Tutorial 3 – Trade and the environment

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1 An industry-firm-plant decomposition of emissions

This exercise is based on Cherniwchan, Copeland, and Taylor (2017), "Trade and the Environment: New Methods, Measurements, and Results", *Annual Review of Economics*.

We are interested in decomposing the pollution of an economy to analyze the determinants of its evolution. Let's denote Z the aggregate emission coming from N sectors. The emissions of sector i are denoted Z_i and can be decomposed into two elements: the scale of the industry denoted S_i, and its emission intensity E_i, such that $Z_i = S_i E_i$. Finally we denote $\Phi_i = S_i / S$ the output share of sector i and $\Theta_i = Z_i / Z$ its emission share.

1. If we denote $\dot{X}$ the time derivative of variable X, show that aggregate emissions evolve as follows:

$$\dot{Z} = \dot{S}\Big(\sum_{i=1}^{N} \Phi_i E_i\Big) + S\Big(\sum_{i=1}^{N} \dot{\Phi}_i E_i + \dot{E}_i \Phi_i\Big) \tag{1}$$

2. Show that the emission share of industry i can be expressed as:

$$\Theta_i = \frac{E_i \Phi_i}{\sum_{i=1}^{N} E_i \Phi_i} \tag{2}$$

3. Using the previous questions, show that the growth rate of total emissions can be decomposed as follows:

$$\frac{\dot{Z}}{Z} = \frac{\dot{S}}{S} + \sum_{i=1}^{N} \Theta_i \frac{\dot{\Phi}_i}{\Phi_i} + \sum_{i=1}^{N} \Theta_i \frac{\dot{E}_i}{E_i} \tag{3}$$

4. Interpret each of the three elements summed on the right-hand side of the equation.

5. Let's now assume that each industry i is itself composed of n_i firms. Let's define $z_i(n)$ the emission of firm n in sector i, $v_i(n)$ its value-added, $\varphi_i(n)$ its share in the production value of the industry, $e_i(n)$ its emission intensity, and $\theta_i(n)$ its industry share of emissions. Formally, we have:

$$Z_i = \sum_{n=1}^{n_i} z_i(n) \quad ; \quad S_i = \sum_{n=1}^{n_i} v_i(n) \quad ; \quad \varphi_i(n) = \frac{v_i(n)}{S_i} \quad ; \quad e_i(n) = \frac{z_i(n)}{v_i(n)} \quad ; \quad \theta_i(n) = \frac{z_i(n)}{Z_i}$$

Show that:

$$\theta_i(n) = \frac{e_i(n)\varphi_i(n)}{E_i} \tag{4}$$

6. Show that the emission intensity of industry i can be expressed as:

$$E_i = \sum_{n=1}^{n_i} e_i(n)\varphi_i(n) \tag{5}$$

7. Show that assuming n_i is exogenous and constant, we have:

$$\dot{E}_i = \sum_{n=1}^{n_i} \dot{e}_i(n)\varphi_i(n) + e_i(n)\dot{\varphi}_i(n) \tag{6}$$

8. Using the previous result, show that the growth rate of the industry's emission intensity can be expressed as:

$$\frac{\dot{E}_i}{E_i} = \sum_{n=1}^{n_i} \frac{\dot{e}_i(n)}{e_i(n)}\theta_i(n) + \frac{\dot{\varphi}_i(n)}{\varphi_i(n)}\theta_i(n) \tag{7}$$

9. Explain why this equation does not hold when n_i is endogenized.

10. Cherniwchan et al (2017) further decompose emissions at the plant level. Following this decomposition, how do you expect firms' emissions to evolve within firms?

11. Imagine you have a dataset with CO_2 emissions of all manufacturing plants' in the U.S. between 1991 and 2007. Your objective is to assess how trade agreements have affacted US manufacturing domestic emissions. Explain how plants' entry and exit decisions would make it difficult to obtain well-identified estimates?

2 Carbon leakages from Kyoto

This exercise is based on Aicheley & Felbermayr (2015) "Kyoto and Carbon Leakage: An Empirical Analysis of the Carbon Content of Bilateral Trade", *Review of Economics and Statistics*.

1. Explain the principle of "common but differentiated responsibilities" of the Kyoto protocol.

2. From the previous exercise, what could be the main concerns about this agreement?

3. Imagine you have a dataset including trade flows between countries and their associated CO_2 emissions. Comparing the evolution of the composition of trade flows between countries with and without binding commitments before and after the protocol, would you be able to identify the effect of the protocol on pollution leakages?

4. How do the authors attempt to solve the previous threat to identification?

5. What do the authors conclude about the extent of pollution leakages in the case of the Kyoto protocol?

6. What other strategy could have been used in order to avoid the previous concerns but still be consistent with the principle of "common but differentiated responsibilities"?