Supplementary material

S1. MRIO-based SDA

According to the MRIO, the following equation can be obtained from the balance between horizontal lines:

$$X = AX + F, \tag{1}$$

where X is the total output column vector, A is the direct consumption coefficient matrix, and F is the final use column vector (contains consumption, investment and export). After the equation conversion, we have:

$$X = (I - A)^{-1}F, \tag{2}$$

Let the superscripts r and s indicate the region and the subscripts i *and* j stand for the sector. G_i^r is the direct carbon dioxide emissions of sector i in region r, and then the carbon dioxide coefficient can be calculated from: $C_i^r = G_i^r / X_i^r$.

Let $\mathrm{diag}(C)$ be the diagonal matrix of the carbon dioxide coefficient, where C is the column vector for the CO_2 emissions coefficient of each sector in each region. G_{total} is the total carbon emissions. Substituting Equation (2) with a matrix, we obtain:

$$G_{total} = \mathrm{diag}(C)X = \mathrm{diag}(C)(I - A)^{-1}F, \tag{3}$$

For employment, W_i^r is the direct employees of sector i in region r, and W_{total} is the total employment. We can obtain the column vector of employment coefficient L, resulting in:

$$W_{total} = \mathrm{diag}(L)X = \mathrm{diag}(L)(I - A)^{-1}F, \tag{4}$$

with the Leontief inverse matrix $(I - A)^{-1}$ as B and the carbon dioxide coefficient $\mathrm{diag}(C)$ and the employment coefficient $\mathrm{diag}(L)$ as $\hat{C}$ and, $\hat{L}$ respectively. In light of the simplicity and equivalence of Sun's [1] method with Diezenbacher and Los's [2] all average method, we apply Sun's [1] and Meng's [3] methods in the following spatial structural decomposition analysis, based on China's MRIO tables, and we provide corresponding equations based on the average of the two polar decompositions. It can be seen from the above equation that carbon dioxide emissions are affected by the carbon emissions coefficient $\hat{C}$, technology factor B and final demand F. Thus, the changes in carbon emission between the base year of 2007 and target year of 2012 can be expressed as:

$$\Delta G = G_{t1} - G_{t0} \tag{5}$$

$$= \hat{C}_{t1}B_{t1}F_{t1} - \hat{C}_{t0}B_{t0}F_{t0}$$

$$= \Delta\hat{C}B_{t0}F_{t0} + \hat{C}_{t0}\Delta BF_{t0} + \hat{C}_{t0}B_{t0}\Delta F + \Delta\hat{C}\Delta BF_{t0} + \Delta\hat{C}B_{t0}\Delta F + \hat{C}_{t0}\Delta B\Delta F + \Delta\hat{C}\Delta$$

$$= \left[\Delta\hat{C}B_{t0}F_{t0} + \frac{1}{2}\Delta\hat{C}(\Delta BF_{t0} + B_{t0}\Delta F) + \frac{1}{3}\Delta\hat{C}\Delta B\Delta F\right] \tag{5.1}$$

$$+ \left[\hat{C}_{t0}\Delta BF_{t0} + \frac{1}{2}\left(\Delta\hat{C}\Delta BF_{t0} + \hat{C}_{t0}\Delta B\Delta F\right) + \frac{1}{3}\Delta\hat{C}\Delta B\Delta F\right] \tag{5.2}$$

$$+ \left[\hat{C}_{t0}B_{t0}\Delta F + \frac{1}{2}\left(\Delta\hat{C}B_{t0}\Delta F + \hat{C}_{t0}\Delta B\Delta F\right) + \frac{1}{3}\Delta\hat{C}\Delta B\Delta F\right] \tag{5.3}$$

Equation (5) shows that the carbon emission change between the base period (t0) and the end period (t1) can first be decomposed into three parts: the change caused by regional carbon intensity change $\Delta\hat{C}$, by technology change ΔB and by final demand change ΔF. In addition, the final demand F can be divided into domestic final demand FD and export E (E is not divided into intermediate products or final products). Within,

$$FD = (K_2 FDK_1)\left[FD\left(\mathrm{diag}(K_2FD)\right)^{-1}\right][\mathrm{diag}(K_2FD)/(K_2FDK_1)] = fPD, \tag{6}$$

where K_1 is a $2R$×1 column vector with 1s, representing consumption and capital formation of R regions, while K_2 is a 1×RN row vector with 1s, representing final use of N sectors in R regions. f is a number representing the domestic final demand of all regions, while P is regarded as a region demand preference (consumption or investment), and D reflects the final demand structure of the region. The carbon emissions change caused by the final demand change can be similarly decomposed as equation (7).

$$\Delta FD = FD_{t1} - FD_{t0} \tag{7}$$

$$= f_{t1}P_{t1}D_{t1} - f_{t0}P_{t0}D_{t0}$$

$$= \left[\Delta f P_{t0} D_{t0} + \frac{1}{2}\Delta f(\Delta P D_{t0} + P_{t0}\Delta D) + \frac{1}{3}\Delta f \Delta P \Delta D\right] \tag{7.1}$$

$$+ \left[f \Delta P D_{t0} + \frac{1}{2}(\Delta f \Delta P D_{t0} + f_{t0}\Delta P \Delta D) + \frac{1}{3}\Delta f \Delta P \Delta D\right] \tag{7.2}$$

$$+ \left[f_{t0} P_{t0} \Delta D + \frac{1}{2}(\Delta f P_{t0}\Delta D + f_{t0}\Delta P \Delta D) + \frac{1}{3}\Delta f \Delta P \Delta D\right] \tag{7.3}$$

Therefore, ΔFD is decomposed into changes in final demand scale Δs, changes in regional final demand preference for products of different sectors ΔP, and changes in expenditure structure of regional final demand ΔD, i.e., the share of consumption and investment in regional final demand.

Similar to the decomposition of Equation (7), the regional carbon emission change caused by exports is:

$$E = (K_2E)[E/K_2E] = f^E P^E, \tag{8}$$

The carbon emission changes caused by export ΔE can be further decomposed into two parts: changes in export scale Δf^E and in export preference for products of different sectors ΔP^E.

$$\Delta E = E_{t1} - E_{t0}$$

$$= f^E_{t1}P^E_{t1} - f^E_{t0}P^E_{t0}$$

$$= \left[\Delta f^E P^E_{t0} + \frac{1}{2}\Delta f^E \Delta P^E\right] + \left[f^E_{t0}\Delta P^E + \frac{1}{2}\Delta f^E \Delta P^E\right] \tag{9}$$

Considering the above equations comprehensively, the regional carbon emission change shown in Equation (5) can ultimately be expressed as:

$$\Delta G = G_{t1} - G_{t0} \tag{10}$$

$$= \hat{C}_{t1}B_{t1}F_{t1} - \hat{C}_{t0}B_{t0}F_{t0}$$

$$= \hat{C}_{t1}B_{t1}(FD_{t1} + E_{t1}) - \hat{C}_{t0}B_{t0}(FD_{t0} + E_{t0})$$

$$= \hat{C}_{t1}B_{t1}(f_{t1}P_{t1}D_{t1} + f^E_{t1}P^E_{t1}) - \hat{C}_{t0}B_{t0}(f_{t0}P_{t0}D_{t0} + f^E_{t0}P^E_{t0}$$

$$= \left[\Delta\hat{C}B_{t0}F_{t0} + \frac{1}{2}\Delta\hat{C}(\Delta B F_{t0} + B_{t0}\Delta F) + \frac{1}{3}\Delta\hat{C}\Delta B \Delta F\right] \tag{10.1}$$

$$+ \left[\hat{C}_{t0}\Delta B F_{t0} + \frac{1}{2}\left(\Delta\hat{C}\Delta B F_{t0} + \hat{C}_{t0}\Delta B \Delta F\right) + \frac{1}{3}\Delta\hat{C}\Delta B \Delta F\right] \tag{10.2}$$

$$+ \left[\hat{C}_{t0}B_{t0} + \frac{1}{2}\left(\Delta\hat{C}B_{t0} + \hat{C}_{t0}\Delta B\right) + \frac{1}{3}\Delta\hat{C}\Delta B\right] \cdot \left[\Delta f P_{t0}D_{t0} + \frac{1}{2}\Delta f(\Delta P D_{t0} + P_{t0}\Delta D) + \frac{1}{3}\Delta f \Delta P \Delta D\right]$$

(10.3)

$$+\left[\hat{C}_{t0}B_{t0}+\frac{1}{2}\left(\Delta\hat{C}B_{t0}+\hat{C}_{t0}\Delta B\right)+\frac{1}{3}\Delta\hat{C}\Delta B\right]\cdot\left[\Delta f^{E}P_{t0}^{E}+\frac{1}{2}\Delta f^{E}\Delta P^{E}\right] \quad (10.4)$$

$$+\left[\hat{C}_{t0}B_{t0}+\frac{1}{2}\left(\Delta\hat{C}B_{t0}+\hat{C}_{t0}\Delta B\right)+\frac{1}{3}\Delta\hat{C}\Delta B\right]\cdot\left[f\Delta PD_{t0}+\frac{1}{2}(\Delta f\Delta PD_{t0}+f_{t0}\Delta P\Delta D)+\frac{1}{3}\Delta f\Delta P\Delta D\right]$$

(10.5)

$$+\left[\hat{C}_{t0}B_{t0}+\frac{1}{2}\left(\Delta\hat{C}B_{t0}+\hat{C}_{t0}\Delta B\right)+\frac{1}{3}\Delta\hat{C}\Delta B\right]\cdot\left[f_{t0}^{E}\Delta P^{E}+\frac{1}{2}\Delta f^{E}\Delta P^{E}\right] \quad (10.6)$$

$$+\left[\hat{C}_{t0}B_{t0}+\frac{1}{2}\left(\Delta\hat{C}B_{t0}+\hat{C}_{t0}\Delta B\right)+\frac{1}{3}\Delta\hat{C}\Delta B\right]\cdot\left[f_{t0}P_{t0}\Delta D+\frac{1}{2}(\Delta fP_{t0}\Delta D+f_{t0}\Delta P\Delta D)+\frac{1}{3}\Delta f\Delta P\Delta D\right]$$

(10.7)

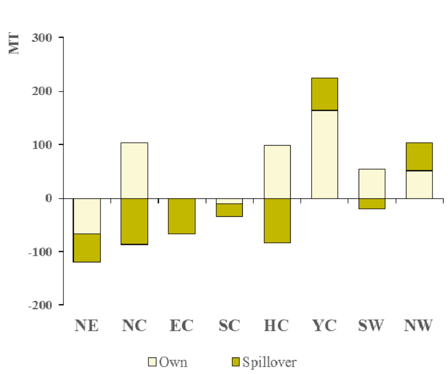
S2. Classification of production sectors

Table S1. Classification of production sectors

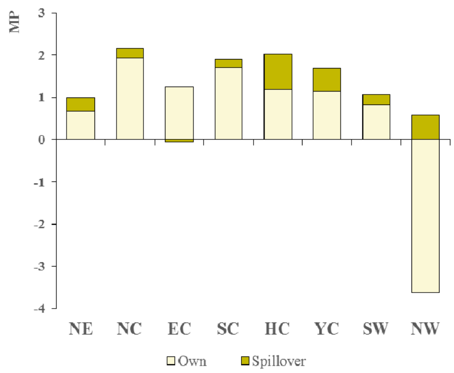
Code	Sector Code	New Code	New Sector Code
S1	Agriculture	S1	Agriculture
S2	Coal mining and processing	S2	Resource exploitation
S3	Crude petroleum and natural gas		
S4	Metal ore mining		
S5	Non-metallic minerals and other mining		
S6	Food processing and tobaccos	S3	Light industry
S7	Textile		
S8	Clothing, leather, fur, etc.		
S9	Wood processing and furnishing		
S10	Paper making, printing, stationery, etc.		
S11	Petroleum refining coking and nuclear fuel	S4	Petrochemical industry
S12	Chemical industry		
S13	Non-metallic mineral products	S5	Raw material manufacturing
S14	Metal smelting and processing		
S15	Metal products	S6	Equipment manufacturing
S16	General and specialist machinery		
S17	Transport equipment		
S18	Electrical equipment		
S19	Electronic equipment		
S20	Instrument and meter		
S21	Other manufacturing		
S22	Electricity and hot water production and supply	S7	Electricity and gas supply
S23	Gas and water production and supply		
S24	Construction	S8	Construction
S25	Transportation and warehousing	S9	Transportation and warehousing
S26	Wholesale and retailing	S10	Other services

S27	Hotel and restaurant
S28	Leasing and commercial services
S29	Scientific research
S30	Other services

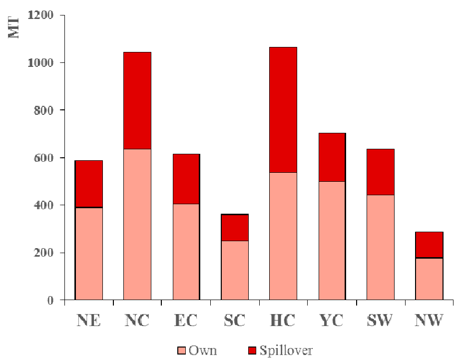
S3. Own influences and spillover effects by region



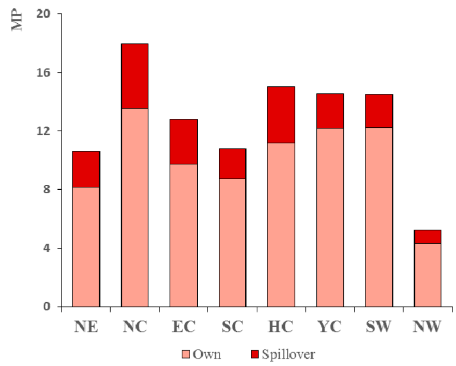
(a) Pte



(b) Pte



(a2) Fds



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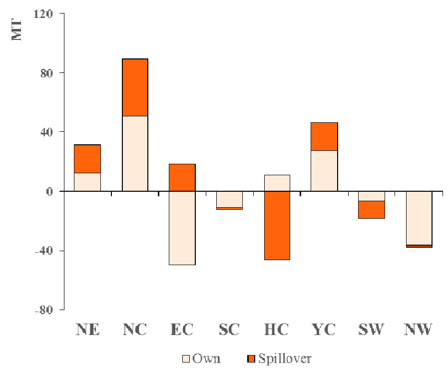
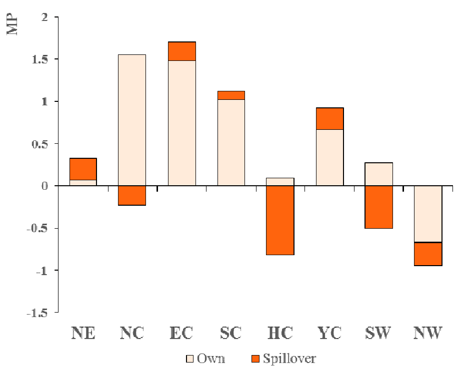


(a3) Fdp



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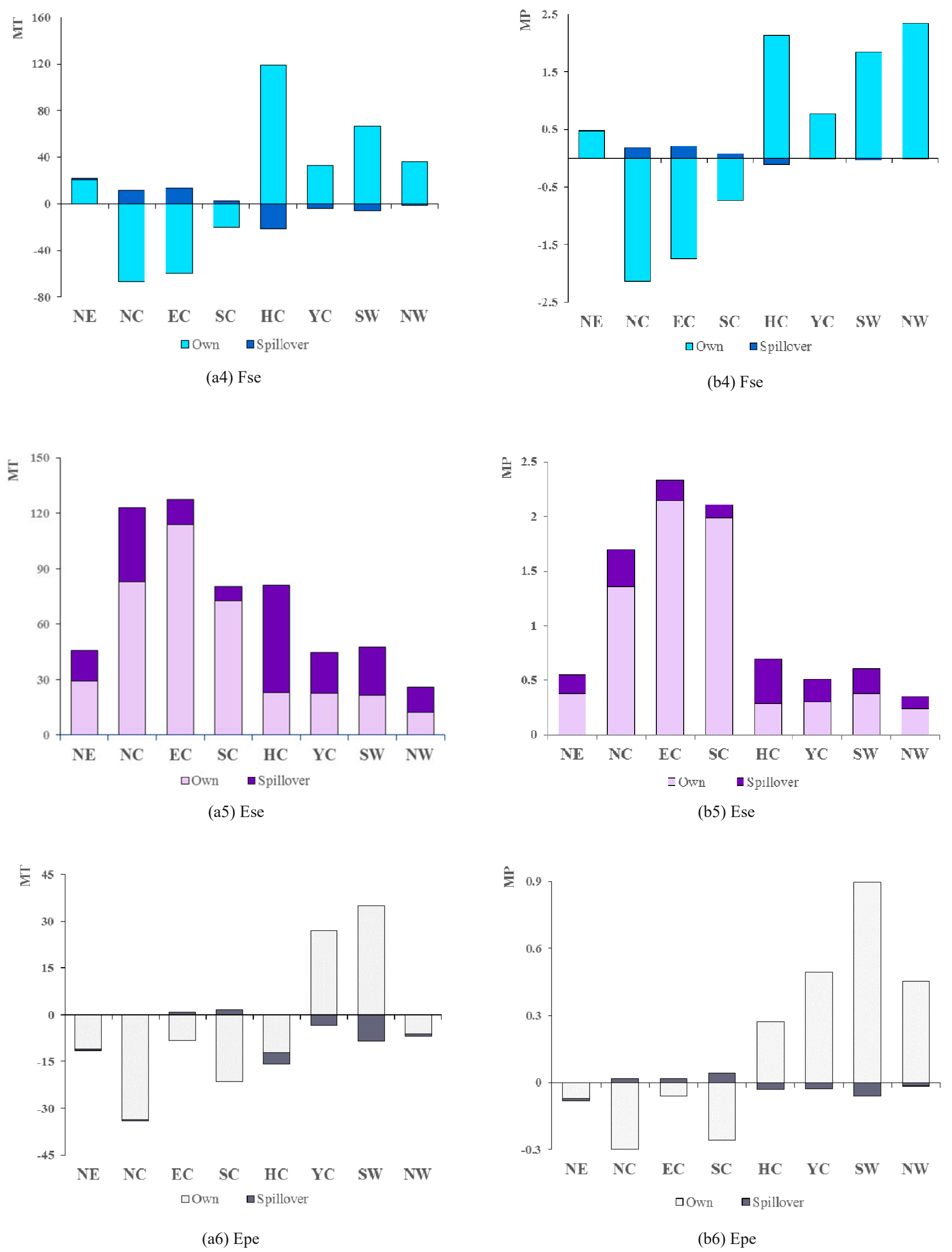
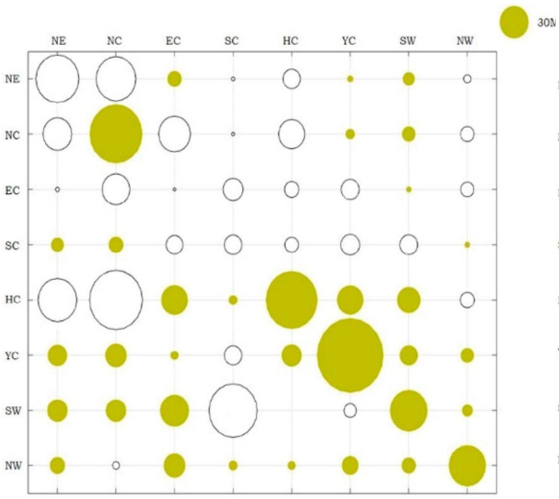


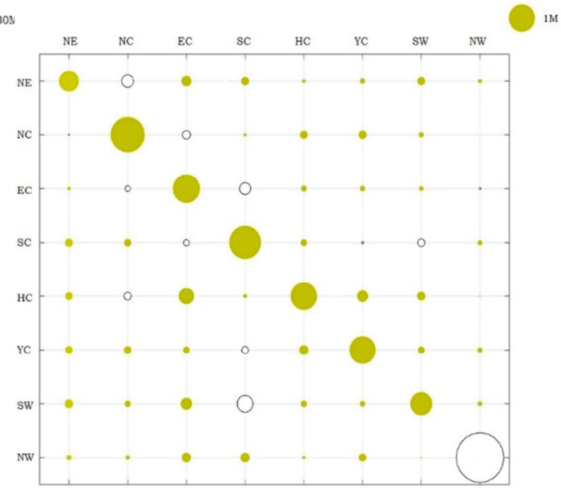
(a) Effects on carbon emissions (b) Effects on Employment

Figure S1. Own influences and spillover effects

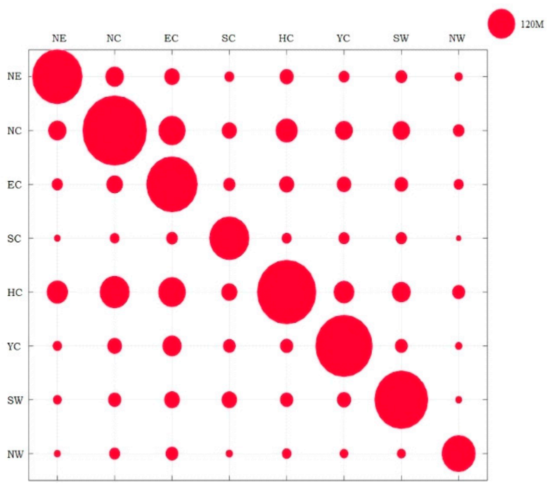
S4 Spillover effects analysis based on results of SDA



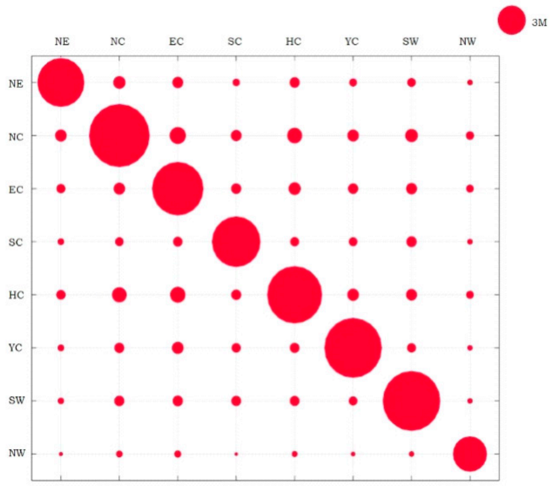
(a1) Pte



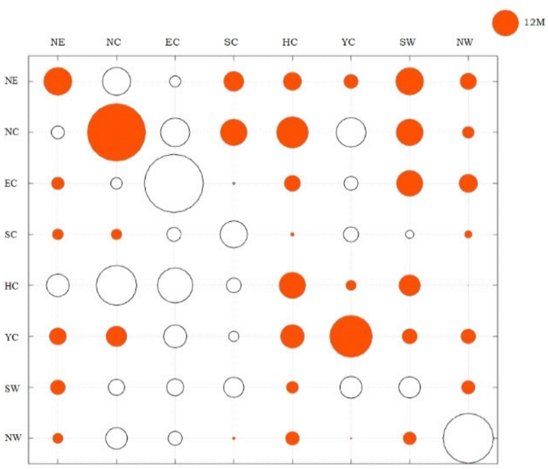
(b1) Pte



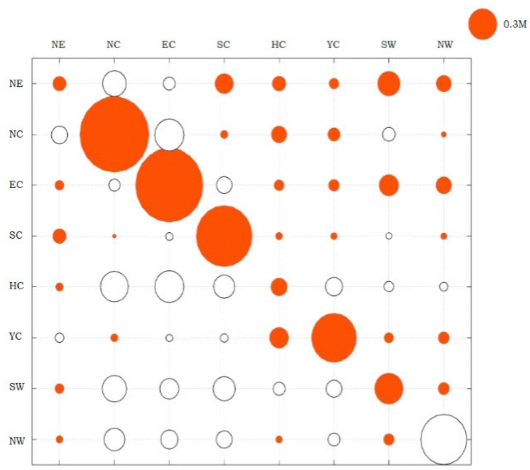
(a2) Fds



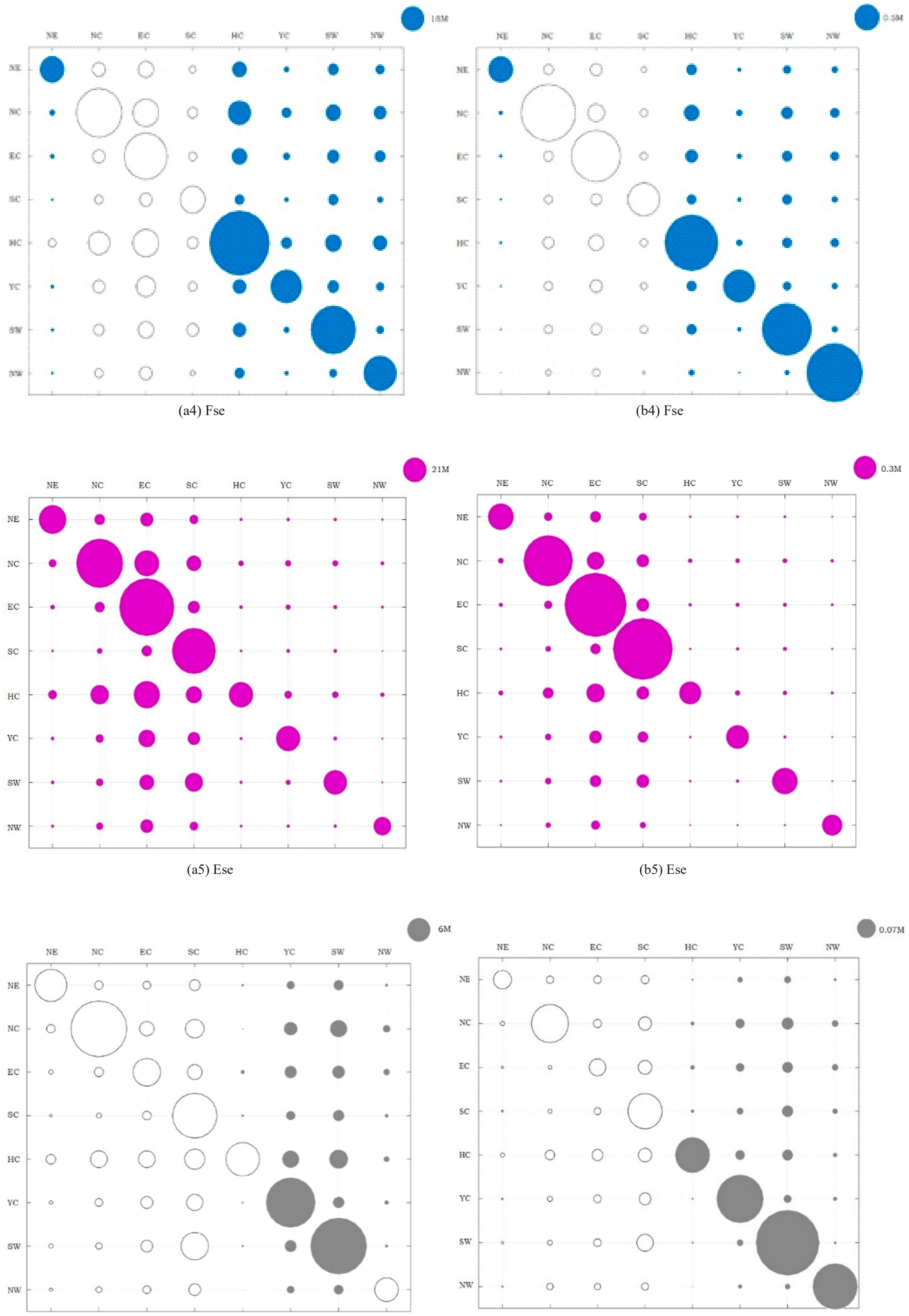
(b2) Fds



(a3) Fdp



(b3) Fdp



(a4) Fse (b4) Fse

(a5) Ese (b5) Ese

(a6) Epe (b6) Epe

(a) Effects on carbon emissions (b) Effects on employment

Figure S2. Bilateral spillover effects

Note: the direction of spillover effect is from the regions in the left row to those in the top line. Solid circles mean positive value and hollow circles mean negative value.

S5. Positive spillover effects analysis

Code	Region	Pte	Fds	Fdp	Fse	Ese	Epe	Total
NE	Northeast Region	34%	8%	25%	8%	0%	36%	19%
NC	North Coastal	32%	20%	51%	20%	20%	11%	13%
EC	East Coastal	10%	33%	34%	33%	22%	14%	25%
SC	Southern Coastal	3%	56%	20%	68%	37%	14%	42%
HC	Middle of the Yellow River	0%	11%	26%	11%	0%	0%	8%
YC	Middle of the Yangtze River	22%	12%	23%	12%	0%	11%	10%
SW	Southwest Region	11%	10%	42%	21%	0%	21%	18%
NW	Northwest Region	14%	3%	45%	3%	3%	32%	16%

Figure S3. Regions' positive spillover effects on other regions

Note: The data are proportions of GDP of eligible regions in total

Code	NE	NC	EC	SC	HC	YC	SW	NW
Region	Northeast Region	North Coastal	East Coastal	Southern Coastal	Middle of the Yellow River	Middle of the Yangtze River	Southwest Region	Northwest Region
Pte	0%	20%	32%	3%	10%	29%	30%	14%
Fds	8%	20%	22%	14%	11%	12%	10%	3%
Fdp	34%	55%	52%	51%	14%	23%	0%	11%
Fse	8%	20%	22%	14%	11%	12%	10%	3%
Ese	0%	20%	22%	14%	0%	0%	0%	3%
Epe	0%	3%	8%	0%	71%	0%	10%	64%
Total	10%	20%	23%	16%	19%	15%	12%	15%

Figure S4. Regions with positive spillover effects from other regions

Note: The data are proportions of GDP of eligible regions in total

References

1. Sun, J., Changes in energy consumption and energy intensity: a complete decomposition model. Energy economics 1998, 20, (1), 85-100.
2. Dietzenbacher, E.; Los, B., Structural decomposition techniques: sense and sensitivity. Economic Systems Research 1998, 10, (4), 307-324.
3. Meng, B.; Wang, J.; Andrew, R.; Xiao, H.; Xue, J.; Peters, G. P., Spatial spillover effects in determining China's regional CO2 emissions growth: 2007–2010. Energy Economics 2017, 63, 161-173.