Analysis of low carbon production chains towards modified forward coefficient

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Abstract:

To achieve the target, the Chinese government announced their pledge to reduce carbon intensity (the amount of CO2 emitted per unit of GDP) by 40%-45% of the 2005 level, by 2020, it is usual to allocate emission reduction tasks based on industrial sectors. However, it is visible that this allocation approach by sector is unfair and unfeasible due to all sectors are correlated with each other. Firstly, industrial sectors do not exist independently in the complexity of economic system. It has relationship between two Industrial sectors, backward and forward partnership, based on certain technical and economic linkages. Secondly, an effective emission reduction allocation is to minimize the reduction cost under a specific target, emphasizing the global optimum rather than local optimum. Thirdly, the adjustment of the industrial structure is shown by the structure of production chains to reduce emissions effectively. Only by evaluating the profit distribution and emission characteristics of the whole production chain, can we upgrade the traditional industrial structure effectively. This will help accelerate the development of low carbon production chains, encourage alternative traditional energy.

This paper establishes the price multiplier model to calculate the major production chains in non-serviced sectors. However, the traditional forward coefficient cannot be reflected the exact forward relationship between service sectors, and there is backward relationship in non-service sectors. So this paper proposes the modified forward coefficient based on input-output model and choose the integrated transmission paths in service sectors. The empirical results show that sectors with high emissions located at the downstream such as electricity sector are key sectors to reduce carbon emissions. Policies to enhance low carbon production chains (LCPCs) should be considered seriously.

1 Introduction

In 2009, the Chinese government announced their pledge to reduce carbon intensity (the amount of CO_2 emitted per unit of GDP) by 40%-45% of the 2005 level, by 2020. To achieve the target, it is usual to allocate emission reduction tasks based on industrial sectors. However, t is visible that the allocation approach by sector is unfair and unfeasible due to all sectors are correlated with each other.

Firstly, as the complexity of economic systems, industrial sectors do not exist independently. Various industrial sectors often form backward and forward partnerships based on certain technical and economic linkages, supply and demand relationships, and develop the form of a production chain to balance and stabilize national economies. For example, photovoltaic cells are an alternative product to fossil fuels and help meet the demands of low energy consumption and low emissions, but the backward sector production requirements of polysilicon feedstock is a high emission product and needs to be controlled. However, from a whole production chain point of view, it is a low carbon production chain (LCPC) that requires further development to replace traditional high-emission production chains.

Secondly, an effective emission reduction allocation is to minimize the reduction cost under a specific target, emphasizing the global optimum rather than local optimum. In order to achieve emission reduction targets and maintain its own profits, an industrial sector generally transfers its own emission reduction cost to its forward sectors, ultimately leading to the whole production chain emission reduction cost increasing. Therefore, we need to re-evaluate the cost effects of the different sectors in various production chains.

Thirdly, the adjustment of the industrial structure is the principal way to promote effective emissions. From a systematic perspective, the evaluation standard of a country's emissions reduction efficiency is the average level from all industries or regions, rather than the best or the worst sector in the production chain.

Fourthly, the adjustment of the industrial structure is shown by the structure of production chains to reduce emissions effectively. Only by evaluating the profit distribution and emission characteristics of the whole production chain, can we upgrade the traditional industrial structure effectively. This will help accelerate the development of low carbon production chains, encourage alternative traditional energy, and result in the optimization and support of the industrial structure. Therefore, compared with energy efficiency among various production chains, it can better embody the overall level of emission reduction and reflect technical efficiency. In order to achieve the emission reduction target, we should focus on improving production chains with higher emissions, rather than focusing on separate industry sectors.

This paper focuses on the cost impact of China's low carbon production chains under the emission reduction target. The remainder of the paper is then structured as follows. Section 2 contains the literature review; the price multiplier model is developed in Section 3 which discusses the size of the linkages between sectors. It estimates the main industrial sectors which are largely influenced by emission reduction targets, taking price multiplier effect into account. In order to investigate the distances between sectors, the averaged propagation length (APL) method has been applied to the Chinese economy, the results of which are shown in Section 4. By analyzing the price multiplier effect and transmission path, we can construct major chains which are the most significant in emission reduction. We can also research the industrial emission and profits distribution, carbon intensity and competitiveness of production chains. The conclusions and policy recommendations are given in Section 5.

2 Literature Review

The general methods used to analyze emission reduction cost and macro-economic impacts are based on input-output methods and computable general equilibrium (CGE) methods, combined with multi-objective programming and econometrics. Manne and Richels (1991), using the Global 2100 model systematically estimated carbon dioxide emission impacts on the U.S. macro-economy; Rose and Steven (1993) proposed a nonlinear programming model to simulate and estimate the net benefit changes resulting from eight countries' carbon dioxide emission reduction strategies; Hsu and Chou (2000) estimated emission macro-economic cost reduction in Taiwan, China, based on a multi-objective planning method for a number of cases; Yang (2000) estimated the carbon dioxide emissions macro-economic costs in Taiwan, based on a multi-objective planning model; Fan, Zhang and Zhu (2010) estimated and systematically analyzed carbon dioxide abatement macro-economic costs in China for 2010, based on input-output multi-objective planning methods; Ellerman and Decaux (1998) and Criqui, Mima and Viguier (1999) analyzed carbon emission reduction costs using a CGE model; Zhang (1996) studied electricity generation costs and the marginal carbon dioxide abatement costs of Chinese power plants; Chen, Gao and He (2004) and Chen (2005) took advantage of China's MARKAL-MACRO model to estimate the marginal abatement cost of carbon; Wang, Chen and Zou (2005) estimated the emission abatement marginal social cost and marginal technology cost using a dynamic CGE model.

Since the global economy over reliance on resource based products, a large number of publications have been concerned with energy price shocks and the macro-economic impact. Bruno and Sachs (1979) claimed that the intermediate inputs' price rises would lead to a total output decrease for the country that was more heavily dependent on oil imports, with limited domestic alternatives. Barsky and Kilian (2002; 2004) explored the macro-economic impact of oil price fluctuations and how oil price fluctuations can affect the economic recession, inflation, growth and so on; Berument and Tasc (2002) used the Diego method to analyze the oil price rise inflationary effects, based on input-output tables in Turkey, 1990; Valadkhani and Mitchell (2002) referred to an improved input-output model to calculate the impact of the rise of oil prices on various sector costs, total output, household spending and inflation in Australia; Doroodian and Boyd (2003) used a dynamic computable general equilibrium (CGE) model to simulate the impact of oil price fluctuations on the U.S. manufacturing sector and the consumer price index in different scenarios; Fan and Jiao (2008) concluded that the rise of the international oil price has a direct impact on China's economy; Lin and Mu (2008) examined the energy price impact on macro-economics under a computable general equilibrium framework; He and Xu (2006), using China's social accounting matrix in 2002, calculated the oil price change impact on product costs in various sectors with the general price level. They then further investigated the specific pathway that the price transmission in other industries caused by refined oil prices.

In addition, from the perspective of the latest input-output technology, Dietzenbacher, Luna and Bosma (2005) proposed that economic distance exists among production sectors based on the input-output technology, and defined it as average production step (APL). Moreover, they analyzed the production chain structure by a combination of Leontief inverse matrix and APL. Deng and Chen (2008) used an APL model to carry out empirical research on important production chains existing in the Chinese national economy, from 1987 to 2002, and investigated the evolution of the agricultural production chain.

3 Model

3.1 Price multiplier model

In order to achieve emission reduction targets, some macro-economic policies, such as carbon tax, may be issued, which usually cause cost and product price rising in most sectors. This cost rising may transfer to other sectors and cause rising of cost more or less in different sectors. This forms the main part of emission abatement costs. So we can explore the effect of emission reduction policies as a price shock.

Price multiplier effect refers to the extent of reaction of the whole production chain in terms of cost and production quantity caused by a price shock (changing) in an iterative way, both directly or indirectly. Therefore, the achievement of emission reduction targets will interfere with business activities in the whole economy. For example, household consumption level is influenced by a variety of consumption activities, which will impact government revenue, capital savings and other kinds of final demands. The impact of emission reduction will be reflected in final demands and the overall price level in the social accounting system. This will ultimately impact on China's macro-economy (Wang and Li, 2008).

In the price multiplier model, the product price is changing at the same proportion as its production cost, and has no relation to the level of production. Assuming that the change of production output and price are independent:

Based on the column equilibrium of social accounts matrix (SAM), the equation is:

$$P = PA + W \Rightarrow P = w(I - A)^{-1} = w'M \tag{1}$$

$$P' = M'w \tag{2}$$

$$\Delta p_j = [I - A^T]\Delta w_i \tag{3}$$

Where, A means the average consumption tendency of endogen variables in SAM, the element a_{ij} denotes direct consumption in sector i per unit product for domestic demands in sector j, $A = \begin{bmatrix} A_{kk} & A_{k(n-k)} \\ A_{(n-k)k} & A_{(n-k)(n-k)} \end{bmatrix}$.

There are (n-k) sectors directly affected by exogenous price shocks and k sectors indirectly affected by price transmission. W is the leakage matrix from endogenous to exogenous accounts. M' is the price multiplier matrix, and I is the unit diagonal matrix.

3.2 Price Sticky

Price stickiness means the real price is not completely changed following the changes of market factors with incomplete information transmission controlled by government guide prices under the planned economic condition. Therefore, production costs of the regulated sectors were changed by external shocks, but their producer price was constant. The transmission is not always complete, which demonstrates the existence of price stickiness when production costs are transmitted to prices between two sectors. The reason can be due to three issues:

1) Government pricing

In order to encourage economic stability, the government usually exerts price control on some important products in different periods, such as oil, electricity, medicine, water, chemicals, foodstuff and post. However, the increased cost of raw materials or other sectors' price rises cannot be completely transmitted to these regulated sectors.

2) Enterprise competition

In order to keep enterprises competitive, the affected enterprises may not pass on price increases into their forward sectors when they are facing the increased price of raw materials. At this time, the transmission of the information from external price shocks is not complete.

3) Salary sticky

Enterprises usually adopt cost plus pricing. As part of the cost, the labor wage influence on producer price is not synchronous. Therefore, the information transmission of labor wage is not complete, either.

In order to verify the price stickiness, this paper discusses the correlation between economic growth rate and the main price indices, such as CPI, PPI, and APPI (Agricultural production price index) and others, as shown in Figure 1. The changes of price indices have the same trend, basically indicating that prices in different sectors are correlated. In addition, it is also shown that different time lags between curves indicate that prices do not change synchronously, and price stickiness exists.

If the change in production cost in sector *i* is Δp_i, under a complete information situation, a corresponding increase in cost in its forward sector *j* is $a_{ij}\Delta p_i$. Defining the real cost change in sector *j* is Δp_j, so the price sticky rate β_{ij} can be written as,

$$\beta_{ij} = \Delta p_j / a_{ij}\Delta p_i \tag{4}$$

The price multiplier model can be expressed in a matrix form as

$$\Delta p_j = [I - \beta A_{kk}{}^{T}]^{-1} \beta A_{(n-k)k}{}^{T} \Delta p_i \tag{5}$$

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Fig. 1
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3.3 MAC and reduction cost model

Taking into consideration the loss of carbon dioxide emissions reduction; the marginal abatement cost (MAC) curve is exponential with a positive initial value. The function for marginal abatement cost is as follows:

$$MC_t(R_t) = a_t^{1+R_t} \tag{7}$$

Where, a_t means initial value of MAC and total technical efficiency in the *t* th year; R_t is the emission reduction ratio, *$R=D/CO_2*100$*; *D* denotes the emission reduction quantity. The reduction cost is calculated as follows:

$$K_t(D) = \int_0^d MC(R)dD \tag{8}$$

Where K_t is the emission reduction cost in t th year. Considering the net present value (NPV) of emission reduction cost, the discount rate is assumed as the one year benchmark lending interest rate at 7%. Based on 7% economic growth, the average annual reduction costs are 215.54 billion and 446.56 billion yuan, under the 40% and 45% reduction targets in 2020, respectively.

Using China's 2007 SAM table with 42 sectors and 8 accounts (see Appendix 1), the price multiplier effect to achieve the emission reduction target is calculated. The endogenous accounts include production sectors, factors, residents and enterprise, while exogenous accounts include government, the rest of the world and capital. The production factors account is further divided into agricultural labor, production labor, professional labor, and value capital. Residents category is also further divided into rural household (HHRural) and urban household (HHUrban). To achieve reduction targets, major sectors and affected degrees are presented on Figure 2.

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Fig. 2

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Figure 2 reveals that the main sectors significantly influenced by price shocks include electricity production, gas, coal mining, petroleum refining and water sector. Taking the electricity production sector for example, in order to achieve emission reduction, the price of power will be affected by cost shocks. It increases by 3%, of which 1.85% comes from direct emission reduction costs in electricity production, and the remainder from indirect reduction costs caused by all the other sectors. The sectors whose prices increase most in direct reduction cost caused by cost shocks, include electricity production, gas, building materials, metal smelting and coal mining sectors. Sectors influenced most by indirect cost increases through price transmission are electricity production, water, construction, building materials and metal smelting sectors. From the industries point of view, it can be seen that electricity production, building materials, coal mining and water sectors are influenced most by all the effects (direct, indirect and total effect), while construction, electricity machinery, other manufacturing sectors have the biggest price multiplier effect and smallest direct influence. Transport and petroleum refining sectors have the greatest pressure on emission reduction cost themselves and are influenced least by indirect effects.

The research also indicates that the overall price index will increase by 0.66% and CPI will increase by 0.52% to achieve the 40% reduction target. They will have to double to achieve the 45% target. Moreover, the effect of emission reduction targets on rural residents is greater than that on urban people. Assuming that the industrial structure is the same as that in 2007, calculation of the results reveals a rural consumption price index (RCPI) rise of 0.5% annually, while urban consumption price index (UCPI) rises by 0.4% annually to meet the 40% target. Although CO_2 emission by rural people is lower than that of urban people, due to the low income reality of urban residents, they will suffer a greater loss and shock per unit emission reduction. If they take no action, emission reduction targets will widen the gap between income and consumption for urban and rural residents. Moreover, emission reduction will become an extra economic burden for rural residents, lowering standards of living, consumption levels, and will affect agricultural development and social stability.

4. Low Carbon Production chain Analysis

4.1 APL model

Production chains are the way sectors are correlated. All sectors, from raw materials to final demand products, are related through production chains. There is a great deal of value flow exchange from backward to forward sectors, and feedback information along the chain in the opposite direction. However, the multiplier is usually induced by the multiplier effect of the production chain, that is, the benefit changes from any noted sector will lead to a corresponding effect on the other related sectors in the same chain. The low carbon production chain (LCPC) is used to describe those chains whose aggregate emissions are relatively low, for example, those with a third industry as the core of the production chains. Finally, the sustainable development of production chains would be realized by low emissions and low energy consumption, from the production of raw materials, to consumers' purchase of the final products. In this paper, the production chain named by its core sector, such as the real estate production chain, refers to the real estate sector as its core in this chain. The LCPC refers to the high value added and low emission of the production chain. Therefore, there are 42 production chains listed with different core sectors which can be found using the 42 sectors of the Chinese SAM table in 2007. By combining the same chain, there are 27 production chains determined in our paper (Appendix 2).

In the Average Propagation Length（APL）model, the correlation among sectors is not only determined by the degree of the linkage among sectors but also influenced by the economic distance among them (Dietzenbacher, Luna and Bosma, 2005). APL denotes the economic distance between two sectors, calculated by the average steps among various paths. The metrics of APL can explicitly shows the industrial structure of an economy. In our paper the APL model is extended by relaxing some restrictive assumptions originally used and by introducing CO_2 emission quantity flows into the 42 production sectors.

Defining the output coefficient b_{ij} denotes the production quantity of the commodity *j* per unit commodity *i*. The changes in output $\Delta X'$ due to the change of Δw as,

$$\Delta X' = \Delta w(I - B)^{-1} = \Delta wG \tag{9}$$

Due to cost push, when production cost change Δw in sector *i*, it would be initially deduced that the output values change by $\Delta X'$, which is decomposed into the initial effect Δw, and indirect effects by matrix G. In matrix G, the element g_{ij} denotes the total direct and indirect influence of cost-push from sector *i* to sector *j*.

The matrix S of APL is defined as

$$S = G(G - I)/(G - I) \tag{10}$$

4.2 Major production Chains

The detailed price transmission path can be developed, after a discussion of the price multiplier model. In this section, we manage to separate the major production chains according to their CO_2 emission (CO_2) and value added (VA), using the price multiplier model in Section 3, and APL model in Section 4 for the Chinese macro-economy. A discussion of the characteristics of production chains by CO_2 and VA distribution are shown in Figure 3 and Table 1. In an input-output framework, the relationships between two sectors, are examined by way of the purchases and sales of intermediate inputs. Forward linkages show the relationship between the core sector and its downstream sector; backward linkages show the relationship between the core sector and its upstream sector. That is, if forward sector j buys some of its inputs from core sector k, and core sector k buys inputs from backward sector i, production cost in forward sector j depends on input price from backward sector i (Dietzenbacher, Luna and Bosma, 2005). This paper defines the linkage between two sectors and is an average value of backward and forward linkage values.

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Table 1
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Fig. 3
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The research results show that the major production chains can be divided into four categories: high emission and high VA; high emission and low VA; low emission and high VA; and low emission and low VA. The former two categories are defined as high-carbon production chains (HCPC), and the latter two are named low-carbon production chains (LCPC).

4.2.1 HCPC - high emission and high VA

In total, 13 production chains belong to this category, mainly involving production chains prioritizing heavy industry. For example, electricity production, metal smelting, petroleum refining and building materials, and some production chains such as agriculture, food, paper and other light industry as the core sector. These production chains generate lots of emissions and gain higher VA (profit). The selective analysis of the most representative production chains is as follows:

(1) ElecProd production chain

It is the largest CO_2 emission and VA production chain, in 2007. CO_2 emissions account for 56.6% of the total emission of China and VA accounts for 22.18% of GDP. The backward and forward sectors of the electricity power sector as core are in turn: coal mining, electricity production, metal smelting, metal production, machinery, transport equipment and transport sector. The strongest linkage is between the coal mining and electricity production sectors in the chain, the linkage value is 0.452. It is an indication that if production costs in the coal mining sector increased by 1 unit, the electricity power producer price will be increased by an average of 0.452. To achieve the 40% CO_2 emission reduction target by 2020, the reduction cost of ElecProd production chain will be increased by 0.378%, of which the cost in electricity production sector will be increased by 1.85% annually. Costs in other forward sectors will be increased by, in turn: 0.148%, 0.196%, 0.096%, 0.063%, and 0.074%. Taking the industry structure into account, the biggest emission resource in the chain comes from the electricity production and metal smelting sectors, but the largest VA share is distributed into the transport sector.

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Fig. 4
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(2) Agri-Food production chain

This is the second largest VA production chain. Its VA accounts for 16.91% of GDP, CO_2 emissions account for 11.6% of total emissions in China in 2007. The backward and forward sectors of the agriculture and food manufacturing sector as core are, in turn: HHRural, agriculture labor, agriculture, food, restaurant, HHUrban and production labor. The strongest linkage is between agriculture labor and agriculture sectors, the linkage value is 1.186. It indicates that if agricultural labor’s salary cost increases by 1 unit, the APPI will be increased by an average of 1.186. The reduction cost of the Agri-Food production chain will be increased by 0.078%, where the cost in agriculture sector will be increased by 0.10% annually. Costs in other forward sectors will be increased by, in turn: 0.038% and 0.028%, UCPI is increased by 0.009% and production labor’s salary is increasing by 0.01%. Taking industry structure into account, the biggest emission resource in the chain comes from the HHUrban sector, but the largest VA share is distributed into the agriculture sector.

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Fig. 5
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4.2.2 HCPC - high emission and low VA

Only 3 production chains belong to this category, including OthManuf, Gas and Water production chains. For example, water is not a high CO_2 emission sector, its VA and emission share account for 3.78% and 0.44% of its production chain, respectively. However, Water production chain accounts for 5.5% of GDP, and 29.62% of total CO2 emissions in 2007. The backward and forward dependencies on the water sector are, in turn: coal mining, electricity production, and water sectors. In this production chain, coal mining and electricity production all belong to the high emission sectors. From a production chain point of view, the chain is also the HCPC.

4.2.3 LCPC - low emission and high VA

Unlike the HCPC, there are 2 production chains (SawFun and Commerce) that belong to the high VA LCPC and can gain lots of VA with lower emissions. For example, with SawFun production chain, its VA accounts for 6.3% of GDP, CO_2 emissions account for 1.56% of total emissions, of which 85% of VA and emission occurs in the construction sector of this chain. The backward and forward sectors are, in turn: sawmills, furniture, fiberboard and other wood products manufacturing and construction sectors. The biggest linkage between the two sectors is 0.16. It is an indication that if the production cost in sawmills, furniture, fiberboard and other wood products manufacturing sector is increased by 1 unit, the production cost of construction will increase by an average of 0.16.

4.2.4 LCPC - low emission and low VA

Ten production chains belong to this category and have low emission and high VA as the tertiary industry sectors core point. The backward and forward sectors involve residents, government and production. From the structure of a production chain point of view, the emissions mainly come from residential activities, but the distribution of VA is always into the tertiary industry point. For example, with the RealEst production chain (Figure 6), its VA accounts for 4.45% of GDP and CO_2 emissions account for 4.91% of total emissions. The backward and forward sectors are, in turn: enterprise, capital, real estate, HHUrban and production labor. The biggest linkage between enterprise and capital in the chain is 1.174. It indicates that if the capital revenue is increasing by 1 unit, the investment will be increased on average by 1.174.

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Fig. 6
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4.3 Emission intensity and market competitiveness in LCPC

In this work, the energy intensity index is introduced to describe emission efficiency in production chains. In 2007, energy intensity of production chains (tce/10^4yuan), MetalProd (0.429), Machinery (0.331) and TranspEq (0.274), are all lower than the national level (1.055). Table 2 lists the highest categories of the energy intensity production chains. The emission efficiency of production chain depends on the average level of all sectors in a production chain, but not the highest or lowest energy efficiency sector. Take the ElecProd chain, for example, table 3 displays the energy intensity by section and overall level in this chain, in which the intensity value of ElecProd (8.382) and MetalSmelt (4.476) are too high, leading to the overall level being only a third of the averaged level.

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Table 2
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Table 3
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In addition, with increasing market demand and expansion of the scale of enterprise, a towing services competition system is gradually formed, with the competition in sectors already changed into that of production chains. Competition is not only involved in product quality and technology, but also in service. To enhance the competitiveness of a production chain, we must strive to develop LCPCs by lowering emissions from manufacturing, sales and service. Defining the market share of the production chain equal to the share of VA, accounts for the GDP. It is shown in Figure 7 that so far, the HCPCs have much more competitiveness than that of LCPCs, with the marketing share of the production chain almost above 10%. The production chains with highest market shares are, in turn: ElecProd, Electron, MetalSmelt, Waste, TranspEq, ElecMac, Textile, Agri-Food, Paper and BuildMat production chains. Compared with the competitiveness of the production chains, the competitiveness of LCPCs are weaker than that of HCPCs. The most probable reason is a different industrial structure. In 2006, the average proportion of American third industry reached 72.8%, with the world's proportion reaching 69%. Even low income countries reached 47.5%, but the Chinese index only reached 43.4% in 2009.

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Fig. 7
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5 Summary and conclusion

To identify production chains in an economy, linkages and distances between sectors play an important role. This paper employs a price multiplier model to measure linkages, and uses an APL model to measure distances between sectors. In our empirical research, we have applied these approaches to the 2007 SAM table of China to identify major production chains in the economy. The results reveal some important conclusions.

Firstly, the electric power industry is the core sector of HCPCs, and it appears to be the key point for adjustment of industrial structure. Urban residents are the core of the LCPCs, and many products are produced directly to meet the residents' demand.

Secondly, sectors with high emissions located at the downstream of most HCPCs, such as traffic transportation and construction production chains, should have imposed a stricter emission standard.

Thirdly, it is known that China had a rapid extensive economic growth. The HCPCs were major drivers to support national economic growth, and also are key sectors to achieve the reduction targets for 2020. Two aspects are very important in complement of emission reduction policies; keeping the HCPCs existing competitiveness and adjusting the internal industrial structure based on production chains.

Policies are known to significantly influence the reduction effect of production chains in general. 1) If upstream sectors in production chains pay cost to reduce their emission, such as petroleum refining, electricity, and chemical fertilizer, the multiplier effect on the forward sectors should be seriously considered. Therefore reduction policies should be issued at the right time to prevent the economy from inflation induced by materials (e.g., agricultural products and imported energy products). 2) Extending the agricultural food manufacturing production chain can improve rural residents' income and reduce the farmers' burden. For example, to promote agriculture and food production chain to business sector, science, education and social services sector; enhance agricultural industrialization; and reduce the economic loss for rural residents. 3) It should be strengthening the competitiveness of LCPCs by boosting the operating profit of services and improving labors' salary, especially those in public services and agriculture labor. For example, to develop and improve the infrastructure, especially in rural areas, to expand the scope and convenience of public transportation, and reduce private car ownership. Further work on this topic will focus on the application of production chains to regional investigations, and enhance the model to produce a dynamic system.

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