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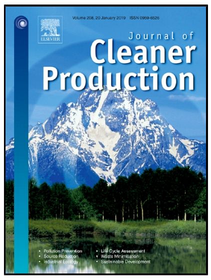

Price transmission mechanism and socio-economic effect of carbon pricing in Beijing: a two-region social accounting matrix analysis

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Title: Carbon price transmission mechanisms in Beijing: a two-region social accounting matrix analysis

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Abstract: Cities are important bases of economic development. It is essential to explore carbon mitigation efforts at the city level, particularly in developing countries with large quantities of energy consumption and carbon emission. This study has focused on the impacts of carbon pricing on sectoral prices and the carbon price transmission mechanism across sectors and along price-transmitted paths, taking the city of Beijing, China, as a case. A two-region social accounting matrix for China in 2012 was built, with one region being Beijing, and the other region representing the rest of China (ROC). The SAM price model and structural path analysis were employed to calculate both the extent of and the detailed price transmission of each sector in Beijing when carbon pricing was implemented just in Beijing or in the whole of China. The results show that the growth of prices is not serious and that the Electricity & Heating Production and Supply Sector in both Beijing and the ROC contributes most to the price growth in almost all sectors in Beijing. The price-transmitted paths starting from Non-metallic Mineral Products and Smelting and Pressing of Metals in ROC transmit the carbon price quickly and directly by the shortest paths. While the price-transmitted paths routed by Electricity & Heating Production and Supply Sector, Transport Service, and Other Services will show far-reaching effect.

Keywords: Carbon Pricing; Social Accounting Matrix; Price Model; Structural Path Analysis; Beijing; Price Transmission

1 Introduction

As the largest carbon emitter in the world, China has a positive attitude towards climate change (Zhou et al., 2010). At the 2015 Paris Summit, China promised to reach its carbon emission peak around 2030 and to reduce its carbon intensity by 60–65% compared to the 2005 level (Mi et al., 2016; Zhang, X. et al., 2016). The national double control target of total energy consumption and energy intensity has been divided into each province/city (NDRC, 2017a). China has also developed bilateral and multilateral cooperation with countries/regions like Australia, New Zealand, Europe Union, Russia, and Korea on emission trading, clean and renewable energy, and low carbon technology, to achieve a win-win situation (NDRC, 2017a).

Carbon tax and the Emission trading system (ETS) are the two most popular market-based carbon pricing approaches, and they are widely used and compared (Elkins and Baker, 2001; Zhao et al., 2017). Theoretically, both carbon tax and ETS can achieve cost-effective emission reductions (Stavins, 2008), and there is a broad equivalence between them under some assumptions (Farrow, 1995; Pezzey, 1992). In China, both measures have been explored, designed, and even attempted; but it is a difficult task to implement and achieve smooth progress with either of these two carbon pricing measures. The attempt to implement carbon tax dates back to 2007 (SC, 2008), but this policy has not been levied yet. On the other hand, in 2011, the National Development and Reform Commission (NDRC) promoted the development of ETS pilot programs (NDRC, 2011), and approved seven provinces and cities for the first pilots, which were launched in succession after June 2013. In December 2016, Fujian and Sichuan started non-pilot ETSs (CBEEX and BETA, 2017). The national ETS was originally announced to be launched by 2016 (Li et al., 2015), and was intended to cover key industries like electricity, cement, steel. However, it was launched at the end of 2017 and only covers electricity at this stage (NDRC, 2017b). As with most developing countries, the reason for this may be that the government worries about the macro-economic effect, in that the public or the companies may be anxious about the affordability of the carbon tax or high energy prices (Alton et al., 2014; Liu et al., 2013; Zhang et al., 2015). Thus, assessing the potential socio-economic effect is crucial to promote carbon pricing policies in China.

Up to now, most studies related to the socio-economic effect of carbon pricing have been conducted at the national level, and limited studies have been conducted at sub-national levels. The macro-economic effects, household effects, sector or enterprise effects of carbon pricing in China, and corresponding complementary measures have all been fully discussed. Studies on macro-economic effects (Lu et al., 2010; Wu et al., 2016; Zhang, D. et al., 2016; Zhang et al., 2017) have usually taken into account indicators such as GDP (growth), total investment, total consumption, employment, disposable income of residents, consumer price index (CPI), and welfare. For household effects (Jiang and Shao, 2014; Liang and Wei, 2012), the distributional effect, expenditure structure, and alleviating policies, such as household income tax cuts, reducing indirect tax, lump-sum transfer, even exemptions from carbon tax were discussed in the existing studies. Most of the studies on sectoral effects have focused on the competitiveness effect by measuring production price (Zhang et al., 2015), sectoral output (Dong et al., 2017; Qi and Weng, 2016; Tian et al., 2017; Wang et al., 2015), sectoral profit (Liang et al., 2007; Liang et al., 2016), trade (Liang et al., 2007; Liang et al., 2016; Qi and Weng, 2016; Wang et al., 2011), and so on. To alleviate the unfavorable impacts on competitiveness, domestic tax cuts and/or border tax adjustments have been recommended. The remaining studies have been concerned with several selected energy-intensive sectors (Guo et al., 2014), including the electricity industry (Li et al., 2014; Liu et al., 2016; Mu et al., 2018; Stua, 2013), the iron and steel industry (Zhu et al., 2017), and the building sector (Wang et al., 2014). The above studies have reflected the carbon pricing effect macroscopically and comprehensively for sectors, it may be easy to identify the sectors most affected and locate the key sectors with large contribution to the price growth of certain sectors; but the related studies have failed to either determine the key price-transmitted paths or identify the price transmission features of each sector. And it is essential to focus on the price transmission and find them out, because all of them are required for us to know much about the price transmission process, effectively bring up complementary measures or inspiring suggestions according to the price transmission features of certain sectors to promote carbon pricing policies in China.

In general, Computable General Equilibrium (CGE) models are regarded as useful quantitative policy tools to access the socio-economic effect of carbon pricing. But they also have some limitations and critics, such as the need of a big amount of statistical data, whose updating or quality is variable; so, the accuracy of their results relay on how the equations reproduce the real behavior of the economy in a certain point of the time (Alejandro Cardenete and López-Cabaco, 2018). And CGE models are too difficult in describing the dynamic development process between the original equilibrium and stable equilibrium to capture the detailed information during the price transmission. While, Input Output Table (IOT) or Social Accounting Matrix (SAM) are widely used and empirically operational due to their simplicity. Especially, they can be used to simulate short-run impacts when there is not enough time to adapt to the new scenarios or all agents are price-takers (Berck and Hoffmann, 2002; Dervis and J deRobinson, 1984; West, 1995). Meanwhile, compared with IOT, the SAM model provides more detailed representation of general equilibrium that captures the underlying connections within production, consumption, and income distribution. Based on the above reasons, SAM models have been used for measuring the price transmission (Akkemik, 2011; Llop, 2012) of energy and environmental policy (Allan et al., 2011; Chapa and Ortega, 2017; Fuentes-Saguar et al., 2017; Meng et al., 2013; Xie, 2000). For example, Saari et al. (2016) examined the potential impacts of deregulation of the petroleum price in Malaysia by using SAM-based price model. Llop (2018) identified the role of energy prices in the cost and price definition processes for the Catalan economy by using SAM-based price model, and found the asymmetric impacts of different forms of energy. Liu and Wu (2017) examined the effects of CO2 and air pollutant emission tax on production sectors and households in China by using the structural path analysis. So in this study, the sectors most affected and the key sectors with large contribution to the price growth of certain sectors during carbon pricing transmission will be picked up by using a SAM-based price model, and the roles of different sectors and key price-transmitted paths in the transmission of the carbon price can be fully analyzed by using structural path analysis.

Beijing city was chosen as a case in point for four reasons. First, cities are primarily responsible for production, energy consumption, emissions, and human activities. In detail, cities account for 60–80% of world economic activities and energy consumption and 75% of carbon emissions (Dietzenbacher et al., 2013; Huisingh et al., 2015). It is essential to conduct research at the city level, particularly in developing countries with large consumption of energy and resources (Huisingh et al., 2015). Second, Beijing is a densely-populated megacity with a high level of economic development. Thus, the additional interference of any mitigation measures may spread to enterprises' benefits, social livelihood, and employment, which are all of great concern to stakeholders. Third, Beijing is a pilot ETS city with poor market liquidity, and the market efficiency is weak, which becomes active only when the ETS compliance deadline is coming (Zhao et al., 2017). Fourth, though energy intensive sectors have moved away from Beijing, because of the headquarters economy effect, the output of the coal mining still accounted for 2% of the total output in 2012 according to the latest input–output (IO) statistics (NBS, 2016). If Beijing achieves success in carbon pricing, it will guide the low carbon development of other provinces and contribute to the building of a national ETS. The main questions this study intends to solve are as follows:

- Which sectors are most affected in Beijing after carbon pricing in Beijing or in China?
- Which sectors are the key sectors with large contribution to the price growth of certain sectors during carbon pricing transmission?
- How does the carbon price transmit either among sectors or along the price-transmitted paths?

The rest of the paper is organized as follows: the SAM-based price model and the establishment of the SAM are presented in Section 2. The results, along with the discussions, are presented in Section 3. Finally, conclusions and corresponding policy recommendations are presented in Section 4.

2 SAM-based Price Model and Data

SAM offers a disaggregated view of value flows in a given period. It portrays both income and expenditure flows, including product markets, where the transactions of goods and services occur, and resource markets, where the transactions of production factors occur, such as wages to employees, profits, and taxes (Miller and Blair, 2009).

In general, the SAM consists of production sectors, commodity sectors, production factors, and institutions' accounts. For the purpose of this study, the domestic indirect tax, import-related tax (including import tariff, value-added tax on import goods, and consumption tax on import goods), and export-related tax (including export tariff and export rebate) were separated from the corresponding government accounts, and the revenues of both tax accounts were returned to the government accounts to maintain the account balance. The framework of a two-region social accounting matrix is shown in Figure 1. It is assumed that different inputs are not substitutable in the short-term and that there is surplus production capacity in each sector. Production and activities are endogenous accounts, and the remaining accounts are exogenous accounts.

		Expenditures													
		Sector		Factors	HOH		ENTE		LG		CG	INV	IDT	IET	ROW
		r1	r2		r1	r2	r1	r2	r2	r2					
Receipts	Sector r1	M	M		HC	HC			LGC	LGC		CF		ERT	E
	Sector r2	M	M		HC	HC			LGC	LGC		CF		ERT	E
	Factors	F	F												
	HOH r1			FID			TRF		TRF		TRF				TRF
	HOH r2			FID				TRF		TRF	TRF				TRF
	ENTE r1			FID											
	ENTE r2			FID											
	LG r2			FID	DT		DT				TRF		IDT		
	LG r2			FID		DT		DT			TRF		IDT		
	CG			FID	DT	DT	DT	DT	TRF	TRF			IDT	IRT	
	INV				SAV	SAV	SAV	SAV	SAV	SAV	SAV				SAV
	IDT	IDT	IDT												
	IET	IRT	IRT		IRT	IRT			IRT	IRT	ERT	IRT			
	ROW	I	I	FID	I	I			I	I		I			

M Intermediate input; HC HOH consumption; LGC LG consumption; CF Capital formation
E Export; ERT Export related tax; I Import; IRT Import related tax
F Factor input; IDT Indirect tax; TRF Transfers; SAV Savings
FID Factor income distribute; DT Direct tax

Figure 1. Framework of a two-region social accounting matrix

Note:

r1,r2: Two regions; Sector: Production & activities; HOH: Household

ENTE: Enterprise; LG: Local government; CG: Central government

INV: Investment; IDT: Indirect tax; ROW: Rest of the world

TRF: Import–export related tax

The traditional SAM-based quantity model (Pyatt and Round, 1979; Stone, 1985) can measure changes in the level of activities by holding price fixed at unity. Roland-Holst and Sancho (1995) put forward the SAM-based price model, which is the dual version of a quantity model. The SAM-based price model can measure the changes in the level of price (arising from the changes in costs) by holding the activity level fixed. Here, a SAM-based price model for two-region SAM is formulated in Equation (1) to measure the influence of carbon pricing policy on the sectors that use fossil fuels both directly and indirectly.

$$\boldsymbol{p} = \boldsymbol{pA} + \boldsymbol{v} = \boldsymbol{v}(\boldsymbol{I} - \boldsymbol{A})^{-1} = \boldsymbol{vM} \qquad (1)$$

Here, $\boldsymbol{p} = \left(p_i^r\right)$ denotes the row vector of production price index, and p_i^r means the production price index of sector i. The initial value of $p_i^{r(0)}$ equals one.

In expression (1), $\boldsymbol{A}$ is the normalized coefficients, and each element in $\boldsymbol{A} = \left(a^{rs}_{ij}\right)$ represents the input from sector *i* in region *r* that is necessary per output of sector *j* in region *s*.

In expression (1), $\boldsymbol{M}$ is the price multiplier matrix and is equal to the inverse matrix of $(\boldsymbol{I} - \boldsymbol{A})$. It can be marked as $\boldsymbol{M} = \left(m^{rs}_{ij}\right)$.

In expression (1) above, $\boldsymbol{v}$ is the row vector of exogenous cost. Each element in $\boldsymbol{v} = \left(v^{r}_{i}\right)$ denotes the row vector of cost index for sector *i*. The initial value for $\boldsymbol{v}$ can be calculated by $\boldsymbol{v}^{(\mathbf{0})} = \boldsymbol{p}^{(\mathbf{0})} \cdot \boldsymbol{M}^{-1}$, which is equivalent to $v^{r(0)}_{i} = 1 - \sum_{j=1}^{n} a^{rr}_{ji} - \sum_{j=1}^{n} a^{sr}_{ji}$.

Carbon price in region *r* is denoted by cp^{r}. The Boolean variable emt^{r}_{i} represents whether sector *i* in region *r* is exempted from carbon pricing. And emt^{r}_{i}=1 means that sector *i* in region *r* is not exempted from carbon pricing; vice versa. Carbon emissions and output of sector *i* in region *r* are marked as ce^{r}_{i} and x^{r}_{i}, respectively. After carbon pricing in region *r*, the exogenous cost of sector *i* in region *r* can be expressed as $v^{r}_{i} = v^{r(0)}_{i} + ce^{r}_{i} \times cp^{r} \times emt^{r}_{i}/x^{r}_{i}$.

2.1 Decomposition of Production Price Growth

In this study, the impact of carbon pricing on production price is classified into two types: initial influence and final influence .

The initial influence $I^{I}_{(i,r)}$ on the production price of sector *i* in region *r* is defined as the price growth driven by the carbon pricing shock directly, i.e., the change of exogenous cost. It be calculated by Equation (2).

$$I^{I}_{(i,r)} = v^{r}_{i} - v^{r(0)}_{i} = ce^{r}_{i} \times cp^{r} \times emt^{r}_{i}/x^{r}_{i} \tag{2}$$

The final influence $I^{F}_{(i,r)}$ on the production price of sector *i* in region *r* reflects the price growth driven by the cost fluctuation of all sectors either within or without the region. It can be measured by Equation (3).

$$I^{F}_{(i,r)} = p^{r}_{i} - p^{r(0)}_{i} \tag{3}$$

p^{r}_{i} can be calculated by $\boldsymbol{p} = \boldsymbol{vM}$, with $v^{p}_{k} = v^{p(0)}_{k} + ce^{p}_{k} \times cp^{p} \times emt^{p}_{k}/x^{p}_{k}$ for each region *p* and sector *k*.

Since SAM is a linear model, the final influence, which reflects the joint impacts from all sectors in all regions, can be decomposed as the sum of influence from each sector in each region. The global influence $I^{G}_{(i,r)\to(j,s)}$, which is driven by the carbon pricing of sector *i* in region *r* on the price growth of sector *j* in region *s*, can be easily calculated using Equation (4). An important assumption here is that sector *i* in region *r* is the only sector that is not exempted from carbon pricing, and the carbon pricing policy is merely implemented in region *r*.

$$I^{G}_{(i,r)\to(j,s)} = \left(v^{r}_{i} - v^{r(0)}_{i}\right) \times m^{rs}_{ij} = \left(ce^{r}_{i} \times cp^{r} \times emt^{r}_{i}/x^{r}_{i}\right) \times m^{rs}_{ij} \tag{4}$$

In this way, the contribution of price growth of sector *i* in region *r* to the price growth of sector *j* in region *s* can be easily calculated using Equation (5).

$$\text{Contribution}^{rs}_{ij} = \frac{I^{G}_{(i,r)\to(j,s)}}{I^{F}_{(j,s)}} \tag{5}$$

2.2 Analysis of Structural Path

Structural path analysis (SPA) is one step removed from the underlying economic and social reality in the sense that it is applied to models that are supposed to capture and describe this reality (Defourny and Thorbecke, 1984). The influence due to the carbon pricing on the origin sector can be interpreted and decomposed by three different quantitative factors: direct influence, total influence, and global influence. In this study, for easy comparison and quantizing of the influence among given origin sectors and destination sectors, the scale of the carbon pricing shock is taken into consideration, so the analysis is little different from traditional SPA (which measures the percentage change in the destination sector's price owing to the cost of the origin sector changes 1%).

(1) Direct Influence

Case of direct influence of sector *i* in region *r* to sector *j* in region *s* along $(i,r)\rightarrow(j,s)$,

$$I^{D}_{(i,r)\rightarrow(j,s)} = \left(ce^{r}_{i} \times cp^{r} \times emt^{r}_{i}/x^{r}_{i}\right) \times a^{rs}_{ij}. \tag{6}$$

Case of direct influence along an elementary price-transmitted path *w*: $(i,r)\rightarrow(k,p)\rightarrow\cdots\rightarrow(m,q)\rightarrow(j,s)$, which links the origin and destination sectors, equals to

$$I^{D}_{w} = \left(ce^{r}_{i} \times cp^{r} \times emt^{r}_{i}/x^{r}_{i}\right) \times a^{rp}_{ik} ... a^{qs}_{mj}. \tag{7}$$

(2) Total Influence

Besides the direct influence, the total influence also includes the indirect influence induced by the circuits adjacent to that same price-transmitted path *w*. It can be expressed as Equation (8):

$$I^{T}_{w} = I^{D}_{w} \cdot M_{w}. \tag{8}$$

Here, M_w is the path multiplier, the principle and calculation can be found in (Roland-Holst and Sancho, 1995).

(3) Global influence

The global influence involves any price-transmitted path linking the given origin and destination. So, it can be decomposed into a series of total influences transmitted along each and all elementary paths spanning (i,r) and (j,s) in Equation (9), and it equals to Equation (4):

$$I^{G}_{(i,r)\rightarrow(j,s)} = \sum_{w} I^{T}_{w}. \tag{9}$$

2.3 Two-region Social Accounting Matrix for China

A SAM for Beijing or China is not readily available. Moreover, Beijing is a large province/city for import from other provinces and countries, especially of energy-intensive products. Therefore, a two-region SAM of 2012 for China was prepared in this study, with one region being Beijing (BJ) and the other region representing the rest of China (ROC).

An assumption adopted here is that each sector produces only one product, and each product can be produced by only one sector; thus, the production sectors and commodity sectors were merged into one account of production & commodity sectors (Sector) to simplify the SAM establishment. The Sector and local institution accounts were all divided into two regions: BJ and ROC. Production factors contain capital (K), labor (L), and Fixed Factor (FF), which refers to some specific factor input, such as natural resources. The institution accounts contain household (HOH), enterprise (ENTE), local government (LGOV), central government (CGOV), domestic indirect tax (IDT), import-export tax (IET), investment (INV), and the rest of the world (ROW). Therefore, the carbon pricing process in each sector can be regard as the change of the indirect tax in a region.

A macro-SAM was firstly compiled in this study, as shown in Table 1. Then, a micro-SAM was compiled according to the macro-SAM and data from various sources (See Section 2.2). In the end, the RAS method (Toh, 1998) was used to balance the micro-SAM. The abbreviations of each sector are listed in Table 2.

Table 1. Two-region Macro-SAM for China 2012 (Unit: hundred million RMB)

	BJ.Sector	ROC.Sector	L	K	FF	BJ.HOH	ROC.HOH	BJ. ENTE	ROC.ENTE	BJ.LGOV	ROC.LGOV	CGOV	INV	IDT	IET	ROW
BJ.Sector	17078	11428				3921	1922			4056	1627		7840		170	3665
ROC.Sector	11325	919848				2070	186896			267	66380		223993		10331	122698
L	8590	196152														
K	9184	224552														
FF	162	22731														
BJ.HOH			7349	490	48			6		1935		94				17
ROC.HOH			197394	50134	4957				159		45159	2204				395
BJ.ENTE				4525	447											
ROC.ENTE				174166	17222											
BJ.LGOV				23	2	927		1086				568		1275		
ROC.LGOV				1296	128		13075		12148			46176		26792		
CGOV				883	87	1346	18995	3797	10456	56	1175			45316	17436	
INV						1538	75301	83	168626	-2500	-15541	40005				-20121
IDT	2707	70677														
IET	378	13960				16	542			1	4	10501	2536			
ROW	2281	84460		2220		120	3671			68	811		13022			

Table 2. The Abbreviation of Sectors

No.	Abbreviation	Description
1	Agri	Agriculture
2	Coal	Mining and Washing of Coal
3	Oil	Extraction of Petroleum
4	NatGas	Extraction of Natural Gas
5	OtherMin	Mining of Other Ores
6	FoodTob	Manufacture of Foods and Tobacco
7	Textile	Manufacture of Textile
8	WearApp	Manufacture of Wearing Apparel and Accessories, Leather, Fur, Feather and Related Products, and Footwear
9	WoodProd	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
10	PaperProd	Manufacture of Paper and Paper Products
11	Petr	Manufacture of refined petroleum products
12	Coking	Manufacture of coke
13	Chemistry	Manufacture of Raw Chemical Materials and Chemical Products
14	NonMetProd	Manufacture of Non-metallic Mineral Products
15	MetalSmelt	Smelting and Pressing of Ferrous Metals and Non-ferrous Metals

16	Metalware	Manufacture of Metal Products
17	Equipment	Manufacture of Machinery
18	Elec	Electricity & Heat Production and Supply
19	GasPandS	Gas Production and Supply
20	WaterProSup	Water Production and Supply
21	Construction	Construction
22	TraStorPost	Transport Service
23	OtherServices	Other Services

2.4 Data Source

When preparing the micro-SAM, the intermediate inputs, the value-added formation, the capital formation (including fixed capital formation and inventory change), and final consumption structure data (household's consumption and government consumption were included) were based on the IO Tables by Provinces 2012 (NBS, 2016). The income compositions of urban and rural households were from the China Yearbook of Household Survey 2013 (NBS, 2013d) and the China Rural Statistical Yearbook 2013 (NBS, 2013b), respectively.

A domestic inter-regional trade matrix was estimated by Gravity Model (Mátyás, 1997) and adjusted by the trade structure based on IO Tables by Provinces 2012 (NBS, 2016). The international trade (trade value plus import–export tax) was also from the IO Tables by Provinces 2012 (NBS, 2016). The international trade values of total import and total export exclusive of import–export taxes were obtained from the General Administration of Customs and China Statistical Yearbook 2013 (NBS, 2013c). All the taxes, including total export tariff, total export rebate, total import tariff, value-added tax on imported goods of each sector, consumption tax on imported goods of each sector, consumer income tax, and enterprise income tax, were from the China Taxation Yearbook 2013 (SAT, 2013). The import tariff rate, the export tariff rate, and the export rebate rate were from the Customs Import and Export Tariff of China 2012 (EDCIET, 2012). Finally, the original tax-inclusive international trade account from the IO tables can be split into two accounts: ROW (international trade volume without taxes) and IET account.

3 Results and Discussion

Table 3 shows the carbon intensity and the CO_2 emissions in BJ and ROC in 2012 under the two most popular emission accounting principles, i.e., consumption-based accounting (CBA) and production-based accounting (PBA). "The PBA is the actual emissions generated by the production activities within a region, and the CBA involves those emissions that result directly from the production of all products used by that region, including both intermediate and final use" (Liu, L.-C. et al., 2015). The total CO_2 emissions under CBA in Beijing were 114.7 million tons, which were 1.47 times those under PBA. The emissions of Coal, Metalware, and Equipment under CBA in BJ were all much higher than were those under PBA, owing to the high dependency on MetalSmelt from ROC during the production process. The emissions of Construction under CBA in BJ were almost 20 times those under PBA, due to the high dependency on NonMetProd and MetalSmelt from ROC. The emissions of WaterProSup under CBA in BJ were more than 10 times those under PBA, since the intra-regional intermediate inputs of Elec were relatively high. The emissions of OtherServices under CBA in BJ were also higher than were those under PBA, because of the high intra-regional intermediate inputs of TraStorPost, Other Services, and Elec. The emissions of Oil, Elec, and TraStorPost under PBA in BJ were higher than were those under CBA, owing to the main intra-regional intermediate input for Petr, OtherServices, and OtherServices, respectively.

Table 3. The CO_2 Emissions in China in 2012

	Carbon Intensity (CO_2/RMB)		CBA (Mt CO_2)		PBA (Mt CO_2)	
	BJ	ROC	BJ	ROC	BJ	ROC
Agri	0.026	0.010	0.303	129.906	0.991	84.399
Coal	0.000	0.057	1.303	114.003	0.013	124.296
Oil	0.984	0.036	0.007	53.167	0.199	21.963
NatGas	0.984	0.036	0.001	6.146	0.231	19.085
OtherMin	0.002	0.022	0.824	157.407	0.071	40.896
FoodTob	0.004	0.011	1.154	156.962	0.355	96.559
Textile	0.009	0.010	0.080	99.104	0.042	32.654
WearApp	0.003	0.004	0.247	47.523	0.054	6.736
WoodProd	0.003	0.007	0.167	53.538	0.027	10.162
PaperProd	0.004	0.017	0.721	107.753	0.133	38.951
Petr	0.036	0.039	1.267	92.077	2.375	105.273
Coking	0.036	0.039	0.291	33.993	0.365	28.324
Chemistry	0.005	0.025	2.963	640.014	0.603	268.056
NonMetProd	0.072	0.270	3.073	521.061	3.508	1163.554
MetalSmelt	0.061	0.158	1.904	1049.876	1.761	1656.522
Metalware	0.002	0.006	2.517	308.663	0.064	15.652
Equipment	0.001	0.004	18.094	1018.136	0.630	70.006
Elec	0.123	0.834	15.759	1281.286	35.951	3812.374
GasPandS	0.003	0.005	0.319	9.431	0.063	1.593
WaterProSup	0.003	0.004	0.135	22.086	0.013	0.692
Construction	0.004	0.003	27.922	1227.565	1.431	37.088
TraStorPost	0.069	0.094	4.816	153.123	16.645	510.467
OtherServices	0.005	0.006	18.136	439.266	12.516	213.737
Rural	-	-	4.105	257.899	3.627	143.831
Urban	-	-	17.192	513.336	11.082	176.059
LGOV	-	-	2.276	57.449		
INV	-	-	3.841	91.494		
Emission of Each Principle in Each Region			129.416	8642.262	92.748	8678.930
Emission of Each Principle in China			8771.678		8771.678	

Note: The emissions embodied in imports and exports are not included, while the emissions directly caused by household consumption of energy products are included. The related energy data come from the energy balance table (NBS, 2013a) and the energy consumption of detailed industries (BMBS and NBS, 2013), and the emission factor of different kinds of energy sources refers to Shan et al. (2016) and Liu, Z. et al. (2015). The accounting principle refers to Liu, L.-C. et al. (2015), Su and Ang (2014), and Minx et al. (2009).

Based on the assumption that different inputs are not substitutable in the short-term and that there is surplus production capacity in each sector, the carbon cost in each sector reflects an exogenous cost shock. To be specific, the carbon price will be added to the taxes or fees of each sector. With the carbon price transmission across production activities, the prices of all goods rise and the sectors' expenditure increases.

In this study, according to our literature review and the practice of ETS pilots running in China (Marron and Toder, 2014; Qi and Weng, 2016), the carbon price was set as 100 RMB/tCO_2 (100 RMB equals approximately 15 USD dollar or 13 Euro in 2012), and we adopted the production-based accounting principle.

3.1 Production Price Growth and Decomposition

The lower half of Figure 2 shows the initial and final influences on price growth after pricing carbon in Beijing. For most sectors, it can be seen that the initial influence dominates. On average, the initial price growth accounts for 45 % of the final price growth. In particular, both the initial and final price growth on NatGas and Oil are more than 9%. The impact on Elec ranks third, with the final influence being 1.87%, followed by the impact on NonMetPro, MetalSmelt, and TraStorPost. For NatGas, Oil, NonMetPro, MetalSmelt, and TraStorPost, the initial price growth accounts for 99%, 97%, 75%, 78%, and 83% of the final price growth, respectively; thus, the high carbon intensity contributes most to the high price growth in these sectors. In particular, the output value of NatGas and Oil account for only 0.05% and 0.04% respectively, while the CO_2 emissions account for up to 0.30% and 0.26%, respectively in Beijing. For Elec, the initial influence only accounts for 66% of the final influence, and both the high carbon intensity and strong linkage with other sectors play an important role in the price growth of this sector.

The upper half of Figure 2 shows the contribution structure of each sector to price growth after carbon pricing in Beijing. The contributions of Elec, TraStorPost, and OtherServices sectors in Beijing to the price growth of each sector in Beijing are significant. The average contribution of these three sectors in Beijing is approximately 33.54%, 15.12%, and 5.46% of the final price growth, respectively. They are closely followed by NonMetPro, MetalSmelt, Agri, and Petr. The average cumulative contribution of these seven sectors adds up to 75% of the final price growth in each sector.

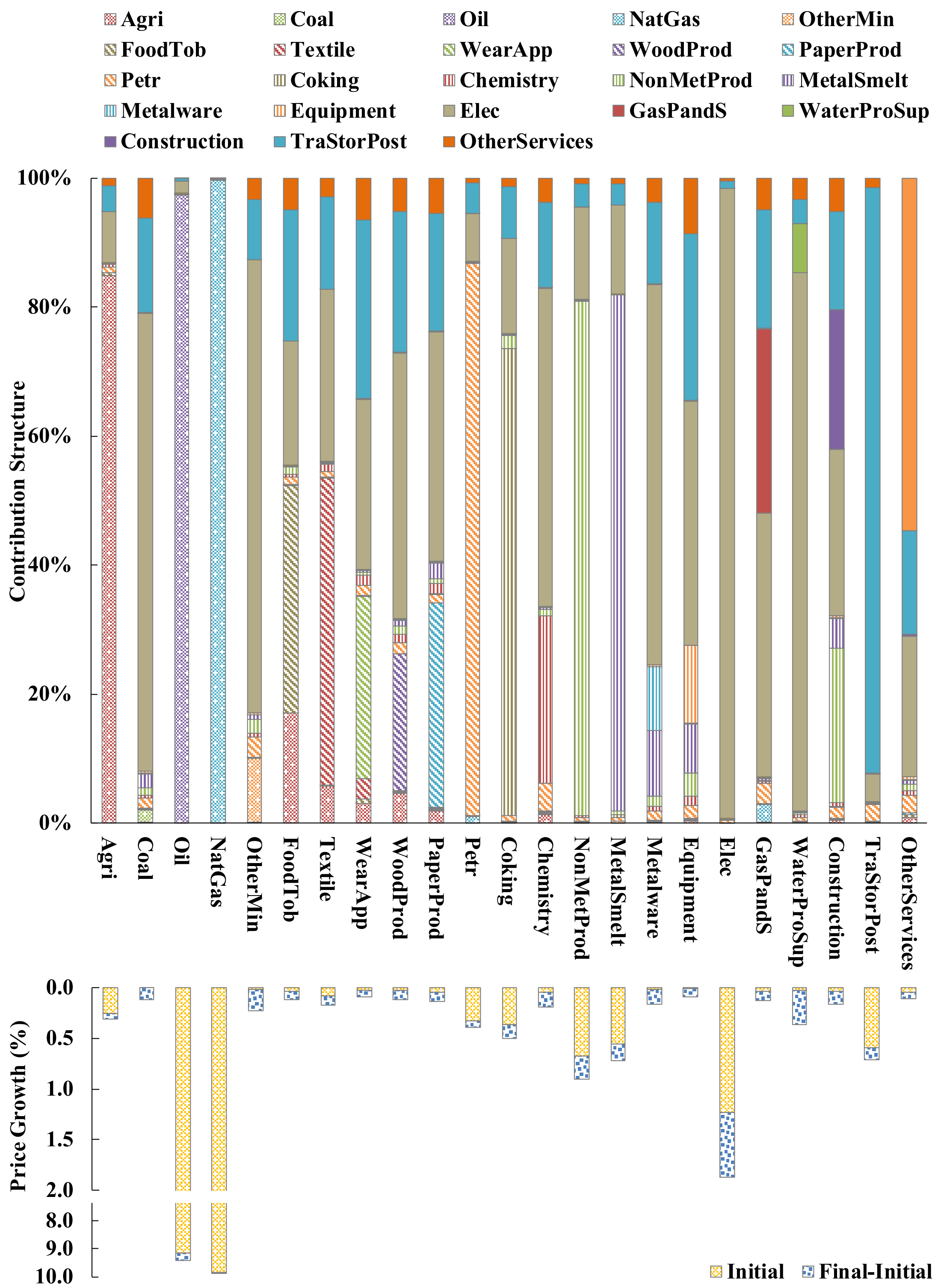

Figure 2. The Price Growth of Each Sector in Beijing.

Note: Carbon Price: 100 RMB/tCO_2 only in Beijing. The yellow bar in the lower axis represents the price growth driven by the exogenous carbon cost directly (i.e., the initial influence), and the sum of the yellow bar and the blue bar in the lower axis denotes the final price growth driven by the joint influence of all sectors (i.e., the final influence). Each color bar in the upper quadrant represents the contribution of carbon pricing in the corresponding sector to the price growth of each sector on the horizontal axis.

Commodities are needed as intermediate input or used to meet the final consumption in Beijing. And a large proportion of them are from ROC. If the carbon pricing is implemented in the ROC, as shown in Figure 3, the price growth in Beijing after carbon pricing in the ROC is much higher for most sectors than is that after carbon pricing in Beijing, especially for Equipment, Metalware, Construction, WearApp, WoodProd, and PaperProd sectors. Meanwhile, for NatGas, Oil, and Elec sectors, the price growth after carbon pricing in ROC is much lower than is that after carbon pricing in Beijing, since the production processes in these sectors rely heavily on the OtherMin and Coal commodities from Beijing, respectively.

The contributions of Elec, MetalSmelt, and NonMetProd in the ROC to each sector in Beijing are significant; they account for 45.73%, 20.32%, and 8.00% of the final price growth, respectively. And they are followed by TraStorPost and Chemistry. The average cumulative contribution of these five sectors adds up to 85% of the final price growth in each sector.

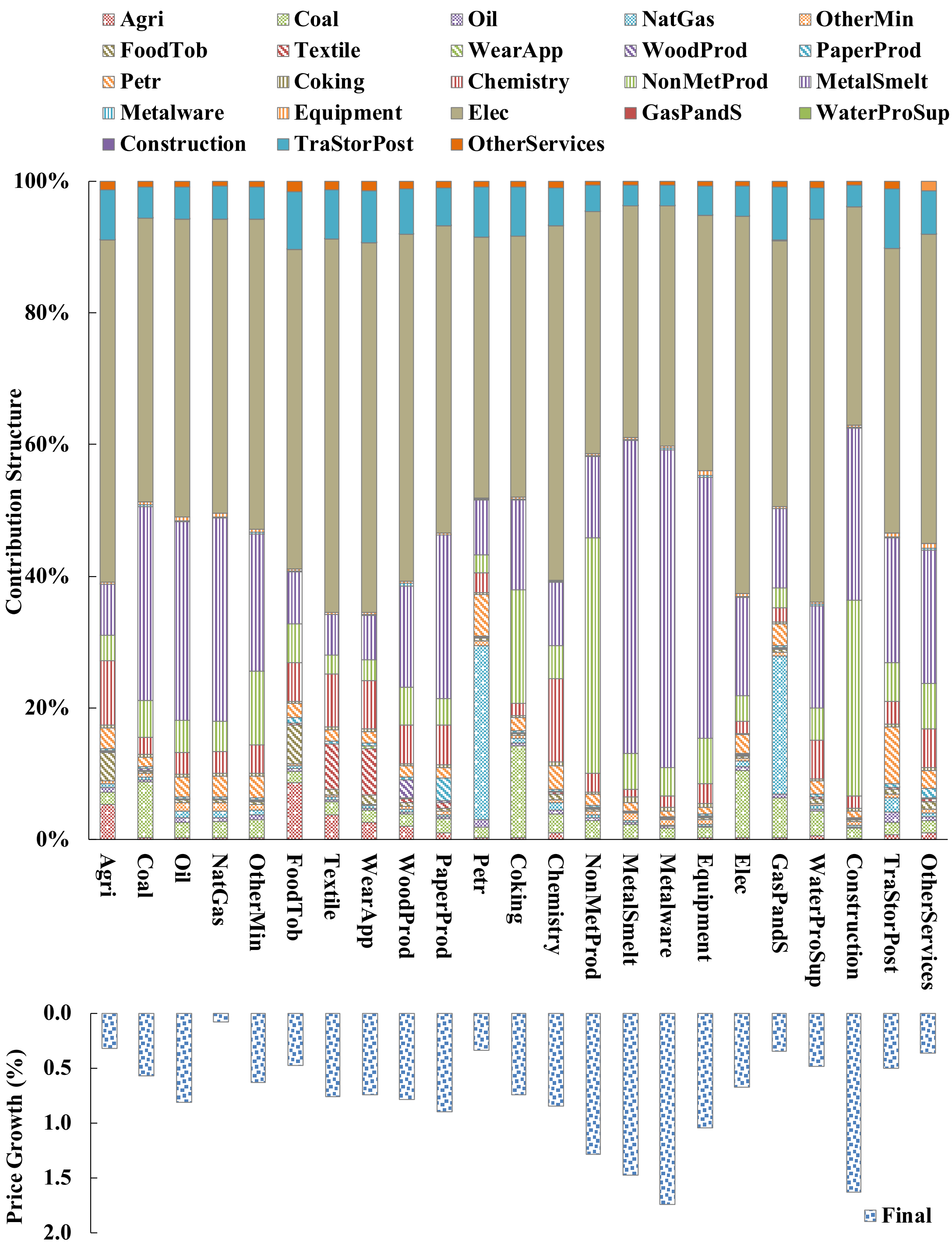

Figure 3. The Contribution of Each Sector in the Rest of China to Each Sector in Beijing.

Note: Carbon Price: 100 RMB/tCO_2 only in the ROC. Each color bar represents the contribution of carbon pricing in the corresponding sector in the ROC to the price growth of each sector on the horizontal axis in Beijing.

3.2 Price-transmitted Paths and Structural Analysis

In this study, price-transmitted paths with either a larger price multiplier (MP) or large global influence from origin sector to destination sector and routed sectors with either a larger distribution coefficient or a larger input coefficient related to destination and origin sector are selected and identified. They are shown in Table 4.

Table 4. Results of the structural path analysis.

Origin	Destination	I^G	PM	Price-transmitted paths	I^D	I^T	T/G
BJ	***BJ***						
Elec	NatGas	0.019	0.016	BJ.Elec-BJ.NatGas	0.011	0.015	81.2
TraStorPost	NatGas	0.003	0.006	BJ.TraStorPost-BJ.NatGas	0.002	0.002	67.9
OtherServices	NatGas	0.001	0.025	BJ.OtherServices-BJ.NatGas	0.000	0.001	61.6
Elec	Oil	0.185	0.154	BJ.Elec-BJ.Oil	0.101	0.150	81.2
TraStorPost	Oil	0.031	0.055	BJ.TraStorPost-BJ.Oil	0.019	0.021	67.7
OtherServices	Oil	0.010	0.244	BJ.OtherServices-BJ.Oil	0.005	0.006	61.5
OtherMin	Oil	0.003	0.144	BJ.OtherMin-BJ.Oil	0.003	0.003	99.1
Equipment	Oil	0.001	0.075	BJ.Equipment-BJ.Oil	0.000	0.001	61.3
TraStorPost	Elec	0.021	0.038	BJ.TraStorPost-BJ.Elec	0.009	0.014	68.9
OtherServices	Elec	0.009	0.212	BJ.OtherServices-BJ.Elec	0.003	0.007	73.6
Elec	NonMetProd	0.129	0.106	BJ.Elec-BJ.NonMetProd	0.067	0.106	81.9
TraStorPost	NonMetProd	0.033	0.057	BJ.TraStorPost-BJ.NonMetProd	0.023	0.026	78.4
OtherServices	NonMetProd	0.008	0.183	BJ.OtherServices-BJ.NonMetProd	0.004	0.005	65.1
Elec	MetalSmelt	0.099	0.082	BJ.Elec-BJ.MetalSmelt	0.050	0.076	77.2
TraStorPost	MetalSmelt	0.024	0.042	BJ.TraStorPost-BJ.MetalSmelt	0.016	0.018	73.8
OtherServices	MetalSmelt	0.006	0.152	BJ.OtherServices-BJ.MetalSmelt	0.003	0.004	63.6
OtherMin	MetalSmelt	0.002	0.075	BJ.OtherMin-BJ.MetalSmelt	0.002	0.002	98.7
Elec	TraStorPost	0.030	0.026	BJ.Elec-BJ.TraStorPost	0.012	0.018	60.7
OtherServices	TraStorPost	0.010	0.242	BJ.OtherServices-BJ.TraStorPost	0.006	0.008	83.2
Equipment	TraStorPost	0.001	0.106	BJ.Equipment-BJ.TraStorPost	0.001	0.001	87.5
ROC	***BJ***						
MetalSmelt	Metalware	0.841	0.577	ROC.MetalSmelt-BJ.Metalware	0.426	0.668	79.2
Elec	Metalware	0.520	0.100	ROC.Elec-BJ.Metalware	0.005	0.010	2.0
				ROC.Elec-ROC.Metalware-BJ.Metalware	0.021	0.036	6.8
TraStorPost	Metalware	0.055	0.094	ROC.TraStorPost-BeiJing.Metalware	0.007	0.008	14.8
				ROC.TraStorPost-ROC.MetalSmelt-BeiJing.Metalware	0.005	0.009	16.0
OtherServices	Metalware	0.010	0.399	ROC.OtherServices-BeiJing.Metalware	0.000	0.001	5.01
				ROC.OtherServices-ROC.MetalSmelt-BeiJing.Metalware	0.000	0.001	11.1
Elec	Construction	0.542	0.088	ROC.Elec-BJ.Construction	0.000	0.006	0.6
				ROC.Elec-ROC.NonMetProd-BJ.Construction	0.043	0.086	16.0
				ROC.Elec-ROC.MetalSmelt-BJ.Construction	0.031	0.074	14.0
				ROC.Elec-ROC.Equipment-BJ.Construction	0.000	0.006	0.9
NonMetProd	Construction	0.487	0.198	ROC.NonMetProd-BJ.Construction	0.327	0.416	85.1
MetalSmelt	Construction	0.427	0.303	ROC.MetalSmelt-BJ.Construction	0.185	0.285	66.6
TraStorPost	Construction	0.054	0.092	ROC.TraStorPost-BeiJing.Construction	0.008	0.009	16.8
				ROC.TraStorPost-ROC.MetalSmelt-BeiJing.Construction	0.002	0.004	7.2
OtherServices	Construction	0.009	0.383	ROC.OtherServices-BeiJing.Construction	0.000	0.000	4.6

Origin	Destination	I^G	PM	Price-transmitted paths	I^D	I^T	T/G
				ROC.OtherServices-ROC.MetalSmelt-BeiJing.Construction	0.000	0.000	4.6
MetalSmelt	MetalSmelt	0.701	0.484	ROC.MetalSmelt-BJ.MetalSmelt	0.395	0.613	87.3
Elec	MetalSmelt	0.520	0.085	ROC.Elec-BJ.MetalSmelt	0.006	0.012	2.2
				ROC.Elec-ROC.MetalSmelt-BJ.MetalSmelt	0.067	0.159	30.5
				ROC.Elec-ROC.OtherMin-BJ.MetalSmelt	0.012	0.018	3.3
NonMetProd	MetalSmelt	0.081	0.037	ROC.NonMetProd-BJ.MetalSmelt	0.022	0.028	33.7
				ROC.NonMetProd-ROC.MetalSmelt-BeiJing.MetalSmelt	0.009	0.015	19.9
TraStorPost	MetalSmelt	0.048	0.085	ROC.TraStorPost-BJ.MetalSmelt	0.007	0.008	16.5
				ROC.TraStorPost-ROC.MetalSmelt-BeiJing.MetalSmelt	0.005	0.008	16.4
OtherServices	MetalSmelt	0.008	0.358	ROC.OtherServices-BJ.MetalSmelt	0.000	0.000	3.5
				ROC.OtherServices-ROC.MetalSmelt-BJ.MetalSmelt	0.000	0.001	10.2
Elec	NonMetProd	0.474	0.081	ROC.Elec-BJ.NonMetProd	0.012	0.018	3.2
				ROC.Elec-ROC.NonMetProd-BJ.NonMetProd	0.041	0.082	17.9
				ROC.Elec-ROC.Chemistry-BJ.NonMetProd	0.012	0.023	5.4
NonMetProd	NonMetProd	0.462	0.189	ROC.NonMetProd-BJ.NonMetProd	0.323	0.423	91.7
MetalSmelt	NonMetProd	0.160	0.127	ROC.MetalSmelt-BJ.NonMetProd	0.024	0.039	24.4
				ROC.MetalSmelt-ROC.Metalware-BeiJing.NonMetProd	0.008	0.013	8.5
TraStorPost	NonMetProd	0.051	0.090	ROC.TraStorPost-BJ.NonMetProd	0.009	0.010	20.3
				ROC.TraStorPost-ROC.NonMetProd-BeiJing.NonMetProd	0.003	0.005	9.2
Chemistry	NonMetProd	0.036	0.227	ROC.Chemistry-BJ.NonMetProd	0.007	0.011	31.5
				ROC.Chemistry-ROC.NonMetProd-BeiJing.NonMetProd	0.001	0.003	8.3
OtherServices	NonMetProd	0.008	0.373	ROC.OtherServices-BJ.NonMetProd	0.000	0.000	4.3
				ROC.OtherServices-ROC.NonMetProd-BJ.NonMetProd	0.000	0.000	5.2
MetalSmelt	Equipment	0.415	0.293	ROC.MetalSmelt-BeiJing.Equipment	0.140	0.266	64.0
Elec	Equipment	0.406	0.070	ROC.Elec-BeiJing.Equipment	0.000	0.006	0.8
				ROC.Elec-ROC.MetalSmelt-BeiJing.Equipment	0.023	0.064	16.4
				ROC.Elec-ROC.Equipment-BeiJing.Equipment	0.006	0.023	5.7
NonMetProd	Equipment	0.072	0.034	ROC.NonMetProd-BeiJing.Equipment	0.017	0.028	37.5
				ROC.NonMetProd-ROC.MetalSmelt-BeiJing.Equipment	0.002	0.008	11.9
TraStorPost	Equipment	0.045	0.080	ROC.TraStorPost-BeiJing.Equipment	0.006	0.008	17.5
				ROC.TraStorPost-ROC.Equipment-BeiJing.Equipment	0.002	0.004	8.5
OtherServices	Equipment	0.008	0.352	ROC.OtherServices-BeiJing.Equipment	0.000	0.000	5.40
				ROC.OtherServices-ROC.Equipment-BeiJing.Equipment	0.000	0.001	8.17
Elec	Elec	0.384	0.073	ROC.Elec-BJ.Elec	0.047	0.110	28.7
				ROC.Elec-ROC.Coal-BeiJing.Elec	0.011	0.032	7.6
MetalSmelt	Elec	0.100	0.089	ROC.MetalSmelt-BJ.Elec	0.000	0.001	1.0
				ROC.MetalSmelt-ROC.Equipment-BJ.Elec	0.006	0.017	16.6
				ROC.MetalSmelt-BJ.Coal-BJ.Elec	0.004	0.010	10.6
				ROC.MetalSmelt-ROC.Coal-BJ.Elec	0.002	0.010	10.4
				ROC.MetalSmelt-BJ.Equipment-BJ.Elec	0.002	0.007	6.5
Coal	Elec	0.069	0.131	ROC.Coal-BJ.Elec	0.029	0.052	74.5

Origin	Destination	I^G	PM	Price-transmitted paths	I^D	I^T	T/G
TraStorPost	Elec	0.030	0.069	ROC.TraStorPost-BeiJing.Elec	0.003	0.005	15.8
				ROC.TraStorPost-ROC.Coal-BeiJing.Elec	0.000	0.001	3.8
OtherServices	Elec	0.005	0.353	ROC.OtherServices-BJ.Elec	0.000	0.000	3.5
				ROC.OtherServices-ROC.Coal-BJ.Elec	0.000	0.000	3.6
Elec	Oil	0.367	0.097	ROC.Elec-BJ.Oil	0.008	0.015	3.7
				ROC.Elec-ROC.MetalSmelt-BJ.Oil	0.008	0.023	5.8
MetalSmelt	Oil	0.244	0.208	ROC.MetalSmelt-BJ.Oil	0.072	0.108	44.2
TraStorPost	Oil	0.040	0.114	ROC.TraStorPost-BJ.Oil	0.004	0.005	11.0
				ROC.TraStorPost-ROC.MetalSmelt-BeiJing.Oil	0.001	0.001	2.6
OtherServices	Oil	0.007	0.637	ROC.OtherServices-BJ. Oil	0.000	0.000	2.1
				ROC.OtherServices-ROC.Equipment-BeiJing.Oil	0.000	0.000	1.5

Note: "MP" column means the price multiplier, which is the element of $\boldsymbol{M}$; "$\boldsymbol{I^G}$" column, "$\boldsymbol{I^D}$" column, and "$\boldsymbol{I^T}$" column means the "Global", "Direct", and "Total" influence on destination sectors owing to the carbon pricing policy in origin sectors; they can be calculated by Equations (4)/(9), (7), and (8). The "T/G" column means the share of total influence in global influence (unit: %).

As shown in Table 4, for the NatGas, Oil, Elec, NonMetProd, MetalSmelt, and TraStorPost destination sectors in Beijing, whose price growths are larger than average after carbon pricing in Beijing (Figure 2), the total influence along the shortest price-transmitted paths from Elec, TraStorPost, and OtherServices in Beijing accounts for more than 60% of the global influence. This indicates that the price transmission along these paths from the origin sectors in Beijing to the destination sectors in Beijing are more rapid and more direct, whereas the price transmissions along other complex price-transmitted paths with the same origin and destination sectors are limited. Furthermore, although the MP and the T/G value along the price-transmitted paths from BJ.OtherMin to BJ.Oil and BJ.MetalSmelt and along the paths from BJ.Equipment to BJ.Oil and BJ.TraStorPost are huge, the low carbon intensity of these origin sectors results in a lesser cost change after the carbon pricing shock. Thus, in general, for these four paths, the global influence is quite small.

Since the price growth in Beijing after carbon pricing in ROC is much higher than is that after carbon pricing in Beijing, we focus mainly on the origin sectors in ROC. For the Metalware destination sector in Beijing, the main global influences from the ROC are the MetalSmelt and Elec sectors (Figure 3). Along the "ROC.MetalSmelt-BJ.Metalware" price-transmitted path, the total influence accounts for 79.2% of the global influence, which indicates that the price transmission is both direct and large. Meanwhile, along the "ROC.Elec-BJ.Metalware" price-transmitted path, the "T/G" value is just 2.0%. Even when the routed sectors with larger distribution coefficients or input coefficients related to the destination and origin sectors are added to the path in sequence, the "T/G" values of the price-transmitted paths are all lower than 6.8%, which indicates that the price transmission along the price-transmitted paths from ROC.Elec to BJ.Metalware is larger but long-range.

For the Construction destination sector in Beijing, the main global influence from the ROC are Elec, NonMetProd, and Metalware (Figure 3). Similar to the Metalware destination sector in Beijing, along the "ROC.NonMetProd-BJ.Construction" and the "ROC.MetalSmelt-BJ.Construction" paths, the total influence accounts for 85.1% and 66.6% of the global influence, respectively. Since the price transmission along the price-transmitted paths from ROC.Elec to BJ.Construction are long-range, the total influence along "ROC.Elec-ROC.NonMetProd-BJ.Construction", "ROC.Elec-ROC.MetalSmelt-BJ.Construction", and "ROC.Elec-ROC.Equipment-BJ.Construction" are all larger than is that along "ROC.Elec-BJ.Construction".

For the MetalSmelt destination sector in Beijing, the main global influences from the ROC are MetalSmelt, Elec, and NonMetProd (Figure 3). Along the "ROC.MetalSmelt-BJ.MetalSmelt" path, the total influence accounts for 87.3% of the global influence, and along the "ROC.NonMetProd-BJ.MetalSmelt" path and the "ROC.NonMetProd-ROC.MetalSmelt-BeiJing.MetalSmelt" path, the cumulative total influence account for 53.6% of the global influence. Meanwhile, any "T/G" values of the price-transmitted paths from ROC.Elec to BJ.MetalSmelt are lower than 30.5%, and the total influence of each price-transmitted path starting from ROC.Elec may not be neglected.

For the NonMetProd destination sector in Beijing, the main global influences from the ROC are Elec, NonMetProd, and MetalSmelt (Figure 3). Among all the related price-transmitted paths, "ROC.NonMetProd-BJ.NonMetProd" is the most effective and direct, and it accounts for 38.5% of the final price growth and 91.7% of the global influence. The price transmitted along the paths starting from "ROC.Elec" and "ROC.MetalSmelt" rely heavily on continuous linkages.

For the Equipment destination sector in Beijing, the main global influences from the ROC are MetalSmelt, Elec, and NonMetProd (Figure 3). Furthermore, the price-transmitted paths, which starting from these three sectors and routed by "ROC.Equipment", also contribute a lot to the price growth. And Elec tends to transmit the price by more complex paths.

For the Elec destination sector in Beijing, the Elec, MetalSmelt, and Coal in the ROC contribute 57.2%, 14.9%, and 10.3%, respectively, of final price growth after carbon pricing in the ROC (Figure 3). The shortest price-transmitted paths starting from ROC.Elec, ROC.MetalSmelt, and ROC.Coal transmit 28.7%, 1%, and 74.5%, respectively, of the global influence. ROC.Equipment and ROC.Coal also act as the key nodes on price-transmitted paths.

For the Oil destination sector in Beijing, the main global influences from the ROC are Elec and MetalSmelt, and the contributions are 45.3% and 30.1%, respectively, of final price growth. However, the price-transmitted path "ROC.Elec-BJ.Oil" only transmits 3.7% of global influence; if the ROC.MetalSmelt is added to the price-transmitted path, the transmission power will increase.

It is worth noting that the price-transmitted paths starting from ROC.TraStorPost and ROC.OtherServices to other sectors in Beijing have relatively low global influence but a high MP, since the relatively low carbon intensity of TraStorPost and OtherServices results in less of a cost change after carbon pricing in the ROC.

4 Conclusions and Policy Implications

4.1 Conclusions

A two-region SAM for China 2012 was built in this study; the regions are Beijing and the Rest of China (ROC). The impacts of carbon pricing, including the final price growth, key sectors with a large contribution to certain sectors during carbon pricing transmission, and the key price-transmitted paths in the transmission of carbon price were discussed based on the established SAM model.

Compared with the latest GDP Deflator (rise 6.8%) or CPI (rise 1.6%) in China,[1] the price growths of most sectors in Beijing are not serious under a carbon price of 100 RMB/tCO_2. Except for Oil and NatGas, the price growth in Beijing is between 0.089% (WearApp) and 1.870% (Elec), when the carbon pricing is only implemented in Beijing, and between 0.468% (OtherServices) and 2.54% (Elec) when the carbon pricing is implemented in both Beijing and the ROC.

When only the carbon in Beijing is priced, the sectors most affected in Beijing include NatGas, Oil, Elec, NonMetPro, MetalSmelt, and TraStorPost. When the same carbon price is applied in the whole of China, Construction and Metalware also appear among the most affected sectors in Beijing.

The price increases in Elec, TraStorPost, and OtherServices contribute most to the price growth in all sectors in Beijing when the carbon pricing is only in Beijing. When the carbon pricing is extended to the ROC, the price increase in Elec, MetalSmelt, and NonMetProd of other regions also show an obvious impact on the price growth of all sectors in Beijing, while the contribution of TraStorPost, and OtherServices in the ROC to price growth in all sectors in Beijing will decrease largely. The Elec in both Beijing and the ROC almost contributes most to the price growth in all sectors in Beijing.

The price-transmitted paths starting from ROC.NonMetProd and ROC.MetalSmelt transmit the carbon price quickly and directly by the shortest paths.

As to the price-transmitted paths, the best transmitter is not always the most direct, and a longer path does not necessarily weaken the transmission capability, especially for those price-transmitted paths routed by ROC.Elec, ROC.TraStorPost, and ROC.OtherServices. The reason may be that these sectors play an important role in the industry chain, and their transmission power is so far-reaching, and they cannot be ignored regardless the length of the path.

If the carbon intensity of TraStorPost and OtherServices in the ROC increased, the global influence should increase sharply due to their high price multiplier (MP) from ROC.TraStorPost and ROC.OtherServices to other sectors in Beijing.

4.2 Policy Implications

Based on the results of this study, and considering the needs for incorporating the carbon-intensive sectors and reducing the negative impact on vulnerable groups, the following policy recommendations are proposed:

China should focus on the low carbon development of the Electricity & Heat Production and Supply Sector, the Transport Service Sector, and OtherServices.

Electricity & Heat Production and Supply shows high final price growth, a large contribution, and far-reaching price transmission to the price growth in all sectors in Beijing after carbon pricing. Considering the electrification policy in the future, the primary task is to promote clean electricity. This will not only contribute to lowering the carbon cost of Electricity & Heat Production and Supply but also promote the low carbon emission of sectors whose intermediate input heavily relies on Electricity & Heat in the long-run. The second task is to promote the share of electricity in final energy consumption to realize larger CO_2 emissions' reduction through the MP effect.

[1]NBS (National Bureau of Statistics of China), http://www.stats.gov.cn/tjsj/.

The Transport Service in China shows a high MP and far-reaching capacity for price transmission to other sectors. Thus, it is necessary to continue reducing the CO_2 intensity of this sector by promoting the ride-sharing service and car-sharing service in road transportation, preferentially using public transportation, and optimizing the logistics' transportation.

OtherServices in Beijing is the third biggest contributor to the price growth in all sectors in Beijing and to the high MP and far-reaching price transmission capacity from ROC.OtherServices to other sectors in Beijing. Thus, keeping a low carbon intensity of OtherServices in both Beijing and the ROC will contribute to reduce the cost of each sector.

It is noted that there are two sectors in which a relatively low carbon price could be applied in the initial stage. One is Chemistry, which is labor intensive. Thus, lowering the carbon pricing for this sector may reduce the negative impact on employment, especially when the carbon pricing is implemented at the national level in China. The other sector is the Extractive Industry. This sector has high carbon intensity but negligible output value. Thus, it is better to exempt it from carbon pricing in Beijing.

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