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Abstract

This study used an Energy-Environmental Version of the Global Trade Analysis Project (GTAP-E) model, a computable general equilibrium (CGE) model that considers the links of economy, energy, and environment (CO_2) to analyze the economic and carbon effects of overseas capital movements of China's power sector. We simulated a 1% decrease (in overseas direct investment) of capital stock defined as a specified production factor in China's power sector and a corresponding increase in capital in the recipient countries.

The overseas movement of capital from China's power sector has had a negative impact on China's GDP and a positive impact on the GDP of the recipient countries. China's equivalent variation (EV) is negative, whereas the EV of the host country is positive. The impact on the EV of other counties depends on the terms of trade effect. Moreover, it is shown that the extent of the reduction of CO_2 emissions in China and the increase/decrease in global CO_2 emissions depend on the investment destination. China making direct investments to reduce domestic CO_2 emissions (local optimization) could be globally counterproductive. This result suggests that China must be cautious about its choice of investment destination countries or regions.

keywords

China, CO_2 Emissions, FDI of power sector, GTAP-E, Power trade

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1. Introduction

China's outward foreign direct investment (FDI) flow was 73 billion USD in 2013, but after the One Belt and One Road Initiative was announced, it increased rapidly to 216 billion USD in 2016, becoming second after the United States[1]. There has been a slight decline since then, but China remains one of the major FDI countries. The current economic slowdown is believed to be behind the expansion of FDI in China. The slowdown in economic growth was accompanied by a decrease in demand from the power sector. It may be an incentive for overseas transfer of the domestic power sector. Furthermore, the overseas transfer from China of energy-intensive industries, such as the power sector, may play a role in solving serious air pollution and achieve China's nationally determined contribution in the Paris Agreement. Therefore, in this study, we analyzed the economic and carbon effects of overseas capital movements in China's power sector, mainly to Asia, using a computable general equilibrium (CGE) model.

A CGE model is an appropriate tool for analyzing FDI because it impacts various sectors differently and affects input markets as well as final goods markets. However, there are few studies on FDI using CGE models compared with studies on free trade agreements. Moreover, there seems to be even less research on FDI impacts on the environment.[2] One way to handle FDI in a CGE model is to treat FDI exogenously. Brown, Deardorff, and Stem (1992) studied the economic effects of increasing Mexican capital stock by FDI from outside NAFTA. Ban et al. (1998) analyzed the economic effects of FDI from Japan to nine Asian countries. We investigated the economic and environmental effects of FDI from Japan to ASEAN in Fujikawa and Ban (2016).

In this study, we set the capital as sector specific and analyzed the economic and environmental effects when China's electric power sector capital moves to a country or a region, mainly in Asia.

2. The Model and Data

In this study, we modified an Energy-Environmental Version of the Global Trade Analysis Project (GTAP-E) model that considers the links between the economy, energy, and the environment (CO_2) so that direct investment by industry can be handled as a specified production factor[3].

First, capital, unskilled labor, skilled labor, land and natural resources are included as production factors in the GTAP standard model, which is a static model. Each

1 See Institute for International Trade and Investment (2020) on statistics of FDI.

2 See Tsutsumi and Kiyota (2002) and Lejour and Romangosa (2006) for surveys on CGE models dealing with FDI.

3 See Burniaux and Truong (2002) and McDougal and Golub (2007) for details on the GTAP-E model. And see Hertel ed. (1997) and Colong et.al. (2017) for details on the GTAP model.

production factor is constant at the initially given amount and does not move internationally. Regarding the capital, because the savings earned during the period are invested in each country according to the expected rate of return on capital in each country, the amount of capital at the end of the period changes. The production factors can be moved between domestic industries. They are classified into three factors: the mobile factor, the sluggish factor, and the specified/fixed factor.

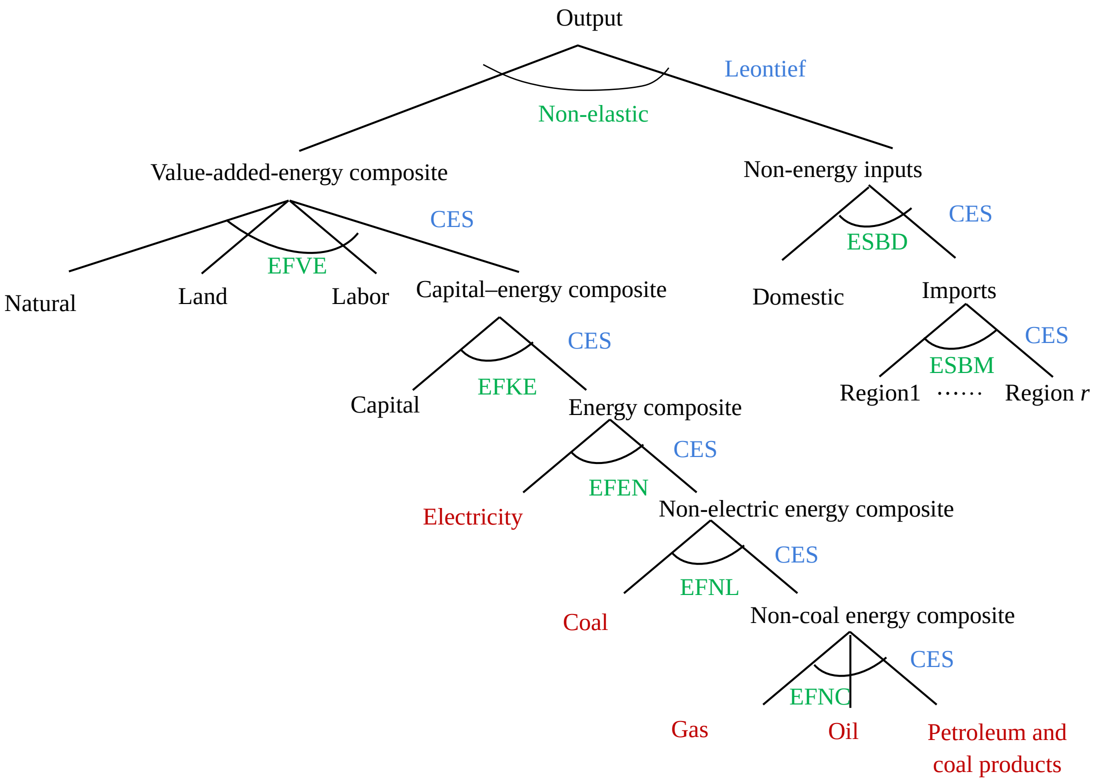
A mobile factor can move freely among domestic industries. Explained in terms of labor, there is one labor market in each country, and the wage rate fluctuates so that the total labor demand is equal to the total labor supply given as an exogenous variable. A sluggish factor is difficult to move to another industry, and its supply to individual industry is less than perfectly elastic. An example of sluggish factor is land. The total amount of land in a country is an exogenous variable. The supply of land to individual industry is determined by the total amount of land and the industry-specific return to land through a transformation function.[4] If the overall land supply increases or the industry-specific return to land rises, the amount of land allocated to that industry increases. The industry-specific return to land is determined so that the supply and demand in each industry's land market are balanced.

A specified factor cannot move between industries. If capital is a specified factor, the amount of capital by country and industry is treated as an exogenous variable and there is a capital market by industry. The industry-specific return to capital is determined so that the supply and demand of each market are balanced. In this study, we modified the GTAP-E model so that the capital and the land and natural resources can be treated as specified factors.

Next, we explain the production functions and the elasticity of substitution required to interpret the results. Figure 1 shows the production function of GTAP-E, which has a structure that allows for the substitution of capital and energy and the substitution between energies.

4 In the GTAP model, a Constant Elasticity of Transformation specification is used. The change rate of the supply of sluggish factor i for use in industry j in country r $qes_{i,j,r}$ is expressed as the follows: $qes_{e,i,r}=qe_{i,r} - \mathrm{ETRE}_{i,r}(pes_{i,j,r} - pe_{i,r})$. $qe_{i,r}$, $pes_{i,j,r}$, and $pe_{i,r}$.are the change rates in aggregate supply of a sluggish factor, the industry-specific return to the sluggish factor, and the aggregate return to the sluggish factor, respectively. $\mathrm{ETRE}_{i,r}$ represents the transformation elasticity and is negative.

Figure 1. Production function of the GTAP-E model



Source: The authors modified the figure in Burniaux and Truong (2002).

Table 1 shows the value of the elasticity of substitution. EFVE to EFNC stand for the elasticity of substitution in the composites showed in Figure 1. ESBD and ESBM are the Armington parameters for domestic or imported allocation and regional allocation of imports, respectively[5]. The values of the elasticity of substitution except for EFVE are common to all countries.

Table 1. Elasticity of substitution in the value added and energy composite

Notation	Composite	Elasticity of substitution
EFVE	Value-added energy	0.0001 (Gas in Taiwan)～4.0000 (Coal in Malaysia)
EFKE	Capital-energy	Coal, Oil, Gas, Oil_Pcts: 0, Other industries: 0.5
EFEN	Energy	Coal, Oil, Gas, Oil_Pcts, Electricity: 0, Other industries: 1
EFNL	Non-electric energy	Coal, Oil, Gas, Oil_Pcts: 0, Other industries: 0.5
EFNC	Non-coal	Coal, Oil, Gas, Oil_Pcts: 0, Other industries: 1
ESBD	Domestic and imports	0.9 (Mining)～12.9680 (Gas)
ESBM	Imports	1.8 (Mining)～32.3893 (Gas)

Source: The authors' compilation based on the GTAP 10A Database.

The model uses the GTAP Database ver. 10A (2014 Global Economic Response). The production factors are land, natural resources, capital, unskilled labor, and skilled

5 The Armington assumption is that products are differentiated by country of origin. See Armington (1969).

labor. Land, natural resources, and capital are specified elements that do not move among industries. Only unskilled labor and skilled labor can move between industries. The regions were organized into 24 regions mainly located in Asia as listed in Table 2. The industry was classified into 28 sectors paying an attention to energy and energy incentive sectors as listed in Table 3[6].

Table 2 this study

	Country/region		Country/region		Country/region
1	Oceania (Oce)	9	Malaysia	17	USA
2	China (Chn)	10	Singapore	18	Latin America
3	Japan (Jpn)	11	Thailand	19	EU and EFTA (EUEFTA)
4	Korea (Kor)	12	Vietnam (Vnm)	20	Rest of Europe
5	Mongolia (Mng)	13	Rest of ASEAN	21	Russia (Rus)
6	Taiwan	14	India (Ind)	22	Turkistan (Trk)
7	Other East Asia (O_EA)	15	Other South Asia	23	Middle East & North Africa
8	Indonesia (Idn)	16	Canada (Can)	24	Sub-Saharan Africa (SSA)

Source：The authors' compilation based on the GTAP 10A Database.

Table 3. Industry classification

	Industry		Industry		Industry		Industry
1	Agriculture	8	Petro & coal prod	15	Mineral prod.	22	Water
2	Livestock	9	Electricity	16	Iron	23	Construction
3	Forestry	10	Other mining	17	Automobile	24	Trade
4	Fishing	11	Processed food	18	Trans. equip.	25	Other trans. service
5	Coal mining	12	Textile & cloth	19	Electro. equip.	26	Water transport
6	Crude oil	13	Paper & pub.	20	Machine equip.	27	Air transport
7	Gas & dist.	14	Chemical prod.	21	Other mfg.	28	Other services

Source：The authors' compilation based on the GTAP 10A Database.

3. Simulation Scenarios

The first-stage analysis sets a scenario in which the capital stock in the donor country decreases according to a conventionally applied scenario in models with exogenous capital stock. This study simulated a 1% decrease in capital in the Chinese power sector and a corresponding increase in capital in the power sector in the recipient country or region. We designated seven countries or regions (Oceania, Mongolia, Indonesia, Vietnam, India, Russia, and Turkistan) as the capital recipients. Table 4 summarizes the shock values for each scenario. The scenarios from 01E-chn to 08E-trk are those where the capital change shock is given for only one country or region. For example, in the 01 E-chn scenario, the Chinese power sector's capital decrease by 1%. In the 02 E-oce scenario, the Oceania's power sector's capital increase by 7.1%. The scenarios from 09E-chnoce to 15E-chntrk are those in which a 1% decrease in the Chinese power sector's capital and the corresponding amount of capital increase in the power

6 See Appendices 3 and 4 for details.

sector in the recipient country take place simultaneously. For example, in the scenario 09 E-chnoce, the 1% capital stock decrease in China's power sector is reinvested in Oceania's power sector.

Table 4. Capital change shock of each scenario

	Chn	Oce	Mng	Idn	Vnm	Ind	Rus	Trk
01 E-chn	−1%							
02 E-oce		7.1%						
03 E-mng			268.6%					
04 E-idn				49.9%				
05 E-vnm					42.2%			
06 E-ind						7.6%		
07 E-rus							6.4%	
08 E-trk								21.9%
09 E-chnoce	−1%	7.1%						
10 E-chnmng	−1%		268.6%					
11 E-chnidn	−1%			49.9%				
12 E-chnvnm	−1%				42.2%			
13 E-chnind	−1%					7.6%		
14 E-chnrus	−1%						6.4%	
15 E-chntrk	−1%							21.9%

Source：The authors' compilation based on the GTAP 10A Database.

4. Impacts on GDP

Table 5 shows the impacts of changes in capital in the power sector on GDP for each country or region. The table shows the trends with industrial production and trade taken into consideration.

Table 5. Impacts on GDP (% change from the baseline)

	01E-chn	02E-oce	03E-mng	04E-idn	05E-vnm	06E-ind	07E-rus	08E-trk
Oce	−0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Chn	−0.01	0.00	−0.00	0.00	0.00	0.00	−0.00	0.00
Jpn	−0.00	0.00	0.00	0.00	0.00	−0.00	−0.00	0.00
Kor	−0.00	0.00	0.00	−0.00	0.00	−0.00	−0.00	−0.00
Mng	−0.01	0.00	3.59	0.00	0.00	0.00	0.01	0.00
Idn	−0.00	0.00	0.00	0.07	−0.00	0.00	0.00	0.00
Vnm	−0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00
Ind	−0.00	0.00	0.00	0.00	−0.00	0.04	−0.00	0.00
USA	−0.00	0.00	0.00	0.00	0.00	0.00	−0.00	0.00
EUEFTA	−0.00	0.00	0.00	0.00	0.00	0.00	−0.00	0.00
Rus	0.00	0.00	0.00	0.00	−0.00	0.00	0.04	0.00
Trk	−0.00	0.00	0.00	0.00	−0.00	0.00	−0.00	0.29

(continued)

	09E-chnoce	10E-chnmng	11E-chnidn	12E-chnvnm	13E-chnind	14E-chnrus	15E-chntrk
Oce	0.06	−0.00	−0.00	−0.00	0.00	−0.00	−0.00
Chn	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Jpn	0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00
Kor	0.00	−0.00	−0.00	0.00	−0.00	−0.00	−0.00
Mng	−0.01	3.59	−0.01	−0.01	−0.01	0.00	−0.01
Idn	0.00	0.00	0.07	−0.00	0.00	0.00	−0.00
Vnm	−0.00	−0.00	−0.00	0.46	0.00	−0.00	−0.00
Ind	0.00	−0.00	0.00	−0.00	0.04	−0.00	0.00
USA	−0.00	−0.00	−0.00	0.00	−0.00	−0.00	−0.00
EUEFTA	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	0.00
Rus	0.00	0.00	0.00	−0.00	0.00	0.04	0.00
Trk	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	0.29

Source: The authors' compilation based on the GTAP 10A Database.

4-1. 01E-chn Scenario

Under the E-chn scenario, production in China will fall by 0.29%, and prices will rise by 0.43% in the power sector, where capital is declining. A decrease in electricity production will reduce coal demand, and China's coal production will decrease by 0.03%. Furthermore, the rise in electricity prices has a negative impact on production in most Chinese industries.

Outside of China, the impact on Mongolia's GDP seems relatively large. This is caused by the trade in coal and electricity.[7] The decline in Chinese coal demand will have a negative impact on coal production in countries other than China. For example, Oceania, Indonesia, and Mongolia's coal exports to China will decrease by 0.05%, 0.05%, and 0.01%, respectively, and production will also decrease slightly.[8] Because the value added of Mongolia's coal industry accounts for a relatively high proportion of its GDP, this shock may lead to a decrease in GDP (see Table 6).

Table 6 Share of value added

	Oce	Chn	Jpn	Kor	Mng	Idn
Coal	2.15	1.20	0.00	0.01	10.79	4.32
Electricity	1.36	1.79	0.98	1.69	8.06	0.31
	Vnm	**Ind**	**US**	**EUEFTA**	**Rus**	**Trk**
Coal	1.22	1.43	0.21	0.08	0.80	1.39
Electricity	2.97	4.46	1.15	1.41	1.66	2.53

Source: The authors' compilation based on the GTAP 10A Database.

The rise in electricity prices in China will affect trade in electricity. In Mongolia, the electricity consumption of industry and households is 1.57 Mtoe (million tons of oil equivalent), of which imported electricity is 0.11 Mtoe or 7.21%. Since 51.25% of

7 See the supplemental tables in Appendices 3 and 4 regarding trade in power and coal.
8 China's importing-country share of coal: Oceania, 41.59%; Indonesia, 29.22%; Mongolia, 5.30%.

imported electricity comes from China, the negative effect of rising imported electricity prices on the Mongolian economy is relatively large.

4-2. 02E-oce−08E-trk Scenarios

In the 02E-oce to 08E-trk scenarios, the GDP increases in the countries or regions where the electricity capital increases, and there is almost no effect on other countries. In the E-mng scenario, the increase in electricity capital in Mongolia is as high as 268.6%; thus, the increase in GDP in Mongolia is also the highest. Electricity production in Mongolia will increase by 43.90%, and production will increase in almost all industries.

In the E-idn and E-vnm scenarios, the rates of power capital increase the most after the E-mng scenario. The GDP growth rate of Indonesia in the E-idn scenario seems to be smaller than that of Vietnam in the E-vmn scenario. One reason for this is that the total share of value added in the power sector is as low as 0.31% in Indonesia (see Table 6). Additionally, as a result of the increase in power capital, other industries such as coal (11.71%), steel (7.50%), paper manufacturing (2.47%), and ceramics (1.31%) will grow in Vietnam. No industry will increase by more than 1% in Indonesia except for the power sector with an increase of 6.47%.

Mongolia's GDP increases in the E-rus scenario. Electricity trade is responsible for this phenomenon. Electricity prices will drop by 1.08% in Russia. Because Mongolia also imports electricity from Russia, this decrease will have a positive impact on the Mongolian economy, contrary to the E-chn scenario.

4-3. 09E-chnoce–15E-chntrk Scenarios

The results of the 09E-chnoce–15E-chntrk scenarios are basically the total of the results of the 01E-chn scenario and those in the 02E-oce–08E-trk scenarios. Mongolia is affected by −0.01% in the 01E-chn scenario, which would be reflected in Mongolia's GDP under the 09E-chnoce–15E-chntrk scenarios.

Electricity capital movement from China has a negative impact on China's GDP and a positive impact on the recipient countries. Mongolia receives complicated effects by the movement of power capital from China because of its background of power trade with both China and Russia.

5. Impacts on Welfare

Table 7 shows the equivalent variation (EV) caused by the change in electricity capital. In the 01E-chn scenario, there are negative EV values not only in China where the capital decreases, but also in other countries. From the results of the 02E-oce to 08E-trk scenarios, the EV is positive in the capital recipient country. In each scenario, there are some changes in economic welfare even in countries where the amount of capital does not change. Some countries or regions have positive effects, whereas others have negative effects. However, looking at the EV as a percentage of GDP, the effect on the EV in countries where the electricity capital is unchanged is extremely marginal.[9]

Table 7. Equivalent variation (in million USD)

	01E-chn	02E-oce	03E-mng	04E-idn	05E-vnm	06E-ind	07E-rus	08E-trk
Oce	−27	595	8	26	9	45	5	3
Chn	−765	40	−31	−4	32	4	−15	19
Jpn	−8	16	−0	0	27	−9	−69	−7
Kor	−1	0	−2	−15	19	−8	−27	−8
Mng	−2	−0	309	0	−0	1	1	0
Idn	−8	10	11	438	11	38	12	5
Vnm	−7	1	0	2	345	5	1	2
Ind	−3	3	−0	−7	6	263	−12	−7
USA	−42	34	11	29	65	43	−0	−11
EUEFTA	−53	58	12	36	77	62	−114	31
Rus	5	6	6	11	−4	17	598	27
Trk	−1	0	0	−0	−0	2	16	816

	09E-chnoce	10E-chnmng	11E-chnidn	12E-chnvnm	13E-chnind	14E-chnrus	15E-chntrk
Oce	568	−18	−0	−18	18	−21	−24
Chn	−725	−796	−769	−734	−761	−780	−746
Jpn	7	−9	−8	19	−18	−78	−16
Kor	−1	−3	−16	18	−9	−28	−9
Mng	−2	307	−2	−2	−1	−1	−2
Idn	2	3	430	3	30	4	−3
Vnm	−6	−7	−5	338	−2	−5	−5
Ind	−0	−3	−11	2	260	−15	−10
USA	−7	−31	−13	23	2	−42	−53
EUEFTA	4	−41	17	24	9	−167	−22
Rus	11	11	17	1	22	604	32
Trk	−1	−1	−1	−1	1	15	816

Source：The authors’ compilation based on the GTAP 10A Database.

To understand the effect on EV, we analyzed the term’s components. In the GTAP-E model, EV can be decomposed into seven components: resource allocation effect, element endowment effect, technological change effect, population effect, terms of trade effect, investment goods price effect, and emissions trading effect.[10] The components related to this research are the resource allocation effect, the element endowment effect, and the terms of trade effect. Resource allocation effects and factor endowment effects are important in the countries where capital stock changes. The terms of trade effect is

9 For the 01E_chn to 08E_trk scenarios, the equivalent variation/GDP ratios of countries with varying capital amounts are as follows. China for E_chn, −0.01%; Oceania for E_oce, 0.03%; Mongolia for E_mng, 2.52%; Indonesia for E_idn, 0.05%; Vietnam for E_vnm, 0.19% scenario; India for E_ind, 0.01%; Russia for E_rus, 0.03%; and Turkistan for E_trk, 0.23%. The equivalent variation in countries where the electricity capital is unchanged is very marginal. Among them, the ones that stand out a little are Mongolia for E_chn, −0.02%, and Mongolia for E_rus, 0.01%.

10 See Huff, K. M. and Hertel, T. W. (2000) for details of decomposing welfare changes in the GTAP model.

brought mainly by changes in the prices of electricity, coal, and gas. The components of EV by country or region are evaluated when those changes in capital stock and energy prices are taken into consideration.

5-1. 01E-chn Scenario

In the E-chn scenario, the Chinese EV mainly consists of the allocation effect (348 million USD), the endowment effect (550 million USD), and the terms of trade effect (138 million USD). The rise in the electricity price causes the price of Chinese exports to rise, improving the terms of trade in China while generally worsening the terms of trade in other countries. The degree of the effect of such deterioration depends on the volume of trade with China. China’s export value is 2,499.8 billion USD, and its share in exports of EUEFTA, the United States, and Japan are 21.47%, 19.01%, and 8.02%, respectively. Therefore, the reduction of EV in these countries or regions is relatively large.

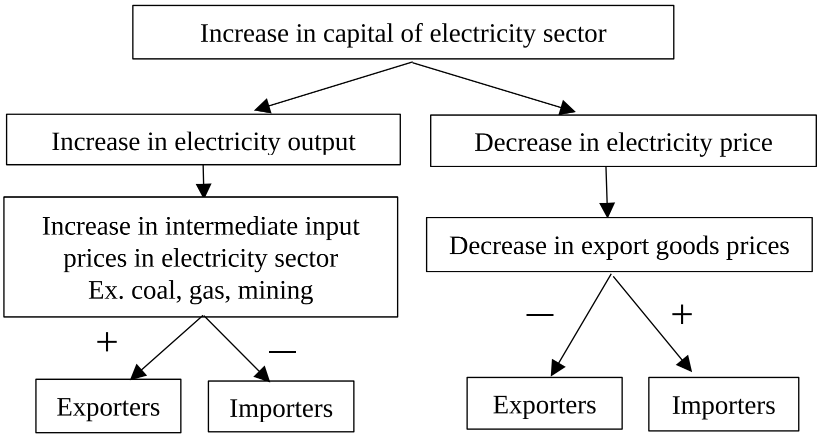
Furthermore, there is a decrease in demand for imported intermediate inputs because of the decrease in production in China’s electric power industry. This worsens the terms of trade for exporting countries through the decrease in their prices. For example, Oceania’s EV is −27 million USD, of which the terms of trade effect is −22 million USD. Furthermore, of the −22 million USD, −7.23 million USD is by mining price and −4.74 million USD is by coal price. The same phenomenon can be observed in Indonesia and Mongolia.

5-2 02E-oce−08E-trk Scenarios

If a decrease in a capital receiving country’s electricity price leads to a decrease in that country’s price of export goods, a negative terms of trade effect will be created about in the capital receiving country. Importing countries with lower export prices will have positive terms of trade effect, and the countries that export those products will have negative terms of trade effect. Conversely, the increase in demand for coal and gas due to the increase in electricity production in the recipient countries will have a negative effect on the terms of trade for importing countries and a positive effect in the terms of trade for exporting countries.

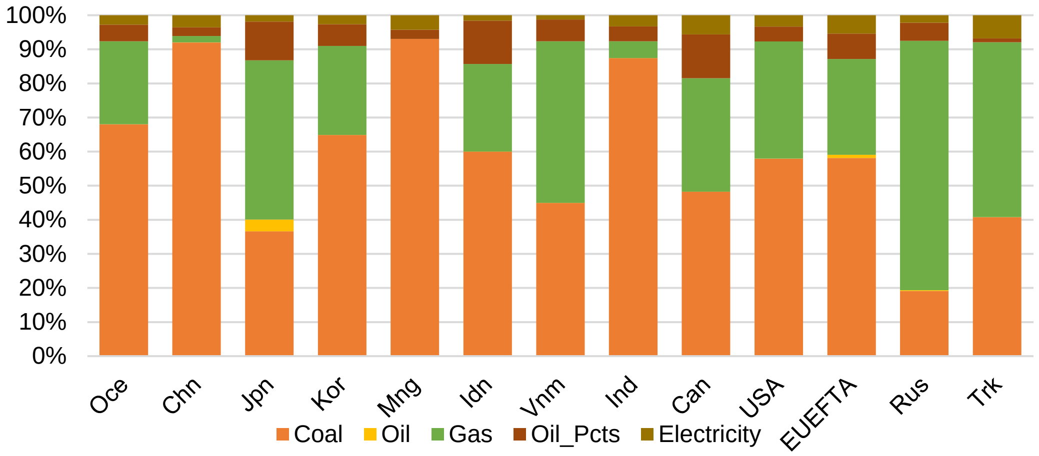
We considered the EV in some scenarios regarding the terms of trade effects shown in Figure 2 by evaluating the energy composition of the power sector in each country. Figure 3 shows the share of energy input measured in Mtoes in the power sector. It is worth noting that the coal share is high in China, Mongolia, and India, whereas the gas share is high in Russia.

Figure 2. The terms of trade effect by capital increases in the power sector.



Source: Authors' compilation.

Figure 3. Energy configuration of the power sector.



Source：The authors' compilation based on the GTAP 10A Database.

First, in the E-oce scenario, the Coal World Export Price Index (the price index of global merchandise exports) increases by 0.02%. The effect of terms of trade by coal price in coal-importing countries is negative, but the effect due to the decrease in the price of export goods in Oceania offsets this negative effect. As imports prices from Oceania decrease, many other countries/regions will benefit. Mongolia is unusual because it shows a small but negative EV although it is a coal-exporting country. Because of the decrease in the mining price in Oceania, the export price of mining in Mongolia also decreases slightly (−0.01%). Mining's share of Mongolia's export value is high at 47.1%, and the terms of trade effect by mining price (−0.2 million USD) exceeds the terms of trade effect by coal price (0.16 million USD).

Second, in the E-mng scenario, China's negative effect is the largest in the E-mng scenario among the 02E-oce–08E-trk scenarios. The EV in China is −30.57 million USD, of which −20.37 million USD is the terms of trade effect. Furthermore, among the terms of trade effects, −16.27 million USD is by coal price. Mongolia is one of the important coal providers of China, whereas China is an export destination accounting for 99.22% of Mongolian coal exports.[11] China's coal import price increases by 0.04% in the E-mng scenario, which is 0.02% higher than in the E-oce and E-idn scenarios. Thus, China's negative terms of trade effects related to coal price increase in the E-mng scenario. Most of the imports from Mongolia to China are mining and coal, so there is almost no effect from reducing the import prices of other products, and the terms of trade effect is a large negative value.

The sign of the EV of countries/regions is not stable in the E-rus scenario. In Russia, the demand for gas in the power sector increases by 0.24%, and the export price of gas increases by 0.08% as electricity production increases. For example, in Japan, the EV is −69.25 million USD, of which the terms of trade effect is −58.03 million USD. The gas price effect is −36.68 million USD in terms of total trade effects. A similar phenomenon can be seen in EUEFTA and South Korea, where gas imports from Russia are large.[12] Conversely, in Indonesia and Turkistan, which are gas-exporting country/region, the terms of trade effect related to gas price increase their EV.[13]

6. Impacts on CO_2 Emissions

6-1 01E-chn Scenario

Tables 8 and 9 summarize the impact on CO_2 emissions. In this subsection, we focused on China. In the E-chn scenario, a 1% reduction of capital stock in China's power sector will reduce China's CO_2 emissions by approximately 2.25 million tons. CO_2 emissions in the power sector will decrease by 4.49 million tons, whereas CO_2 emissions will increase in many other sectors and regional households. This is especially true in the ceramics industry (0.51 million tons), steel (0.36 million tons), chemicals (0.22 million tons), services (0.25 million tons), and regional households (0.39 million tons) where increments in CO_2 emissions are relatively large. Because the capital rental cost in China will increase by 0.02%, electricity prices will increase by 0.43% in this scenario. The price of coal will decrease by 0.01%, and CO_2 emissions will increase in many sectors other than electricity.

11 China's coal import share by country based on the GTAP 10A Database is as follows: Oce, 41.59%; Idn, 29.22%; Rus, 9.73%; Mng, 5.30%; O_EA, 5.01%; Can, 3.47%; SSA, 2.17%; Vnm, 1.57%; USA, 1.19%; SSA, 2.17%.

12 See the supplement table in Appendix 5 for gas trade.

13 Of $11.41 million terms of trade effect in Indonesia, the gas price effect is $7.99 million. Of $18.37 million terms of trade effect in Turkistan, the gas price effect is $3.24 million.

Table 8. Change in CO_2 emissions (in 10 thousand tons)

	01E-chn	02E-oce	03E-mng	04E-idn	05E-vnm	06E-ind	07E-rus	08E-trk
Oce	−0.6	194.1	−0.6	0.2	−0.0	−3.0	−3.2	−1.5
Chn	−225.1	4.9	1.0	11.0	−31.0	14.4	−14.0	−25.3
Jpn	−0.3	−1.5	−1.4	−2.1	−0.0	−6.4	−12.2	−0.9
Kor	0.4	−1.5	−1.1	−1.8	0.2	−5.1	−5.2	−1.0
Mng	0.2	−0.1	427.2	−0.0	−0.1	−0.1	−0.4	−0.0
Idn	0.0	−0.6	−0.5	219.4	−0.4	−4.3	−2.4	−0.0
Vnm	0.1	−0.2	−0.3	−0.1	94.9	−0.5	−0.1	−0.7
Ind	2.3	−4.0	−2.7	−8.1	−2.9	583.2	−5.3	−5.0
USA	−5.0	−0.9	0.7	−1.0	2.1	−5.1	−52.7	−11.6
EUEFTA	−2.2	−5.2	−1.8	0.2	−5.3	−4.1	−48.2	−27.9
Rus	0.6	−1.2	−6.6	−1.3	−0.9	−2.6	126.1	−8.9
Trk	0.3	−1.4	−0.3	−0.4	−2.6	−1.2	−7.5	602.8
ROW	−4.1	−9.1	−3.2	−2.5	−7.5	−23.8	−74.6	−55.3
Total	−233.4	173.1	410.3	213.3	46.4	541.4	−99.9	464.6

	09E-chnoce	10E-chnmng	11E-chnidn	12E-chnvnm	13E-chnind	14E-chnrus	15E-chntrk
Oce	193.5	−1.2	−0.4	−0.6	−3.6	−3.8	−2.1
Chn	−220.2	−223.7	−214.1	−255.4	−210.8	−239.0	−250.1
Jpn	−1.8	−1.7	−2.4	−0.3	−6.7	−12.5	−1.3
Kor	−1.1	−0.7	−1.4	0.7	−4.7	−4.8	−0.5
Mng	0.1	427.4	0.1	0.1	0.1	−0.2	0.1
Idn	−0.6	−0.5	219.4	−0.4	−4.3	−2.4	−0.1
Vnm	−0.1	−0.2	0.0	95.0	−0.4	0.0	−0.5
Ind	−1.7	−0.4	−5.8	−0.6	585.5	−2.9	−2.7
USA	−5.8	−4.5	−6.0	−2.6	−10.1	−57.6	−16.4
EUEFTA	−7.3	−4.0	−2.0	−7.6	−6.4	−50.4	−30.1
Rus	−0.6	−6.0	−0.7	−0.3	−2.1	126.6	−8.3
Trk	−1.2	0.0	−0.1	−2.3	−0.9	−7.2	603.2
ROW	−13.4	−7.4	−6.6	−11.7	−27.9	−78.7	−59.5
Total	−60.1	177.0	−19.9	−186.0	307.8	−333.0	231.9

Source: Authors' calculation based on the GTAP 10A Database

Table 9 Change in China's CO_2 emissions by sector (10 thousand tons)

	Coal	Oil_Pcts	Ely	Chm	NMM	Iron	O_Trs	W_Trs	A_Trs	Service
01 E-chn	0.1	−0.3	−449.0	22.1	51.2	35.7	−11.2	−2.5	−2.2	24.7
02 E-oce	0.3	0.3	−0.6	0.3	2.4	1.1	0.6	0.2	0.0	0.4
03 E-mng	0.9	0.7	−2.8	0.6	1.1	−0.6	0.2	0.0	0.1	0.3
04 E-idn	0.5	0.5	3.2	0.6	1.6	0.9	1.1	0.3	0.2	0.5
05 E-vnm	0.2	0.2	−33.6	0.8	−3.0	0.6	1.4	0.6	0.3	0.3
06 E-ind	0.9	0.7	8.9	0.5	2.1	−0.1	0.3	0.2	0.1	0.4
07 E-rus	0.1	0.3	−3.0	−2.0	0.0	−1.3	−2.2	0.0	0.0	−1.0
08 E-trk	0.1	0.8	−17.3	−1.1	0.9	−1.8	−1.9	0.1	0.1	−0.9

Source：The authors' compilation based on the GTAP 10A Database.

6-2. 02E-oce−08E-trk Scenarios

The increase in electricity capital stock in Vietnam, Russia, and Turkistan reduces CO_2 emissions in China, whereas the increase in electricity capital stock in Oceania, Mongolia, Indonesia, and India increases CO_2 emissions in China.

In the E-vnm, E-rus, and E-trk scenarios, electricity trade helps reduce CO_2

emissions from China's electricity sector.[14] In the E-vnm scenario, the CO_2 emissions from China's power reduction are relatively large at approximately 0.34 million tons. Moreover, in these scenarios, China's CO_2 emissions are also reduced in industries such as chemicals, steel, or ceramics in addition to reductions in the electric power sector.

Under the E-oce, E-mng, and E-idn scenarios, CO_2 emissions in China's power sector will decrease, but CO_2 emissions will increase in coal, chemicals, steel, and ceramics. In the E-ind scenario, CO_2 emissions from China's power sector are also increasing. Additionally, the increase in CO_2 emissions from the coal sector in China is also noticeable in the E-mng, E-idn, and E-ind scenarios that include the increase in electric power capital in countries with a high share of thermal power generation.

6-3 09E-chnocek−15E-chntrk Scenarios

From the results of the 09E-chnoce to 15E-chntrk scenarios, the global CO_2 emissions decrease in the E-chnoce, E-chnidn, E-chnvnm, and E-chnrus scenarios, whereas the global CO_2 emissions increase in the E-chnmng, E-chnind, and E-chntrk scenarios. The sign of global CO_2 change depends on the degree of increase in CO_2 emissions in the host country and the impact on other countries' CO_2 emissions. The increase in emissions in Oceania, Indonesia, and Russia is less than the decrease in CO_2 emissions in China. Furthermore, the reduction of CO_2 emissions in countries other than Russia is also relatively noticeable in the E-rus scenario. Conversely, the increase in emissions in Mongolia, Indonesia, and Turkistan is more than the decrease in CO_2 emissions in China, which causes an increase in global CO_2 emissions. In this way, the investment destinations of China's electric power capital influence the CO_2 emissions throughout the world.

7. Concluding Remarks

This study analyzed the economic and environmental (CO_2) effects of overseas direct investment by China's power sector using the GTAP-E model. The main conclusions obtained in this study are summarized here.

- A 1% decrease in China's electricity capital will reduce China's GDP by approximately 0.01%, and the decline in China's coal demand will have a negative impact on coal production in coal-exporting countries.
- A decrease of capital stock in China's power sector worsens not only China's economic welfare but also other countries' economic welfare through the terms of trade effect.
- An increase in electricity capital in the recipient country improves economic welfare in the recipient country. The impact on the economic welfare of other countries,

14 Under the E-vnm, E-rus, and E-trk scenarios, Vietnam, Russia, and Turkistan increase their power exports to China by 102.04%, 6.10%, and 45.33%, respectively.

however, depends on the terms of trade effect. The effect of the terms of trade depends on the trade and cost structures of the country.

- The reduction of CO_2 in China by the overseas movement of capital stock in China's power sector can be strengthened through international electricity trade.
- Electricity capital increases in Vietnam, Turkistan, and Russia will reduce CO_2 emissions in China, whereas in India, Indonesia, Oceania, and Mongolia, CO_2 emissions will increase in China.
- Overseas movement of capital in the power sector from China to Russia, Vietnam, Oceania, and Indonesia will reduce global CO_2 emissions, whereas those to India, Turkistan, and Mongolia will increase global CO_2 emissions.

This study shows that the economic and carbon effects of overseas capital movement from the Chinese power sector may differ depending on the investment's destination, although the parameters used in the model are not necessarily general. If China makes direct investments to reduce domestic emissions (for local optimization), such a decision could be globally counterproductive. This result indicates that China must be cautious about its choice of investment destination countries/regions.

By focusing on FDI, we assumed that the capital of the investing country decreases and that of the recipient country increases by the same amount. It is unavoidable, however, that the productivity of capital (power generation efficiency in this study) depends on the recipient country or the productivity of the investing country's capital cannot be reflected in the recipient country in the model because of the nature of the GTAP model.

However, along with the development of FDI stock data and foreign affiliate sales data, it has recently become possible to analyze FDI using the GTAP-based FDI model that distinguishes between domestic companies and foreign-owned companies (Fukui and Lakatos, 2012; Lakatos and Fukui, 2014; Tsigas and Yuan, 2017). It is necessary to apply such a model to the analysis of FDI's environmental effects.

Additionally, China's electricity capital is expected to continue to increase. In the model analysis, it is ideal to describe reality as accurately as possible, and the current simulation assumptions do not necessarily reflect reality, which is a problem. To more faithfully depict reality, it is necessary to modify simulation assumptions, internalize FDI, and make models dynamic. These are subjects for future analysis.

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