

# Is trade of bioenergy good for the environment?

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# Motivation

- Bioenergy and climate policies context in North
  - Market potential for bioenergy production
  - Competition with oil: need for subsidies for domestic producers
  - Problem: low environmental gains
- Opening North-South bioenergy trade
  - Low production cost and high yields in South
  - Potential for resource-based development
  - Problem: increasing pressure on land use (deforestation)

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Literature on trade and environment (Copeland and Taylor, 1994, 1995, 2003) based on

- Factor abundance and technological differences  
(Heckscher-Ohlin-Samuelson, Dornbusch-Fisher-Samuelson)
- Pollution haven  
A country with low pollution taxes has a comparative advantage in pollution-intensive sector
- But agriculture has been neglected  
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# Framework: Copeland and Taylor (1994,1995)

- Hypotheses:
  - transboundary pollution
  - general equilibrium (continuum of industries)
  - North-South difference: labor is more productive in North
  - Nash equilibrium with endogenous policy on pollution
- Results:
  - Pollution haven in South
  - FPE: same global pollution level as in autarky but  $\nearrow$  in South and  $\searrow$  in North
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## 2 goods, 3 factors model

- Agricultural sector:  $A = K_A^\mu L_A^{1-\mu}$ 
  - 2 inputs:  $L_A$  labor and  $K_A$  natural capital available in the country
  - Substitution in output between food and bioenergy
- Industrial sector:  $M = L_M^{1-\alpha} [Z^{1-e} B^e]^\alpha$   
3 inputs: labor  $L_M$ , fossil fuel  $E$ , bioenergy  $B$
- Both sectors are responsible for GHG emissions  
either through the use of natural capital, or through the use of fossil fuel
- Bioenergy intermediate product can reduce industrial emissions but generates emissions from production

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# Endogenous pollution regulation

- Each government decides to regulate pollution using two sectoral policies:
  - $\tau$  tax per unit of fossil fuel emissions (affecting the industrial sector)
  - $\tau_A$  tax per unit of natural capital considering its externality (chemicals, deforestation)
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# Demand

- Representative consumer's utility:

$$U = b_A \ln D_A + b_M \ln D_M - \beta \frac{(Z^w)^\gamma}{\gamma}$$

- $b_A, b_M$  shares of food and industrial goods in spendings
  - $\beta > 0$  constant determining the welfare loss from pollution
  - $\gamma \geq 1$  to ensure environmental quality is a normal good
- Income:  $I = wL + \tau Z_M + \tau_A K_A$

lump-sum redistribution of pollution taxes

full employment

# Optimal regulation

Dual approach

Whatever the region, optimal taxes are defined by

$$\tau = \beta I (Z^w)^{\gamma-1} \quad (1)$$

$$\tau_A = \psi'(K_A)\tau \quad (2)$$

then pollution taxes increase in income and global pollution

# Factor intensity hypothesis

- **H1: The industry is pollution-intensive:**

$$Z_M/L_M > Z_A/L_A$$

- Rationale: LULUCF represents almost 20 percent of global emissions in 2004, industries 29 percent (and transport 15 percent)

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# Pollution supply and demand

- Equilibrium equalizes pollution demand and supply:

Supply depends on technologies and relative share of each sector

Demand is implicit when consumers demand consumption goods

- Inverse supply pollution function:

$$\frac{\tau}{w} = \frac{\beta L (Z^w)^{\gamma-1}}{1 - \beta [Z_M + \sigma Z_A] (Z^w)^{\gamma-1}}$$

which depends on the national labor endowment  $L$

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# Autarky equilibrium

- Only domestic demand
- Total pollution demand for North:

$$Z = Z_M + Z_A = \frac{\theta}{\beta(Z^w)^{\gamma-1}}$$

with  $\theta \equiv (1 - e)\alpha b_M + \mu(e\alpha b_M + b_A)/\sigma$ .

Hence  $Z = Z^*$

- Global level of pollution:

$$Z^{wa} = nZ + n^*Z^* = \left[ \frac{(n + n^*)\theta}{\beta} \right]^{\frac{1}{\gamma}}$$

# Autarky results

Despite different labor endowment ( $L > L^*$ ), in autarky, North and South are characterized by

- Same national level of pollution
- Same natural capital use
- Same industrial pollution levels
- Relative factor price difference

$$\tau/\tau^* = \tau_A/\tau_A^* > 1 \text{ and } w/w^* < 1.$$

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# Comparative advantages

- HOS predictions: labor-abundant North should specialize in labor-intensive agriculture and pollution-abundant South in industry.
- However same pollution levels and intermediate product
- **H2: South specializes in agriculture and North in industry if** given industrial unit-cost function  $c_M(w, \tau) = \kappa_M w^{1-\alpha} \tau^{(1-\theta)\alpha}$ ,

$$c_M(w, \tau) < c_M(w^*, \tau^*) \text{ if } \mu > 1/\xi = \frac{\alpha(1-e)}{1-e\alpha} \quad \text{H2}$$

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# Diversified trade equilibrium

- Producers face international demand
- Iceberg cost approach (Samuelson, 1954):
  - No friction for agricultural good
  - Trade frictions for industrial good: 'shrinkage'
- If trade frictions are high, close to autarky
  - Free trade corresponds to no friction

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- No factor price equalization

$\tau/\tau^* = I/I^*$  increases if high  $\sigma$ ,

$\tau_A/\tau_A^*$  decreases and  $w/w^*$  increases.

- Pollution demand depends on international demand

$$Z_M + \sigma Z_A = \frac{\phi \delta_Z / \delta_I}{\beta (Z^W)^{\gamma-1}}$$

where  $\phi \equiv (1 - e)\alpha b_M + \mu(e\alpha b_M + b_A)$  share of taxes in income

$\delta_I$  Northern share of global revenue

$\delta_Z$  Northern share of environmental taxes.

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# Trade impacts on the environment

Proposition 1: With the opening of the frontiers, compared to autarky,

- Agriculture use more natural capital in South and less in North
- Industries pollute more in North and less in South
- Northern total level of pollution increases whereas Southern one decreases
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# Trade impacts on the welfare

Proposition 2: With the opening of the frontiers, compared to autarky, the revenue of Northern countries increases provided that  $\sigma > \bar{\sigma}$  whereas the revenue of Southern countries decreases.

As a consequence,

- Reduction in global emissions is welfare improving
- Trade widens the North-South divide since  $I^N / I^S$  increases
- Net effect: positive for North, whereas for South it depends on  $\beta$  (environmental preference versus consumption)

# Conclusion

- Focus on energy and natural capital as sources of emissions
- Bioenergy is the intermediate factor that allows to pollute less in industry but increases pressure on lands
- Decrease in global emissions due to a technique effect
- With optimal taxes in both sector, detrimental effect on Southern revenue

Hence strong case against South's involvement in international agreements (stricter regulation)

Even if bioenergy trade is seen as a compensation

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# Trade equilibrium

- Income shares for environmental taxes and wages depend on global income:

$$\begin{aligned}\tau Z_M^N + \tau^* Z_M^S + \tau_A K_A^N + \tau_A^* K_A^S &= \phi(I^N + I^S) \\ wL^N + w^*L^S &= (1 - \phi)(I^N + I^S)\end{aligned}$$

where  $\phi \equiv (1 - e)\alpha b_M + \mu(e\alpha b_M + b_A)$   
share of all environmental taxes in global income

- For regional shares, denote

$$\begin{aligned}\delta_Z &\equiv \frac{\tau Z_M^N + \tau_A K_A^N}{\tau Z_M^N + \tau_A K_A^N + \tau^* Z_M^S + \tau_A^* K_A^S} \\ \delta_L &\equiv wL^N / (wL^N + w^*L^S) \\ \delta_I &\equiv I^N / (I^N + I^S)\end{aligned}$$

- Relationship between the shares:  $\delta_I = (1 - \phi)\delta_L + \phi\delta_Z$

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# Trade equilibrium

- Inverse pollution demand function in trade:

$$\frac{\tau}{w} = \frac{\phi\delta_Z L}{(1-\phi)\delta_L [Z_M + \sigma Z_A]}$$

- At the equilibrium, supply and demand of pollution are equalized:

$$Z_M + \sigma Z_A = \frac{\phi\delta_Z / \delta_I}{\beta(Z^w)^{\gamma-1}}$$

which is combined with  $\frac{\sigma}{\mu} Z_A + \xi Z_M = 1 / [\beta(Z^w)^{\gamma-1}]$  to give

- Sectoral levels of pollution:

$$Z_M^t = \frac{\mu - \phi\delta_Z / \delta_I}{(\mu\xi - 1)\beta(Z^w)^{\gamma-1}}$$

$$Z_A^t = \frac{\mu[\xi\phi\delta_Z / \delta_I - 1]}{\sigma(\mu\xi - 1)\beta(Z^w)^{\gamma-1}}$$

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