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Can Urban-rural Integration Decrease Energy Intensity? Empirical Study Based on China's Inter-provincial Data

Czy integracja obszarów miejsko-wiejskich prowadzi do ograniczenia energochłonności? Przykład Chin

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Abstract

The paper discusses the mathematical relationship of Urban-rural integration and energy intensity based on the production function including capital, labor and energy. Then, the empirical analysis on how it affect energy intensity, on the basis of the static and dynamic panel model with China's 30 provincial economic data in 2005-2014 years, using four estimation methods – FE, IV-FE, IV-GMM and MG. As part of integration, urbanization, industrialization and technology are found from the empirical results. Firstly, urbanization can significantly reduce energy intensity in short run, while the effect is positive in long term, as China didn't lastly use the role in saving energy on the process of urbanization. Secondly, industrialization can effectively cut down energy intensity. Thirdly, it is worthy to pay more attention to the ability to improve energy efficiency and lower energy intensity of technology in short and long run.

Key words: urban-rural integration, urbanization, industrialization, technology, energy intensity

Streszczenie

W artykule przeanalizowano matematyczną zależność integracji obszarów miejsko-wiejskich i energochłonności opartej na funkcji produkcyjnej z uwzględnieniem kapitału, rynku pracy i energii. Jest to podstawą do analizy empirycznej odnoszącej się do tego, jak integracja wpływa na energochłonność, na bazie statycznych i dynamicznych paneli odnoszących się do 30 regionów w Chinach, uwzględniając dane z lat 2005-2014 i używając metod szacowania FE, IV-FE, IV-GMM i MG. Jako części procesu integracji, na podstawie danych empirycznych, wyróżniliśmy urbanizację, industrializację i stronę technologiczną. Okazało się, że po pierwsze urbanizacja może znacząco obniżyć energochłonność w krótkiej perspektywie czasowej, jednak korzyści pojawiają się po dłuższym czasie, ponieważ Chiny nie przywiązywały roli do oszczędzania energii w kontekście urbanizacji. Po drugie, industrializacja może efektywnie obniżyć energochłonność wykorzystywanych technologii i to zarówno w perspektywie krótko, jak i długoterminowej.

Słowa kluczowe: integracja obszarów miejsko-wiejskich, urbanizacja, industrializacja, technologia, energochłonność

1. Introduction

Energy is an indispensable input factor for the rapid development of economy and society. However, excessive consumption of non-renewable energy resources has berried the sustainable development of the economy. As clean energy or renewable energy still cannot replace non-renewable energy sources, apossible way to get rid of the energy abuse is to reduce energy intensity and improve energy efficiency. The energy quantity of China is great, but the per capita quantity is relatively poor. The extensive development of China exacerbated the problem between environment, energy and economy. Sustainable development is particularly desirable to energy saving. At present, China is at a critical stage of modernization. The prominent feature of this process is the accelerated development of urbanization, industrialization and technology. On the one side, will promote total factor productivity as well as economic growth, on the other side it will result in the rise of energy consumption. How positive and negative effects the China energy intensity, which is dominated by the traditional fossil energy, is a topic worthy of further discussion.

Existing domestic and foreign research literatures focus on the relationship between technology, industrial structure, and energy consumption structure or energy efficiency. We believe that urbanization, industrialization and technology are part of urban-rural integration, which affect energy intensity extremely. From the perspective of technological progress, technology innovation and investment increase will often bring energy efficiency improvement, thus it is possible reducing the energy consumption intensity (such as Garbaccio et al., Fisher-Vanden & Jefferson, 1999; K., 2006). However the technological will lead to the increase of energy consumption of the rebound effect was partially offset by the energy savings due to technical progress. The final effect of technological progress on energy consumption intensity becomes more and more complicated (Khazzoom, 1980).

Other scholars are concerned about the impact of urbanization on energy size, energy intensity, or energy efficiency. Sathayo & Meyers (1985) observed that with the development of urbanization, developing countries are speeding up the process of replacing coal with oil. Parik (1995) points out that commuting energy expenditure is related to urban spatial structure, and energy consumption is related to urban scale structure. According to Dzioubinski & Chipman (1999), in developing countries, the development of urbanization will lead to higher energy consumption of residents. Hiroyuki (1997) uses data of year 1980-1993 from several countries, and finds that there is a positive correlation between the proportion of urban population and the logarithm of energy consumption per capita. Gates & Yin (2002) studies the relationship between urbanization in China and residential and commercial energy sources. By analyzing the urban and rural structure of energy type appliances household consumption, the demand for electricity in urbanization is greatly improved. Along with the urbanization advancement, the resident and the commercial energy correspondingly increase. B., R., Wei, et, Al (2003) found that urbanization has two ways of increasing energy consumption and reducing energy consumption.

The impact of industrialization on energy consumption, energy intensity is also a core study of scholars. Industrialization has expanded the scale of energy consumption (Donald, W., Jones, 1989), which is not conducive to the reduction of energy intensity. Zhujun Jiang & Boqiang Lin (2014) found that economic globalization makes the industrialization be shortened, but to promote faster growth in energy consumption, the inverted U curve of energy consumption are likely to be changed. Perry Sadorsky (2013, 2014) pointed out that industrialization will increase energy consumption, and its long-term elasticity of energy intensity is positive, which is about 0.07 to 0.12. The changes of industrial structure and economic growth are reciprocal causation. The change of energy consumption is not only due to the economic growth, but also affected by the industrial structure. In other words, the proportion of the first, second and third industries in the industrial structure has a direct impact on the energy efficiency of a region. The energy factor will flow in different industries for the optimization of industrial structure, and the direction is mainly from the first industry to the second and third industries with high productivity, and high added value. This has been demonstrated by the experience of numerous research results, such as Samuels et al (1984); Richard et al; Liu ET (1999); Ian sue Wing et al (2004).

In summary, this research contributes to three aspects as below.

First, technology is introduced into the conceptual framework. Current papers in this field mainly study the impact of industrialization and urbanization on energy intensity. However, as the three variables (technology, industrialization and urbanization) are intertwined and mutually supportive in affecting energy intensity, it is biased to exclude technology out of the analysis. This paper in contrast, examines technology based on the data measuring technology level sourced from the information statistical evaluation study group, NBS institute.

Second, estimation is made based on a structural model. This paper emphasizes the theoretical base of econometric modeling and is based on C-D production function. Through analyzing the correlation mechanism between the three variables and total factor productivity, their mathematical relation with energy intensity is deduced.

Third, the endogenity stems from the reverse causality of energy intensity to industrialization. For example, some less developed provinces are inclined to achieve targeted economic growth through extensive industrialization. This potential endogenous problem causes estimation deviation of industrialization. Thus, this paper introduces IV-FE and IV-GMM estimator to solve this problem. Secondly, ordinary panel analysis hypothesizes that each sectional variable is homogenous as the explained variable, when there are too many sections or sections are mutually correlated, this hypothesis becomes too rigid and deviation emerges. This paper adopts a recently prevalent method, Mean Group (MG), to solve this problem. This method can also distinguish the long-run and short-run impact of the three variables on energy intensity.

The conceptual framework of this paper comprises of four parts. Section 2 deduces the mathematical correlation expression of energy intensity including three variables based on the production function of capital, labor and energy, under the hypothesis that the evolution of technology, industrialization and urbanization is the function of energy intensity variation. Section 3 elaborates the variable declaration and their statistical description. Section 4 tests the long-run and short-run correlation between the three variables and energy intensity through static and dynamic panel models with a sample of economic data from 30 China provinces from 2005 to 2014, based on the constructed expression of energy intensity.

2. Theoretical model

It is generally acknowledged that energy intensity is usually measured by the ratio of total energy consumption to total yield. Energy consumed in urbanization, industrialization and technology through various conduction mechanism will ultimately be realized as yield. Therefore, to derive an expression of mathematical correlation between energy intensity and urbanization, industrialization, technology, merging the three with capital, labor and energy in a production function seems feasible.

Based on traditional two-factor production function, the three-factor total production function of capital, labor and energy can be expressed as below.

$$Y = A(\cdot)F(K, L, E) \quad (1)$$

In the expression, *Y* stands for total yield, *K* for capital input, *L* for labor input, *E* for energy input, $A(\cdot)$ for total factor productivity (TFP) which represents all factors affecting total yield except capital, labor and energy. For TFP $A(\cdot)$, the impact of urbanization, industrialization and technology is emphatically concerned.

By bringing urbanization (*u*), industrialization (*ind*), and technology (*tec*) into $A(\cdot)$, the following expression can be derived:

$$Y = A(\ln u, \ln ind, \ln tec) * F(K, L, E) \quad (2)$$

Further, with C-D production function and productivity in the form of the exponent, expression (2) can be dominated as:

$$Y = A_0 e^{\varphi \ln u + \phi \ln ind + \eta \ln tec} K^{\alpha} L^{\beta} E^{\gamma} \quad (3)$$

In expression (3), A_0 stands for initial productivity, α, β, γ for the yield elasticity capital, labor and energy respectively. By dividing *E* from both sides of expression (3), and naturally logarithmizing both sides, the following expression can be derived:

$$\ln\left(\frac{E}{Y}\right) = -A_0 - \varphi \ln u - \phi \ln ind - \eta \ln tec + \alpha \ln\left(\frac{E}{K}\right) + \beta \ln\left(\frac{E}{L}\right) \quad (4)$$

Expression (4) shows clearly that factors influencing national or regional energy intensity include energy consumption per unit capital, energy consumption per unit labor and TFP, which further include urbanization level, industrialization level and technology level. This is the theoretical foundation for the proceeding construction of empirical models.

3. Variable declaration

There are 6 Variables involved in this research, including 1 explained variable which is energy consumption per unit GDP, and 5 explanatory variables including energy consumption per unit capital, energy consumption per unit labor, urbanization level, industrialization level, and technology level. Among the explanatory variables, energy consumption per unit capital and energy consumption per unit labor are control variables, urbanization, industrialization and technology are variables of urban-rural integration.

Energy consumption per unit GDP (*E/Y*) is an index internationally used to measure the comprehensive benefit of national or regional energy consumption, favorable for horizontal or vertical comparison of energy intensity of different locations or time points. This index is directly acquired from *China Energy Statistics Yearbook*, measured in terms of ton coal equivalent (tce) per ￥10000.

Energy consumption per unit capital (*E/K*) refers to the scale of energy that is taken by each unit of capital in production. This is a compound index calculated from dividing the size of the total energy consumption, sourced from *China Energy Statistics Yearbook*, by the size of total capital input. The size of total capital input is roughly measured by the total size of fixed asset investment sourced from *China Statistics Yearbook* over the years[1], in terms of tce per ￥10000.

Energy consumption per unit labor (*E/L*) is also a compound index referring to the energy consumption taken by each unit of labor in production. This index is measured by the total size of energy consumption sourced from *China Energy Statistics Yearbook* and the scale of local practitioners sourced from *China Statistics Yearbook*, in terms of tce per capita.

Urbanization level (*u*) refers to the level of urban development in a nation or district. It is the main indi-

[1] Given the absence of consensus on the measurement of the stock data of capital, and that capital depreciation in different provinces is unlikely to be defined scientifically, only stream data is used for the estimation. However, the estimation made after differencing in the empirical research can neutralize the effect of the substitution of stream data for stock data.

cator of urban population intensity level. This index is measured by urbanization rate sourced from *China Statistics Yearbook* over the years, in terms of a percentage (%).

Industrialization level (*ind*) is an important reference to the economic development of a nation or district. Existing peer papers generally measure industrialization by the weight of industrial value added (employment), non-agricultural value added (employment) or service industry value added (employment). Given that China's industrialization is in the middle and late period when non-agricultural industries go servitization, this index is measured by the ratio of service industry value added accounting for non-agricultural value added, in terms of a percentage (%).

Technology level (*tec*) is the basis and symbol of the advancement and modernization of post-industrial society. This index is measured by the comprehensive index comprised of five aspects including industrial technology, infrastructure, applied consumption, and knowledge support and development effect.

4. Econometric models & empirical research

4.1. Econometric models

In order to study the impact of urbanization (*u*), industrialization (*ind*) and technology (*tec*) on energy intensity, the following model is built based on mathematic expression (4).

$$\ln\left(\frac{E}{Y}\right)_{it} = \beta_1 \ln u_{it} + \beta_2 \ln ind_{it} + \beta_3 \ln tec_{it} + \alpha_1 \ln\left(\frac{E}{K}\right)_{it} + \alpha_2 \ln\left(\frac{E}{L}\right)_{it} + X'_{it}\Gamma_i + \varphi_i + \varepsilon_{it} \quad (5)$$

In the expression, *i* stands for provinces, *t* for time. $\ln u_{it}$, $\ln ind_{it}$, $\ln tec_{it}$ is the logarithm of *u*, *ind* and *tec* of *i* province in the year *t* respectively. $\ln(\frac{E}{K})_{it}$, $\ln(\frac{E}{L})_{it}$ is the logarithm of *E/K* and *E/L* of *i* province in the year *t* respectively. X_{it} stands for other control variables. Some scholars found that income level lays significant impact on energy intensity (Jones, 1989; Martinez-Zarzoso and Maruotti, 2011), therefore net income per capita is added into the model as a control variable. φ_i controls the inter-provincial fixed effect. ε_{it} is the error term. The estimation coefficient of interest in this research is $\beta = (\beta_1, \beta_2, \beta_3)'$. As each variable in the model has been naturally logarithmized, β can be explained as the energy intensity elasticity of *u*, *ind* and *tec*.

In the model above, there is one problem that may cause estimation deviation, which stems from the endogenity of the variable $\ln ind_{it}$. The reason is that the energy intensity of a district can affect its industrialization process. To solve this problem, a two-stage least square method is employed to estimate the fixed effect estimator (abbreviated as IV-FE below), in which the instrumental variable is the industrialization level with two periods' lag[2].

Since improvement of energy efficiency takes a fairly long time, energy efficiency in the current period could be affected by the previous period, implying possible accumulated lagging effect of energy intensity. Upon this issue, Sadorsky (2013, 2014) claims that by introducing one-period lagged energy intensity into the model the accumulated lagging effect can be restrained. Thus the dynamic model below is built.

$$\ln\left(\frac{E}{Y}\right)_{it} = \lambda \ln\left(\frac{E}{Y}\right)_{it-1} + \beta_1^0 \ln u_{it} + \beta_2^0 \ln ind_{it} + \beta_3^0 \ln tec_{it} + \beta_1^1 \ln u_{it-1} + \beta_2^1 \ln ind_{it-1} + \beta_3^1 \ln tec_{it-1} + \alpha_1 \ln\left(\frac{E}{K}\right)_{it} + \alpha_2 \ln\left(\frac{E}{L}\right)_{it} + X'_{it}\Gamma_i + \varphi_i + \varepsilon_{it} \quad (6)$$

In the expression, $\ln\left(\frac{E}{Y}\right)_{it-1}$, $\ln u_{it-1}$, $\ln ind_{it-1}$, $\ln tec_{it-1}$ stands for energy intensity, and the first-order lag term of urbanization, industrialization, technology respectively[3]. Expression (6) is referred to as ARDL, short for Autoregressive Distributed Lag model.

As expression (6) contains fixed effect, after eliminating the fixed effect with difference method, the difference term of the explained variable will be correlated with error term ($E[\Delta \ln(\frac{E}{Y})_{i,t-1} \cdot \Delta\xi_{it}] \neq 0$), which is referred to as dynamic panel bias (Nickell, 1981). To address this issue, Arellano and Bond (1991) proposed that when error term ξ_{it} bears no serial correlation, the second or higher order lag of the explained variable can be used as an instrumental variable of the difference term, that is to say, for endogenous variable $\Delta \ln(\frac{E}{Y})_{i,t-1}$, applicable instrumental variables include $\ln(\frac{E}{Y})_{i,t-2}, \ln(\frac{E}{Y})_{i,t-3}, ... \ln(\frac{E}{Y})_{i,1}$.

When the difference equation does not bear serial correlation, consistent estimation of coefficient $(\lambda, \beta, \alpha, \Gamma)'$ can be made. This method (IV-GMM) can not only eliminate dynamic panel bias of the equation, but solve multiple issues of variable endogenity. Besides, when there is another endogenous variable in the regression equation, adding in its lag term as the instrumental variable can eliminate endogenity.

However, IV-GMM method is limited due to the hypothesis that each cross section has equal elasticity to explained variable it is based on. When the data are cross-sectionally correlated, this hypothesis becomes too rigid and thus estimation deviation arises. To address this issue, this paper adopts a recently

[2] Using the two-period lagged data is in consideration that energy intensity is affected by the current and one-period lagged data, which will be illustrated in the dynamic model.

[3] The first-order lag term is added in order to deduce the error correction model, and study the long-run and short-run impact of the variables on energy intensity.

prevalent method which is mean group (MG) regression method (Pesaran and Smith, 1995; Pesaran, 2006). This method can not only eliminate fixed effect and dynamic panel bias (Pesaran and Shin, 1999), but study the long-run and short-run impact of the variables of interest[4]. Specifically, the idea structure of MG estimation is that regression is made for every cross section, and then the estimation coefficients generated are used as the short-run impact of the variables, the mean value of the estimation coefficients are used as the long-run impact of the variables. Thus MG method allows heterogeneity of the elastic coefficients of different cross sections. correspondent error correction model (ECM) can be deduced as below:

$$\Delta \ln\left(\frac{E}{Y}\right)_{it} = \tau\left[\eta \ln\left(\frac{E}{Y}\right)_{it-1} - \theta_1 \ln u_{it-1} - \theta_2 \ln ind_{it-1} - \theta_3 \ln tec_{it-1}\right] + \mu_{i\Delta} \ln\left(\frac{E}{Y}\right)_{it-1} + \rho_{i1} \ln u_{it} + \rho_{i2}\Delta \ln ind_{it} + \rho_{i3}\Delta \ln tec_{it} + \alpha_1 \ln\left(\frac{E}{K}\right)_{it} + \alpha_2 \ln\left(\frac{E}{L}\right)_{it} + X'_{it}\Gamma_i + \varphi_i + \varepsilon_{it} \quad (7)$$

In the expression, coefficient τ is referred to as error correction coefficient which decides the speed of adjustment to long-run equilibrium. If $\tau \in (-1, 0)$, the equation is dynamically stable and feasible to be converged to long-run equilibrium.

$\theta = (\theta_1, \theta_2, \theta_3)'$ measures the long-run impact of urbanization, industrialization and technology. Coefficient $\rho = (\rho_{i1}, \rho_{i2}, \rho_{i3})'$ measures the short-run impact of the three variables on energy intensity.

4.2. Empirical research

In this section, static and dynamic panel models will be applied to estimate the impact of urbanization, industrialization and technology on energy intensity. In the application of static models, fixed effect estimator (FE) will be first applied to eliminate unobservable inter-provincial heterogeneity, and 2SLS will then be applied to eliminate the endogenity of industrialization (IV-FE). While applying dynamic models, the estimation method by Arellano and Bond (1991) will first be used to settle dynamic panel bias and the endogenity of $\ln ind_{it}$ (IV-GMM), and then MG method will be used to estimate the long-run and shot-term impact of urbanization, industrialization and technology.

(1) Static panel models

a. Fixed-Effect (FE) estimator

Table 1 shows the estimation results generated by the fixed effect estimator based on expression (5). In Table 1, column (1) and (2) illustrates the results from the national sample, column (3) and (4) from the east sample, column (5) and (6) from the mid-west sample; column (5) and (6) illustrates the regression results from the mid-west sample; column (2), (4) and (6) has controlled provincial GDP per capita.

By analyzing the data above, several findings have been made as below.

Firstly, the rise of urbanization level has prompted energy intensity increase. No matter on which level, national, east or mid-west, the elastic coefficient of urban population proportion to energy consumption per unit GDP is significantly positive. Generally, energy consumption per capita in urban areas is greatly higher than that in rural areas. Ongoing urbanization will essentially spur increase of total energy consumption. Urbanization is always accompanied by massive concentration of population and industries into urban areas, with soaring development of transportation and telecommunication, which substantially drives up energy consumption and energy intensity, naturally hindering decrease of energy consumption per unit GDP. This also implies that years of extensive urbanization that features high energy consumption, high cost and low profit is obstructive to sustainable development. In addition, it is notable that urbanization in the east has laid greater impact on energy intensity than in the mid-west. A potential reason for this situation is that the east has an earlier start and faster development, and higher concentration of urban population and non-agricultural industries. Furthermore, with the accumulative effect of energy intensity, years of high energy consumption due to extensive urbanization cannot be digested shortly, causing higher elasticity of energy intensity to urbanization in the east than in the mid-west.

Secondly, rise of industrialization level can significantly lower energy intensity. The regression coefficients of industrialization level from the total sample and subsamples, which is measured by the proportion of service industry value added to non-agricultural industries, are all significantly negative. This suggests that as industrialization moves on, industrial structure has been gradually upgraded and optimized, energy efficiency has been greatly improved, and the servitization of non-agricultural industries has brought about more yield than the energy increase for this transformation which can effectively lower production energy consumption. Due to the implementation of various energy-saving measures and the promotion of energy-saving technology that results in higher efficiency of energy deployment, rise of the portion of third industry can lower energy intensity, and the total effect of economic structure on energy efficiency is positive. These findings also echo the conclusion that structural adjustment can effectively improve energy efficiency by many other scholars.

[4] Generally, MG method obtains consistent and valid estimation by handling samples with large N and large T. Of the sample in this research, T=8, thus the sample does not fully bear characteristics of long time series. However, $\sqrt{N} / T = 0.69$, which is close to 0, and furthermore lower when analyzing subsamples of the east and mid-west. Peasaran (1999) hold the opinion that even when T is relatively small, MG estimation is still consistent, but less valid.

Table 1. Estimation results of FE

	National		East		Mid-west	
	(1)	(2)	(3)	(4)	(5)	(6)
Ind	-0.069**	-0.071***	-0.092***	-0.009***	-0.038	-0.019
	(0.021)	(0.024)	(0.030)	(0.023)	(0.094)	(0.096)
u	0.472***	0.485***	0.913***	0.909***	0.501***	0.511**
	(0.056)	(0.052)	(0.301)	(0.298)	(0.127)	(0.178)
tec	-0.339***	-0.304***	-1.546***	-1.166***	-0.330*	-0.211
	(0. 097)	(0.101)	(0.214)	(0.276)	(0.163)	(0.159)
E/K	0.078***	0.059**	-0.065	-0.040	0.158***	0.121***
	(0.024)	(0.024)	(0.025)	(0.024)	(0.052)	(0.031)
E/L	-0.123***	-0.062	0.026	0.072	-0.182***	-0.164***
	(0.024)	(0.037)	(0.061)	(0.059)	(0.034)	(0.032)
GDP per capita		-4.019***		-3.765**		-2.503
		(1.148)		(1.799)		(1.597)
Constant	-1.316*	8.102***	-5.691***	3.432	-2.054	6.341
	(0.712)	(2.623)	(1.322)	(5.689)	(1.208)	(4.988)
Observation	300	300	110	110	190	190

*Note: ***, **, * indicates significance at the level of 1%, 5%, 10% respectively.*

Table 2. Estimation results of IV-FE

	National		East		Mid-west	
	(1)	(2)	(3)	(4)	(5)	(6)
ind	-0.054**	-0.069**	-0.107**	-0.118**	-0.010*	-0.013
	(0.037)	(0.035)	(0.029)	(0.030)	(0.006)	(0.227)
u	0.426**	0.466***	1.091***	1.117***	0.617**	0.743**
	(0.070)	(0.068)	(0.205)	(0.205)	(0.241)	(0.233)
tec	-0.639***	-0.578***	-1.619***	-1.342***	-0.401***	-0.398***
	(0.108)	(0.112)	(0.244)	(0.431)	(0.132)	(0.139)
E/K	0.060	0.040	-0.119*	-0.146*	0.096*	0.080
	(0.038)	(0.042)	(0.064)	(0.077)	(0.050)	(0.068)
E/L	-0.123***	-0.116**	0.033	-0.002	-0.200***	-0.195***
	(0.046)	(0.047)	(0.071)	(0.085)	(0.063)	(0.063)
GDP per capita		-3.255		-6.307		-2.065
		(2.912)		(8.022)		(5.027)
Constant	-1.328*	5.790	-3.976***	11.103	-0.825	3.856
	(0.686)	(6.432)	(1.268)	(19.228)	(1.152)	(11.699)
Observation	300	300	110	110	190	190

*Note: ***, **, * indicates significance at the level of 1%, 5%, 10% respectively. The instrumental variable is the second-order lag term of industrialization.*

Thirdly, the rise of technology is conducive to lower energy intensity. The elastic coefficient of- energy intensity to technology is significantly negative. It is observable that the level of technology on different layers is negatively correlated with energy intensity. Technology is particularly crucial for raising energy efficiency and lowering energy consumption per unit GDP. In terms of the energy-saving effect of technology, the east district shows greater capability than the mid-west. To specify, when income per capita is controlled, every 1% rise of technology level will result in a 1.166% decrease of energy intensity in the east, which is 0.304% higher than national average, in contrast to a 0.211% decrease in the west. The reason might be that the east district has achieved the highest economic development and the optimal industrial structure, together with greater concentration, developing capability and promotion of information industry in the east than in the mid-west. Therefore the east is better at every aspect of applying IT in energy saving such as energy monitoring and managing consumption, precise energy use and so on, which finally results in higher effect of lowering energy intensity of technology in the east than in the mid-west.

b. Instrumental Variables-Fixed Effect (IV-FE) estimator

It is possible that the results in Table1 are biased due to the endogenity that energy intensity might exert reverse effect on industrialization. To address this issue, two-stage least square is applied to estimate the fixed-effect estimator, with two-period lagged values of industrialization used as the instrumental variable for the current values (see Table 2).

Table 3. Estimation results of IV-GMM

	National		East		West	
	(1)	(2)	(3)	(4)	(5)	(6)
Energy intensity (-1)	0.892***	0.879***	0.864***	0.852***	0.869***	0.870***
	(0.078)	(0.084)	(0.107)	(0.108)	(0.088)	(0.089)
ind	-0.043	-0.046	-0.077**	-0.064*	-0.150**	-0.162**
	(0.209)	(0.199)	(0.031)	(0.031)	(0.134)	(0.137)
u	0.066	0.071	0.038	-0.046	0.062	0.069
	(0.266)	(0.257)	(0.452)	(0. 416)	(0.465)	(0.463)
tec	-0.371**	-0.371**	-1.420**	-1.474***	-0.725***	-0.736***
	(0.165)	(0.163)	(0.242)	(0.245)	(0.036)	(0.028)
ind (-1)	0.038	0.044	0.011	0.008	0.075	0.122
	(0.047)	(0.051)	(0.025)	(0.023)	(0.133)	(0.116)
u (-1)	0.808	0.833	0. 877**	0.825**	0.834	0.874
	(0.542)	(0.564)	(0.341)	(0.270)	(0.593)	(0.596)
tec (-1)	0.316***	0.305***	0.506	0.432	0.349***	0.342***
	(0.084)	(0.076)	(0.614)	(0.672)	(0.069)	(0.070)
E/K	0.052	0.054	-0.091	-0.033	0.001	0.001
	(0.099)	(0.098)	(0.056)	(0.060)	(0.093)	(0.092)
E/L	-0.291***	-0.307***	0.106***	0.033	-0.215***	-0.210***
	(0.033)	(0.030)	(0.054)	(0.058)	(0.029)	(0.024)
GDP per capita		0.004		1.875		1.394
		(4.269)		(6.284)		(5.073)
Hensen *P*	0.328	0.327	1.000	1.000	0.943	0.946
AR2 *P*	0.735	0.755	0.449	0.895	0.964	0.953
Observation	300	300	110	110	190	190

*Note: ***, **, * indicates significance at the level of 1%, 5%, 10% respectively. The instrumental variables are the second and higher order lag terms of energy intensity and the second-order lag term of industrialization.*

Table 4. Estimation results of MG

	National		East		Mid-west	
	(1)	(2)	(3)	(4)	(5)	(6)
Long-run impact						
ind	-0.113	-0.127	-0.310**	-0.312**	-0.282	-0.198
	(0.108)	(0.133)	(0.125)	(0.127)	(0.476)	(0.499)
u	1.766**	1.819**	1.910**	2.142*	2.531**	2.601**
	(0.620)	(0.617)	(0.911)	(1.136)	(1.130)	(1.302)
tec	-0.412	-0.593	-2.108***	-2.308	-0.226	-0.249
	(0.445)	(0.516)	(0.348)	(2.445)	(0.781)	(0.633)
GDP per capita		9.464		33.670		29.886
		(7.251)		(58.245)		(42.612)
Short-run impact						
Error correction coefficient	-0.313***	-0.320***	-0.281***	-0.276***	-0.249***	-0.244***
	(0.054)	(0.057)	(0.082)	(0.078)	(0.062)	(0.061)
ind	-0.033	-0.034	0.023	0.025	-0.148	-0.177
	(0.092)	(0.097)	(0.034)	(0.037)	(0.134)	(0.136)
u	-0.628***	-0. 655***	-0.698**	-0.701**	-0.908**	-0.907**
	(0.139)	(0.141)	(0.349)	(0.350)	(0.366)	(0.367)
tec	-0.331***	-0.329***	-0.675	-0.698	-0.355***	-0.367***
	(0.096)	(0.100)	(0.871)	(0.824)	(0.109)	(0.109)
Constant	-1.027**	-7.565	-1.809*	-19.624	-1.886**	-14.476
	(0.340)	(6.265)	(1.024)	(32.72)	(0.899)	(19.857)
Observation	300	300	110	110	190	190

*Note: ***, **, * indicates significance at the level of 1%, 5%, 10% respectively.*

Table 2 shows that elastic coefficients of industrialization are between -0. 01 and -0.07, lower than that in Table 1, implying upward bias of estimation due to uncontrolled endogenity of industrialization. One possible reason is that some less developed provinces are inclined to extensive industrial develop-

ment for expected economic growth. It is found by the regression of the mid-west sample (results unreported) that every 1% rise of energy intensity will cause a significant 0.12% rise of industrialization.
As for the other two variables of interest, urbanization and technology has similar estimation results from IV-FE as those from FE. When the model controls regional income level, the elastic coefficients of urbanization are between 0.47 – 1.12, all significant at the level of 5%. This suggests poor energy efficiency and unrestrained energy intensity in the urbanization of China, and that energy intensity kept rising during the process of urbanization as a matter of fact. Similarly, compared to the mid-west, the east makes higher energy intensity with the same rise of urbanization level. In terms of technology, the elastic coefficients are between -0.40 to -1.34 all significant at the level of 1%. Particularly, every 1% rise of technology level can bring about 1.342% decrease of energy intensity in the east, 0.944% higher than that in the mid-west, again confirming the capability of saving energy by information technology of the east.

(2) Dynamic models

a. Instrumental Variables-Generalize Method of Moments (IV-GMM) estimator

The static FE estimator hypothesizes that energy intensity is only affected by the current values of the variables, which is too rigid for the concerned issues in this paper. On one hand, as regional energy efficiency is influenced by cohesive factors such as technology and industrial structure, energy intensity might as well be influenced by the past values of these factors. On the other hand, national or regional energy intensity can possibly possess an accumulative effect, meaning probable impact of the past energy intensity values on the current values. Given the two problems above, IV-GMM by Arellano and Bond (1991) is introduced in this paper to estimate the dynamic model set by expression (6). To eliminate the dynamic panel bias, second and higher order lag of energy intensity is used as the instrumental variable. Meanwhile, considering the endogenity of industrialization level, the instrumental variable also contains second-order lag of industrialization level[5]. Table 3 illustrates detailed estimation results.
Table 3 gives out several messages. Firstly, the impact of current values of urbanization on energy intensity is obviously smaller than that in Table 2. To illustrate, on the basis of national sample, the elastic coefficient shrinks from 0.47 to 0.07 with insignificance, which, however, does not negate the impact of urbanization on energy intensity. Instead, it is found that the impact lies with the lag terms of urbanization. As column (2) in Table 3 shows, the elasticity of energy intensity to urbanization is 0.83. The reason is that urbanization has different impact on energy intensity in a short term and a long term, which will be discussed thoroughly in the next section.
Secondly, compared to the results from IV-FE, the impact of industrialization on energy intensity is also greatly smaller, and yet unlike the pattern that the impact transfers to lag terms of urbanization, the elastic coefficients of industrialization lag terms are tiny and insignificant, possibly due to the control on the lag terms of energy intensity in the dynamic model. This confirms the idea that energy intensity lays reverse impact on industrialization in the former section.
Thirdly, the estimation values of technology are between -0.37to -1.47, all significant at the level of 5%. Technology is more effective in lowering energy intensity in the east than in the mid-west.
Fourthly, significant accumulative effect has been observed in energy intensity. Every estimator has generated similar coefficient estimation values of around 0.87, all significant at the level of 1%, well supporting the hypothesis of accumulative effect in energy intensity. The estimation value is lower than 1, implying a decline with time of the accumulative effect.
Lastly, the last two rows in Table 3 reports *P* values of Hensen over-identification test and autoregressive test on the second-order residual. Relatively high *P* of over-identification test evidences that the model does not reject the selected instruments. Relatively high *P* of second-order autoregressive test suggests that the residual of the difference equation[6] of expression (6) does not bear first-order serial correlation, so that the second-order lag of energy intensity can be used as the instrumental variable for its difference term.

b. Mean Group (MG) estimation

The IV-GMM estimator has controlled the lag values of energy intensity, industrialization, urbanization and technology. When the model controls first-order lag terms, it equivalently assumes a time limit of the correlation between the explanatory variables and the explained variable. Thus questions arise, is the impact of industrialization, urbanization and technology on energy intensity in long run or short run? Is the long-run and short-run impact the same? MG

[5] Using only the second order without higher order lag terms of industrialization is to cohere with the instrumental variables in IV-FE estimator, so that the results can be comparable.

[6] It is necessary to do a first-order difference when estimating expression (6) by the method of Arellano and Bond (1991). As the right side of the equation contains the difference terms of the explained variable, it will be inevitably correlated with the difference terms of the residual, which is called the dynamic panel bias. Only when the residual of the difference equation does not bear first-order serial correlation, (immediately the original equation does not bear second-order serial correlation), second or higher order lag terms of explained variable can be used as the instrumental variables for the equation's difference terms.

method can answer to these questions fairly well. Table 4 illustrates the estimation results of expression (7) by MG method.

In the short run, urbanization has negative impact on energy intensity. When the local income level is controlled, the elastic coefficients are between -0.66 to -0.91. As in the early stage of urbanization, it is possible to quickly integrate industries, intensively using resources and forming a competitive labor market to increase yield fast, so that energy efficiency is improved, which echoes the conclusion of Sadorsky (2013, 2014). However, in the long run, the impact of urbanization on energy intensity is positive. When the local income level is controlled, the elastic coefficients are between 1.82 to 2.60, all significant at the level of 5%. The diametrical results have revealed the abnormality of China's urbanization that after achieving fixed advantage in the early stage of urbanization, districts failed to maintain the energy saving advantage from urban concentration and intensity, especially to reconcile energy consumption and urban development. Therefore rapid urbanization has always been accompanied by wasteful consumption. It can be foreseen that China trades energy efficiency for urban development in the long run, the potential and sustainability of urbanization is undermined greatly.

The impact of industrialization on energy intensity is insignificant in both short and long run, except that it is significantly negative in the east. It is notable that MG method cannot possibly control the endogenity of industrialization, so the estimation of industrialization elasticity will be upward biased. Therefore, the estimation results of industrialization elasticity in Table 4 are more acceptable.

The impact of technology on energy efficiency is positive in both short and long run, while it is greater in the long run, and yet more significant in the short run. To illustrate, based on the national sample, the long-run impact of technology is -0.59 compared to -0.33 for the short-run impact, but the latter is significant on the level of 1% while the former is not. The east is more effective in applying technology in energy saving in both short and long run, coherent with previous findings. In the short run, the technology elasticity in the east is 1.90 times of that in the west, but in the long run this number rises up to 9.27.

5. Research conclusion and policy suggestion

China has a large stock of energy, but its per capita stock is poor. Years of extensive development in China have aggregated the conflicts between energy consumption, ecological environment and sustainable economy. The economic and intensive use of energy, reduction of energy intensity and realization of sustainable development has become an issue of common concern in Chinese political and academic field. The acceleration of China's urban-rural integration is doomed to cause higher energy consumption and greater burden on energy conservation and consumption reduction. However, on the other hand, urban-rural integration can improve the energy intensity through the urbanization, industrialization and technology. The compound of the positive and negative effect makes the trend of Chinese energy intensity appear to be complicated and confusing.

Proceeding from Chinese national condition of economic development mode transformation and against the backdrop of accelerated and integrated development of urbanization, industrialization and technology, this research discusses the mathematical relationship between energy intensity and urbanization, industrialization and technology by relying on the production function of three factors, namely capital, labor and energy. Based on that, the static and dynamic panel models are established. Four estimation methods, including FE, IV-FE, IV-GMM and MG are used to analyze the economic data of 30 provinces and cities from 2005 to 2014, which empirically demonstrate the relationship between energy intensity and urbanization, industrialization and technology. The research findings show that, first, urbanization can significantly reduce energy intensity within a short period of time, but Chinese government fails to continuously employ its positive role in energy conservation, thus resulting in the positive long-run influence of urbanization on energy intensity. Second, after the endogenity of industrialization is controlled, IV-FT and IV-GMM suggests that the acceleration of industrialization level could effectively improve energy intensity. Third, the short-run and long-run role of technology in promoting energy efficiency and reducing energy intensity is worth more attention.

Based on this research, the following policy suggestions can be put forward. First, Chinese government should emphasize on the lagging and cumulative effective, actively coordinate the short-run and long-run relationship between energy consumption in the past, present and future, between economic and social development and energy consumption, and strive to build an energy-saving and environmental-friendly society. Second, Chinese government should handle well the short-run and long-run conflicts in the urbanization development, improve the urbanization develop path, and innovatively transform the short-run growth advantage of talent, techniques and industry into long-run energy saving and cost-effective advantages, and vigorously promote the construction of environmental-friendly, low-carbon and intensive urbanization. Third, Chinese government should strengthen the transformation of its industrial development mode, accelerate the upgrade of industrial structure, build a modern energy-saving industrial system and fully release and promote the structural bonus of energy efficiency in the dynamic promotion of new type industrialization. Forth, Chinese government should emphasize the role of technology in energy-saving fields, dig the potential of technology-based energy conservation in the big data era and contribute to the reduction of energy intensity.

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