Competitiveness and Carbon Taxes

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Abstract

Blah blah blah

1 Leakage

We focus on the case of $\eta = 1$, in which energy is consumed only indirectly through consumption of manufactures. In that case emissions show up in four terms: M_e^{HH}, M_e^{FH}, M_e^{HF}, and M_e^{FF} (the first subscript is the point of consumption and the second the point of production). In a baseline of no carbon taxes, the fraction of emissions due to *production* in $\mathcal{F}$ is:

$$\begin{aligned}\frac{M_e^{HF}+M_e^{FF}}{M_e^{HH}+M_e^{FH}+M_e^{HF}+M_e^{FF}} &= \frac{p_e M_e^{HF}+p_e M_e^{FF}}{p_e M_e^{HH}+p_e M_e^{FH}+p_e M_e^{HF}+p_e M_e^{FF}} \\ &= \frac{(1-\gamma)\left(1-\bar{j}\right)\left(\pi_c Y+\pi_c^* Y^*\right)}{(1-\gamma)\left(\pi_c Y+\pi_c^* Y^*\right)} \\ &= 1-\bar{j},\end{aligned}$$

where $\bar{j}$ is $\mathcal{H}$'s market share in tradable manufactures. The fraction of emissions due to *consumption* in $\mathcal{F}$ is:

$$\frac{M_e^{FH}+M_e^{FF}}{M_e^{HH}+M_e^{FH}+M_e^{HF}+M_e^{FF}} = \frac{(1-\gamma)\,\pi_c^* Y^*}{(1-\gamma)\left(\pi_c Y+\pi_c^* Y^*\right)} = 1-\omega_c,$$

where

$$\omega_c = \frac{\pi_c Y}{\pi_c Y+\pi_c^* Y^*}$$

is $\mathcal{H}$'s share of world spending on the c-good.

We define *modified leakage* $\tilde{l}_P$ as the increased emissions in $\mathcal{F}$ resulting from a unilateral carbon tax in $\mathcal{H}$ relative to the resulting decline in global emissions. A value of $\tilde{l}_P > 0$ means that $\mathcal{F}$ has increased its emissions even as global emissions have declined due to the carbon tax in $\mathcal{H}$. Recall that the proportional change in global emissions is denoted by G (so that for any carbon tax worth considering, we can take $G < 1$). Our leakage formula is thus:

$$\begin{aligned}
\tilde{l}_P &= \frac{\left(M_e^{HF'} + M_e^{FF'}\right) - \left(M_e^{HF} + M_e^{FF}\right)}{\left(M_e^{HH} + M_e^{FH} + M_e^{HF} + M_e^{FF}\right)(1-G)} \\
&= \frac{1}{1-G}\frac{M_e^{HF}\left(\hat{M}_e^{HF} - 1\right) + M_e^{FF}\left(\hat{M}_e^{FF} - 1\right)}{M_e^{HH} + M_e^{FH} + M_e^{HF} + M_e^{FF}} \\
&= \frac{1-\bar{j}}{1-G}\left(\omega_c \hat{M}_e^{HF} + (1-\omega_c)\,\hat{M}_e^{FF} - 1\right).
\end{aligned}$$

Leakage is driven by the proportional increase in $\mathcal{F}$'s use of energy in manufactures produced for its export market and in manufactures produced for its home market. To derive expressions for these changes, we need to take a stand on the specific carbon taxes being considered.

We treat the carbon tax in $\mathcal{H}$ as a combination of a production tax t_p' and a border tax adjustment $t_b' \in [0, t_p']$. With no border adjustments ($t_b' = 0$) it is a pure production tax (at rate t_p') while with full border adjustments ($t_b' = t_p'$) it is a pure consumption tax (at rate t_b'). The reduction in global emissions G under such policies is acheived through reduced demand for energy, which drives down the price of energy faced by the extraction sector, leading that sector to supply less energy on the world market. This reduction in the price of energy $\hat{p}_e$, known as the *fuel price effect*, is connected to the reduction in global emissions via the energy supply curve:

$$\hat{p}_e = G^{(1-\beta)/\beta}. \tag{1}$$

The effect of such policies on changes in $\mathcal{F}$'s energy use are given by:

$$\hat{M}_e^{HF} = \frac{1-\bar{j}'}{1-\bar{j}}\frac{\hat{\pi}_c \hat{Y}}{(1+t_b')\,\hat{p}_e}$$

and

$$\hat{M}_e^{FF} = \frac{1-\bar{j}'}{1-\bar{j}}\frac{\hat{\pi}_c^* \hat{Y}^*}{\hat{p}_e}.$$

Plugging these expressions into the leakage formula:

$$\tilde{l}_P = \frac{1-\bar{j}}{1-G}\left(\frac{1-\bar{j}'}{1-\bar{j}}\left[\omega_c\hat{\pi}_c\hat{Y}/\left(1+t_b'\right)+\left(1-\omega_c\right)\hat{\pi}_c^*\hat{Y}^*\right]\frac{1}{\hat{p}_e}-1\right)$$

Leakage depends on three basic factors: (i) the trade share effect is the change in $\mathcal{F}$'s market share in manufacturing $(1-\bar{j}')/(1-\bar{j})$, (ii) the fuel price effect is the inverse of the proportional decline in the global energy price $1/\hat{p}_e$, and (iii) the spending effect is the change in world spending on manufactured goods (taking account of any border tax adjustment) $\omega_c\hat{\pi}_c\hat{Y}/\left(1+t_b'\right)+\left(1-\omega_c\right)\hat{\pi}_c^*\hat{Y}^*$. We can consider these factor separately.

The trade share effect is given by:

$$\frac{1-\bar{j}'}{1-\bar{j}} = \frac{1}{\bar{j}\left(\frac{1+t_p'}{1+t_b'}\right)^{-\theta(1-\gamma)}+1-\bar{j}}.$$

This factor is increasing in the effective production tax rate $\tilde{t}_p'$, defined by $1+\tilde{t}_p' = (1+t_p')/(1+t_b')$, which shifts production from $\mathcal{H}$ to $\mathcal{F}$. With full border tax adjustments this factor reduces to 1 and thus no longer contributes to leakage.

The second factor is the fuel price effect. If a carbon tax leads to a reduction in global emissions, equation (1) tells us there will be a reduction in the energy price. Since this change is in the denominator, the fuel price effect always contributes positively to leakage. For a given change in spending on manufactures (and hence on energy), it implies a greater increase in energy use. But, unlike the trade share effect, the fuel price effect leads to greater energy use in both countries. In fact, there would be a fuel price effect even with no trade in manufactures.

The third factor is the most nuanced. Income falls in both countries due to reduced rents from energy deposits. But, income may rise in $\mathcal{H}$ due to new tax revenue. There are also changes in the share of income spent on manufactures, due to price changes from both taxes and the fuel price effect. The change in the share of income spent on the manufactured good in $\mathcal{H}$ is:

$$\hat{\pi}_c = \frac{\hat{p}_c^{-(\sigma-1)}}{\pi_c\hat{p}_c^{-(\sigma-1)}+1-\pi_c}$$

and likewise for $\mathcal{F}$. The change in the price of the manufactured good in $\mathcal{H}$

is given by:

$$\begin{aligned}\hat{p}_c &= \hat{p}_m = \hat{p}_e^{1-\gamma}\left(\bar{j}\left(1+t_p'\right)^{-\theta(1-\gamma)} + (1-\bar{j})\left(1+t_b'\right)^{-\theta(1-\gamma)}\right)^{-1/\theta} \\ &= \left(1+t_b'\right)^{(1-\gamma)}\hat{p}_e^{1-\gamma}\left(\bar{j}\left(\frac{1+t_p'}{1+t_b'}\right)^{-\theta(1-\gamma)} + (1-\bar{j})\right)^{-1/\theta},\end{aligned}$$

while in H:

$$\hat{p}_c^* = \hat{p}_e^{1-\gamma}\left(\bar{j}\left(\frac{1+t_p'}{1+t_b'}\right)^{-\theta(1-\gamma)} + (1-\bar{j})\right)^{-1/\theta}.$$

Prices fall due to the fuel price effect, but taxes that shift trade shares push prices up. In general, these shifts work in parallel in either country. The border tax adjustment, however causes prices to rise more in $\mathcal{H}$ than in $\mathcal{F}$:

$$\frac{\hat{p}_c}{\hat{p}_c^*} = \left(1+t_b'\right)^{(1-\gamma)}.$$

2 Welfare

The ultimate goal of any carbon taxing scheme is to maximize welfare conditional on meeting emissions reduction criteria. In this model, a country's welfare is its spending power - more precisely, its income divided by a price index of energy, manufactures, and the l-good (see :

$$W = \frac{Y}{p}$$

After taxes, welfare can change, and we denote this as before with a hat:

$$\hat{W} = \frac{W'}{W}$$

These expressions are analogous for Foreign with stars. There is one more relevant measure which is world welfare. Since welfare can differ between Home and Foreign, world welfare is expressed in expectation, weighted by the sizes of the countries' respective labor forces:

$$W_{world} = \omega_L * W + \omega_L^\star * W^\star \tag{2}$$

where ω_L and $\omega_L^\star$ denote the world share of labor returns in Home and Foreign, respectively (recall that wages are equalized):

$$\omega_L = \frac{\pi_L * Y_{rel}}{\pi_L * Y_{rel} + \pi_L^\star} \tag{3}$$

$$\omega_L^\star = \frac{\pi_L^\star}{\pi_L * Y_{rel} + \pi_L^\star} \tag{4}$$

3 Changes in Production and Consumption of Energy

After imposing a tax, the value of the energy used in $\mathcal{H}$ to supply the domestic market is:

$$p_e' M_e^{HH\prime} = (1-\gamma)\,\bar{j}'\,\frac{\pi_c' Y'}{1+t_p'}$$

while for the foreign market:

$$p_e' M_e^{FH\prime} = (1-\gamma)\,\bar{j}'\,\frac{\pi_c^{*\prime} Y^{*\prime}}{1+\tilde{t}_p'}.$$

The value of the energy used in $\mathcal{F}$ to supply manufactures to $\mathcal{H}$ is:

$$p_e' M_e^{HF\prime} = (1-\gamma)\,(1-\bar{j}')\,\frac{\pi_c' Y'}{1+t_b'},$$

while in producing for $\mathcal{F}$:

$$p_e' M_e^{FF\prime} = (1-\gamma)\,(1-\bar{j}')\,\pi_c^{*\prime} Y^{*\prime}.$$

From these expressions, we can derive:

1. The post-tax change in Home production of energy:

$$
\begin{aligned}
(M_e^{HH} \hat{+} M_e^{HF}) &= \frac{M_e^{HH\prime} + M_e^{HF\prime}}{M_e^{HH} + M_e^{HF}} \\
&= \frac{\frac{(1-\gamma)\bar{j}' \frac{\pi_c' Y'}{1+t_p'}}{p_e'} + \frac{(1-\gamma)\bar{j}' \frac{\pi_c^{*\prime} Y^{*\prime}}{1+\tilde{t}_p'}}{p_e'}}{\frac{(1-\gamma)\bar{j}\pi_c Y}{p_e} + \frac{(1-\gamma)\bar{j}\pi_c^* Y^*}{p_e}} \\
&= \frac{\bar{j}'}{\hat{p_e} j} \frac{\pi_c' Y' + \pi_c^{*\prime} Y^{*\prime}(1+t_b')}{(\pi_c Y + \pi_c^* Y^*)(1+t_p')} \\
&= \frac{\bar{j}'}{\hat{p_e} j} \frac{\omega_c \hat{\pi_c} \hat{Y} + (1-\omega_c)\hat{\pi_c}^* \hat{Y}^* (1+t_b')}{1+t_p'}
\end{aligned}
$$

2. The post-tax change in Foreign production of energy:

$$
\begin{aligned}
(M_e^{HF} \hat{+} M_e^{FF}) &= \frac{M_e^{HF\prime} + M_e^{FF\prime}}{M_e^{HF} + M_e^{FF}} \\
&= \frac{1-\bar{j}'}{(1-j)\hat{p_e}} \frac{\omega_c \hat{\pi_c} \hat{Y}(1+t_b') + (1-\omega_c)\hat{\pi_c}^* \hat{Y}^*}{1+t_b'}
\end{aligned}
$$

3. The post-tax change in Home consumption of energy:

$$
\begin{aligned}
(M_e^{HH} \hat{+} M_e^{HF}) &= \frac{M_e^{HH\prime} + M_e^{HF\prime}}{M_e^{HH} + M_e^{HF}} \\
&= \frac{\hat{\pi_c} \hat{Y}}{\hat{p_e}} \left(\frac{\bar{j}'}{1+t_p'} + \frac{1-\bar{j}'}{1+t_b'} \right)
\end{aligned}
$$

4. The post-tax change in Foreign consumption of energy:

$$
\begin{aligned}
(M_e^{FH} \hat{+} M_e^{FF}) &= \frac{M_e^{FH\prime} + M_e^{FF\prime}}{M_e^{FH} + M_e^{FF}} \\
&= \frac{\hat{\pi_c}^* \hat{Y}^*}{\hat{p_e}} \left(\frac{\bar{j}'}{1+\tilde{t_p}'} + (1-\bar{j}') \right)
\end{aligned}
$$