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 as: 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:

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

It 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 production in $\mathcal{F}$ 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 is driven by three basic factors: (i) the trade share effect is the change in $\mathcal{F}$'s market share in manufacturing $\left(1-\bar{j}'\right)/\left(1-\bar{j}\right)$, (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 the change in $\mathcal{F}$'s market share in manufactures, 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 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.

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

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

and likewise for $\mathcal{F}$. Changes in these shares depend on changes in the price of the manufactured good. In $\mathcal{H}$ that change is given by:

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

while in H:

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

The last term in each expression is the proportional increase in the price of the manufactured good caused by the effective production tax, which raises costs in $\mathcal{H}$ and leads to a change in the goods that each country specializes in. The fuel price effect partially offsets this price increase. Only the border tax adjustment causes prices to rise more in $\mathcal{H}$ than in $\mathcal{F}$:

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

To understand these three factors more clearly, it is helpful to consider two special cases.

1.1 Pure Production Tax

In the case of a pure production tax ($t_b' = 0$), these price changes would be the same. If the initial shares were the same ($\pi_c = \pi_c^*$) then changes in shares would be the same $\hat{\pi}_c = \hat{\pi}_c^*$. In this case leakage is simply:

$$\begin{aligned}l_P &= \hat{\pi}_c\frac{\omega_c\hat{Y} + \left(1-\omega_c\right)\hat{Y}^*}{\bar{j}\left(\frac{1+t_p'}{1+t_b'}\right)^{-\theta(1-\gamma)} + 1 - \bar{j}}G^{-1/\beta} \\ &= \end{aligned}$$

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

1.2 Pure Consumption Tax

In the case of a pure consumption tax ($t_b' = t_p'$), there is no change in F's trade share:

$$\frac{1-\bar{j}'}{1-\bar{j}} = \frac{1}{\bar{j}+1-\bar{j}} = 1.$$

Thus leakage is due only to the increase in foreign consumption brou

$$l_P = \left(\omega_c \hat{\pi}_c \hat{Y} + (1-\omega_c)\, \hat{\pi}_c^* \hat{Y}^*\right) G^{-1/\beta}$$