emissions, the blue curve shows the impulse response function, and the red dotted line represents the response function value of two times the standard error confidence bands.

Figure 1. Impulse response results of model 1



Source: own elaboration.

As is shown in the Figure 1, there is a positive impulse on the proportion of coal consumption (lnEcoal), and carbon emissions react intensely in the first 3 periods and tend to be stable from the beginning of the third period. This response shows an intense and positive carbon emissions reaction in response to coal consumption clearly indicating that higher proportions of coal consumed in the energy consumption structure bring significant increases in carbon emissions. We assign a positive impulse on economic growth (LnY), carbon emissions show a trend of first rising and then falling, reaching the peak of carbon emissions in the fourth phase. This indicates that when per capita income is at a low level, carbon emissions increase with the rise in per capita income, and when per capita income is at a high level, carbon emissions decrease with the rise in per capita income. This shows that the relationship between carbon emissions and economic growth in Shaanxi province is in line with the "U" type EKC. The level of urbanization (U) also had a positive impulse; carbon emissions in the first 4 periods react violently. After the fourth period it begins to stabilize and the impulse response function shows this effect is negative, indicating that the level of urbanization in Shaanxi province does not have a significant impact on carbon emissions. We increase the consumption proportion of natural gas (lnEgas) in the energy structure, and find that the carbon emissions before phase three trend downward. This shows that raising the proportion of natural gas consumption can effectively reduce carbon emissions. Next, the proportion of consumption of oil (lnEoil) in the energy structure is increased, and the carbon emissions response function at first displays an increase and then a decrease but with a weaker reaction than coal consumption, indicating oil consumption has increased carbon emissions less than those caused by coal. When we impose a positive impulse on total energy consumption, the response function shows the carbon emissions reaction is not obvious.

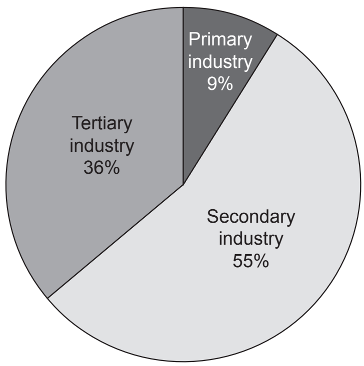
Conclusions and policy implications

Carbon emissions in Shanxi Province are mainly derived from the consumption of traditional energy sources (especially coal). In three big energy consumption aspects, coal and oil have a positive impact on carbon emissions, but the degree of the carbon emissions impact is different to the carbon emissions. The former has a significant influence on carbon emissions, which will be sustained for a long time, while the latter is weak in intensity and duration. Natural gas consumption has a negative impact on carbon emissions, therefore, increasing the consumption of natural gas can alleviate air pollution in Shaanxi province to some extent. The relationship between economic growth and carbon emissions meets the environmental Kuznets inverted "U" type curve, that means, when the per capita income is low, carbon emissions increase with the rise in per capita income, and when per capita income is at a higher level, carbon emissions follow a reducing trend as per capita income rises. The number of carbon emissions in Shaanxi province has reached the peak or inflection point, and the influence of urbanization on carbon emissions was not significant.

During the economic period which is known as "the new normal" now of Shaanxi province, considered the center of economic development in the western regions, must realize that keeping a balance between economic growth and environmental protection is significant to achieve sustainable economic development. In order to alleviate the contradiction between economic growth and environmental protection, we must constantly change the approach to economic development and take a new road to industrialization.

First, we should adjust the industrial structure to meet the needs of environmental protection. In recent years, economic development in Shaanxi province has mainly depended on the development of secondary industry, and industrial growth was mainly based on the development of energy-intensive, highly polluting industries. In 2014, the proportion of secondary industries in the GDP of Shaanxi province was as high as 54.8%, and the proportion of the tertiary industries accounted for only 36.4%. The increase in the value of the economic contribution from tertiary industries is conducive to energy conservation and emissions reduction. Shaanxi province has a long history, a profound cultural background and an abundant natural and human landscape. As the starting point of the ancient Silk Road, Shaanxi province should seize the opportunity to rebuild the Silk Road Economic Zone with the Central Asian regions and accelerate the development of an upgraded industrial structure. We can cultivate tourism, cultural exhibitions, and other modern new services to enhance us.

Figure 2. Composition of gross domestic product of Shaanxi Province in 2014



Source: own elaboration.

Secondly, we should optimize the structure of energy consumption and raise the proportion of new energy consumption. Impulse response function analysis showed coal consumption has the greatest impact on carbon emissions. Since the 1980 s, the coal industry in Shaanxi province, especially in the Shanbei region, developed rapidly and quickly grew into a pillar industry in the province. In 2014, the number of large-scale coal enterprises in the province was about 439, accounting for 9.5% of industrial enterprises above designated size. In industrial consumption, the six major energy-consuming industries consumed 65.0965 million tons of standard coal, accounting for 80.5% of industrial energy consumption. In total energy consumption, the proportion of coal consumption is still over 70%, and wind power, hydropower, solar, biomass energy and other new and renewable energy accounts for a small proportion. Based on the current status of energy consumption, Shaanxi should rely on the resource conditions in different areas, and develop them in a timely manner using clean energy such as wind, hydro, solar, and CBM. Meanwhile, Shaanxi should increase funding and policy support for new energy, encourage enterprises to invest in new energy projects and gradually increase the proportion of natural gas and other clean energy in the energy consumption structure. The utilization efficiency of coal should be improved to extend the industrial chain of the coal industry.

Thirdly, at present, Shaanxi province is in the early stage of industrialization and there is a certain amount of time before the arrival of peak carbon emissions. In the current economic development model, if we want to improve the regional air quality, we must find the sources of pollution and improve the legal system to make full use of legal means to promote regional environmental governance. We should emphasize two aspects of market access and enterprise emission regulations to promote the environmental protection process in the province. In terms of market access, the local government should take into consideration environmental factors when they review enterprise establishment qualifications. For new entrants to the market that bring negative externalities, we should take effective steps to assess, and ban enterprises that are highly polluting, energy intensive, and have high emissions from entering the market. For existing enterprises in the market, the government should strengthen regulations, and adhere to the "who pollution, who governance" basic principle. Meanwhile, environmental governance tools such as pollution taxes and pollution emissions targets can be used to modify enterprise behavior. At the same time, strengthen regulations related to polluting enterprises, and carry on the necessary rectification process, through enterprise mergers, and the mergers and reorganization to change the market boundary, thus eliminating enterprises that are small market with high pollution emissions.

Finally, we should establish carbon measurement, and a carbon market, and make full use of market means to develop a low carbon economy. Carbon measurement is the basis of a carbon trading market, and there is no unified emissions measurement method in China. The international accounting system for carbon emissions uses mostly macro level top-down and bottom-up micro level accounting methods. Shaanxi province should examine the carbon accounting measurement experiences at home and abroad, and calculate and regularly publish regional greenhouse gas accounting reports, thus making carbon emissions in Shaanxi province measurable, verifiable and reportable. The current national carbon trading pilots are working well, and carbon trading has reached 20 million tons including 7 pilot provinces and cities and close to 1.3 billion yuan. The national carbon trading market has been established. Shaanxi province does not belongs to the carbon trading pilot areas, but it can utilize the carbon trading pilot experience to contribute to its capability. It can also introduce regional policies related to carbon trading and technical specifications for the construction of supporting systems. For example, we can establish a local greenhouse gas accounting system, develop carbon emissions quota allocation methods to meet the needs of regional economic development, and use a performance incentive mechanism to encourage enterprises to actively participate in carbon trading using default penalties. Following these actions, perhaps we can promote the smooth construction of the national carbon trading market and make full use of the market as a means to alleviate the contradiction between regional economic development and emission reduction. In the meantime, in this paper, our research also has some shortcomings. Due to the limitations in data collection, we had to use a reduced data set. If the data set can be expanded to cover more years, the trends observed in this paper would be more significant.

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