Environmental and economic efficiencies in a location optimization strategy

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Plan

- Introduction
- The general problem
- Space representation
- Some results in two cases
  - Complementary inputs
  - Substitutable inputs
- Concluding remarks

Motivations (1)

- .. "given the role that transport plays in causing greenhouse gas emissions, any serious action on climate change will zoom in on the transport sector"

  (Yvo de Boer, Executive Secretary of the United Nations, 15 Jan 2009).

- Transport of commodities is a big and growing emitter of GHG (OECD, 2008).
  - 30% (resp., 20%) of total GHG emissions in the USA (resp., the EU-15)
  - has increased by 28% over the period 1990-2006.
  - Road-based transport accounts for approximately 80% of transport sector GHG emissions.

- A significative share of the GHG emissions are generated by the shipping of commodities

Motivations (2)

- **Environmental policies** neglect their impact on the spatial organization of the economy and, in turn, on transport demand and the resulting GHG emissions.

- However, when assessing the ecological impact of carbon taxation, the existing literature has partially neglected two issues:

  - The supply firms are assumed to be given (no supply choice…),

  - Production technology matters.

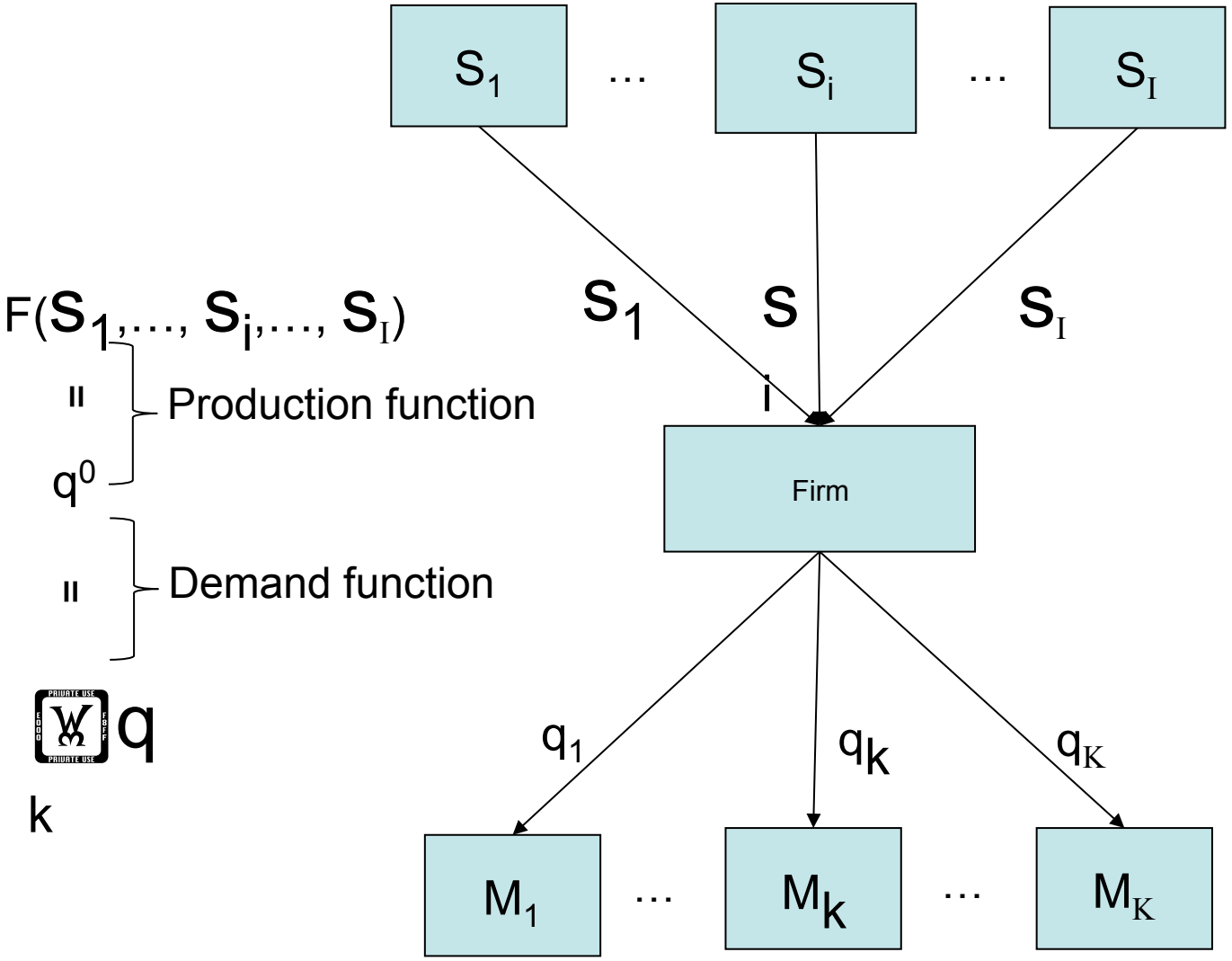
Literature on Location, Transport and GHG Emissions

- Location, transport… => numerous works in OR and in Reg Urb Econ
- GHG emissions, sustain… => emerging works in economy,…, SCM
- Peeters and Thisse (2001)
  - Production-location problem
- Gaigné, Riou and Thisse (2011)
  - both firms and households are free to locate between and within cities.
  - agglomeration : polluting emissions vs worktrips.

Objective

- Economic vs environmental
- Our analysis relies on the following major trade-off:
  - Agglomeration decreases the polluting emissions downstream…
  - But, agglomerating activities increases emissions upstream…
- Production technology AND the spatial pattern of activities.
- This work is in progress…

The production problem



The production-location model

the objective of the firm is to find the best location l
to maximize her profit function

$$\Pi(l, q^0) = \underbrace{\sum_{k=1}^{K} p_k q_k}_{\text{turnover}} - \underbrace{\sum_{i=1}^{I} w_i s_i}_{\text{purchase}} - \underbrace{\sum_{k=1}^{K} t_{lk} d_{lk} q_k}_{\text{dowstream transport cost}} - \underbrace{\sum_{i=1}^{I} t_{il} d_{il} s_i}_{\text{upstream transport cost}}$$

$$- \underbrace{\tau \sum_{k=1}^{K} \alpha_k d_{lk} q_k}_{\text{dowstream carbon cost}} - \underbrace{\tau \sum_{i=1}^{I} \beta_i d_{il} s_i}_{\text{upstream carbon cost}}$$

Environmental costs

sujet to $q^0 = F(s_1, \ldots, s_I)$ and $\sum_{k=1}^{K} = q^0$.

Production-location optimization

- Technology design

$$\bar{s} = \underset{q=(s_1,\ldots,s_I)}{\arg\min} \left(\sum_{i=1}^{I} w_i s_i + \sum_{i=1}^{I} t_{il} d_{il} s_i + \sum_{i=1}^{I} \beta_i d_{il} s_i \right)$$

- l^P : economic efficiency location

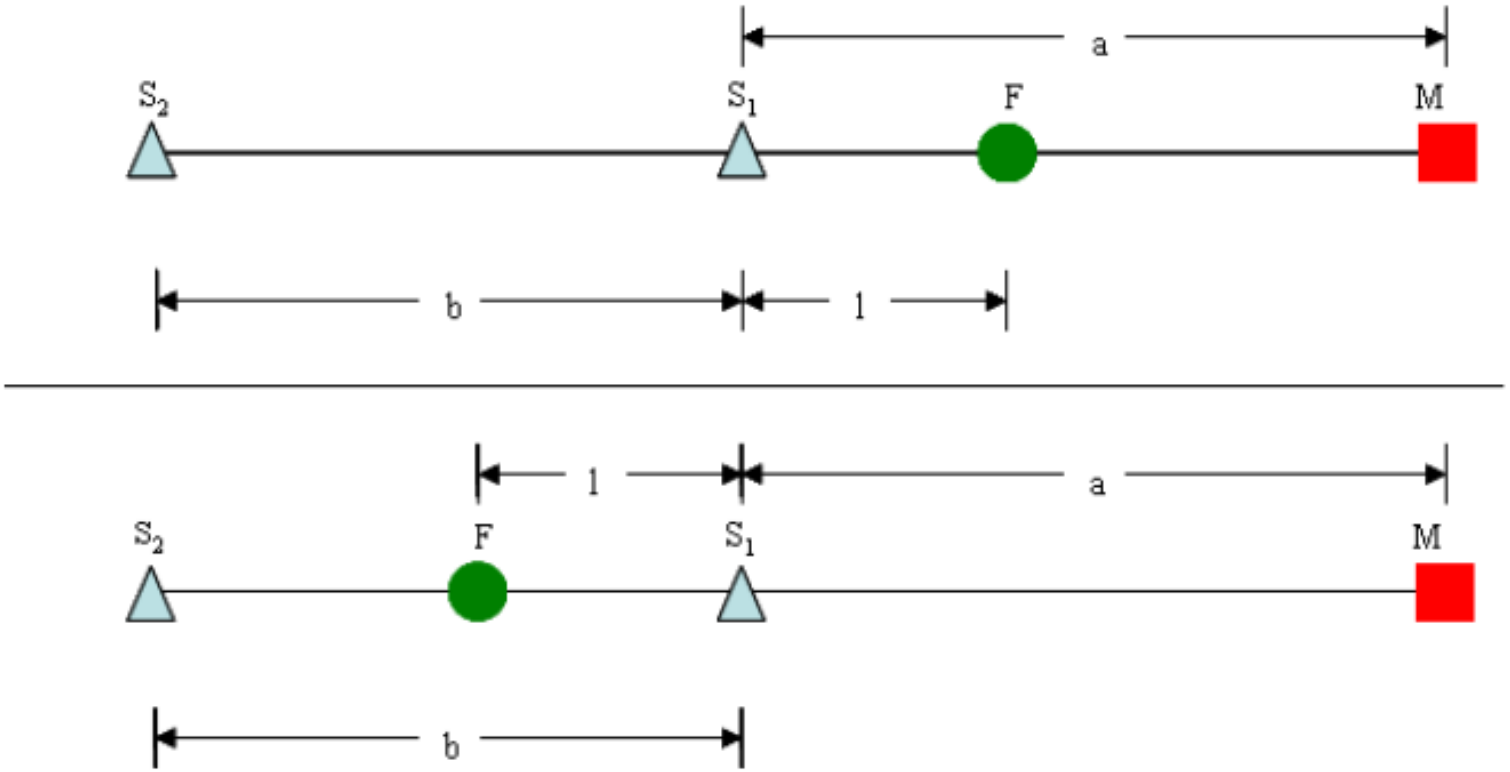
$$l^P = \underset{l \in L}{\arg\max} (\Pi(l, \bar{s}))$$

- l^E : environmental efficiency location

$$l^E = \underset{l \in L}{\arg\min} \left(Env(l, \bar{s}) = \sum_{k=1}^{K} \alpha_k d_{lk} q_k + \sum_{i=1}^{I} \beta_i d_{il} s_i \right)$$

Spatial representation

- 2 suppliers and 1 demand market



Complementary goods (Leontief production function)

- Hypothesis
  - Each input is used with a fixed coefficient

$$s_i = a_i q^0$$

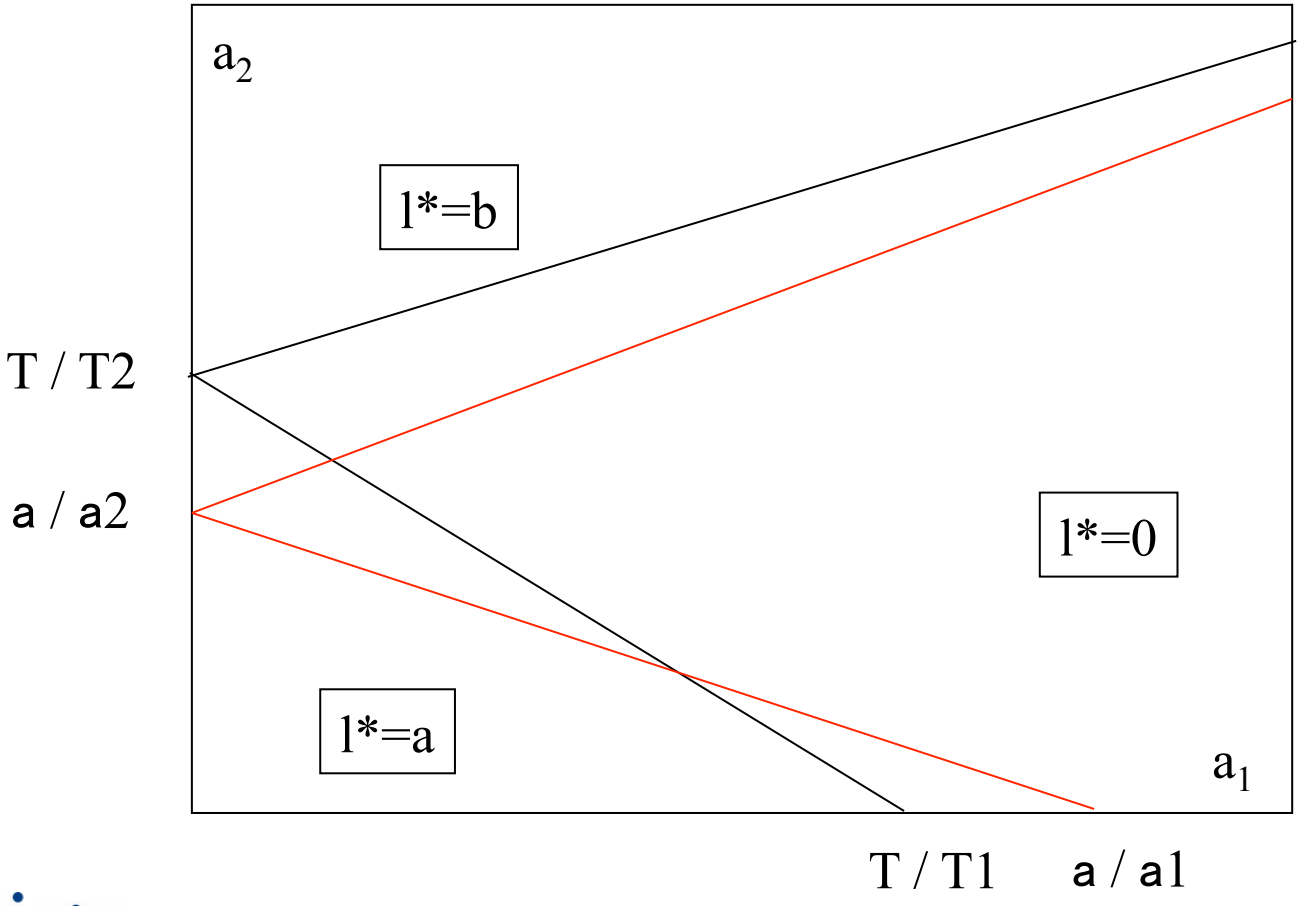
- First result
  - Whether economic or environmental efficiency, the optimal location of the firm lies in S1, S2 or M.
  - This result comes from the shape of the two functions which are linear in *l*.

case a :

$$\frac{\partial \Pi(l, \bar{s})}{\partial l} = q_0(t + \tau\alpha - a_1(t_{1l} + \tau\alpha_1) - a_2(t_{2l} + \tau\alpha_2))$$

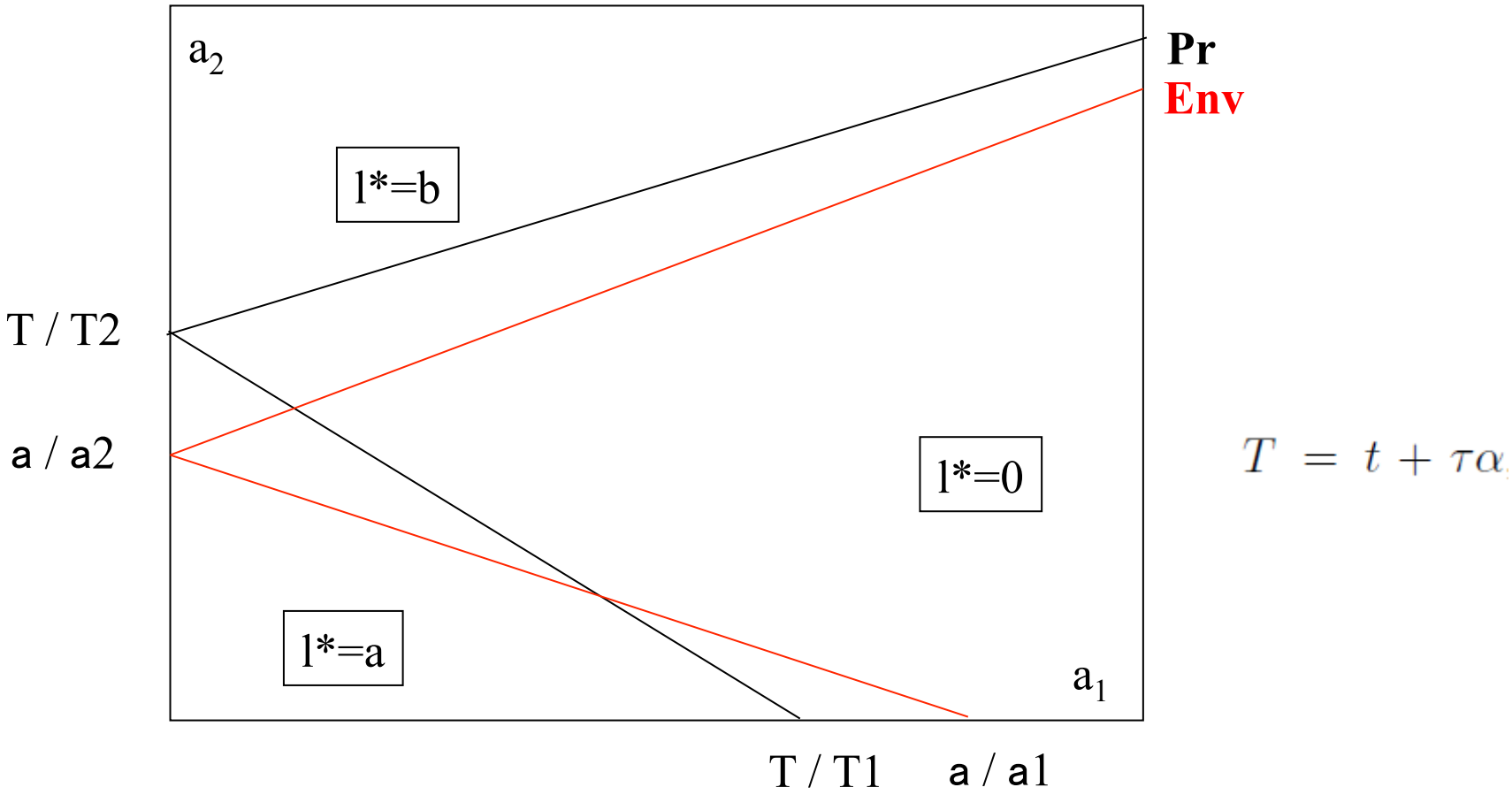
$$\frac{\partial Env(l, \bar{s})}{\partial l} = q_0(a_1\alpha_1 + a_2\alpha_2)$$

Graphical analysis



$$T = t + \tau\alpha$$

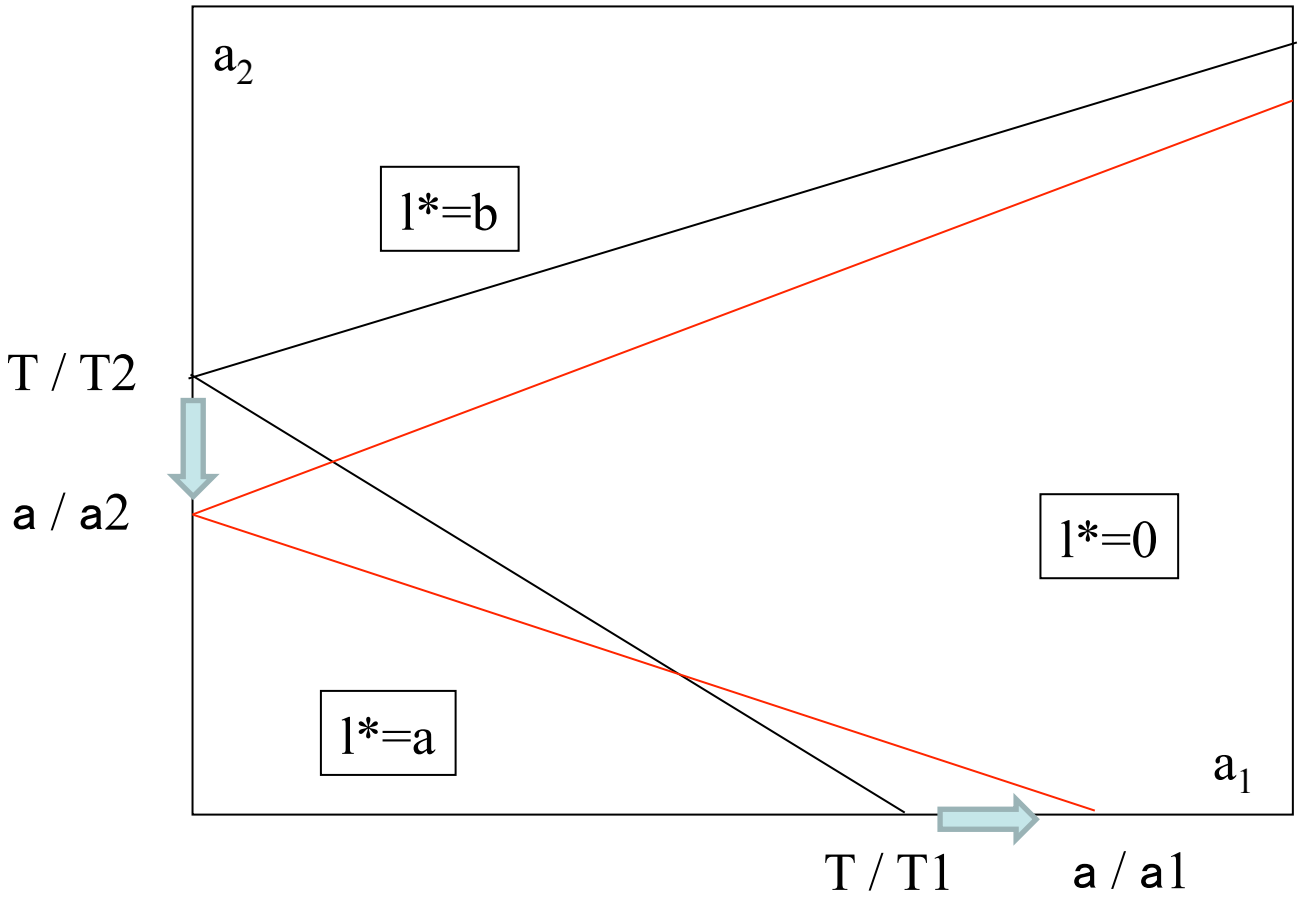
Carbon tax impact (1)



$$T = t + \tau\alpha$$

- a / a2 = t / t2 and a / a1 = t /t1 => tax inefficient

Carbon tax impact (2)



$$T = t + \tau\alpha$$

- otherwise, a tax increases the number of cases of dual optimization (eco and env). A perfect situation is obtained for an infinite tax.

Substitute input (Cobb-Douglas production function)

- Hypothesis
  - Different technological combinations of input exist to produce goods.

$$q^0 = a_0 s_1^{a_1} s_2^{a_2}$$

- First result
  - Whether economic or environmental efficiency, the optimal location of the firm lies in S1, S2 or M.
  - This result comes from the shape of the two functions (second derivatives).

$$\frac{\partial^2 \Pi(l, \bar{s})}{\partial l^2} > 0 \quad and \quad \frac{\partial^2 E(l, \bar{s})}{\partial l^2} < 0$$

Optimization process

- Optimal supply quantities

$$\bar{s}_1 = \left(\frac{q^0}{a_0}\right)^{\frac{1}{a_1+a_2}} \left[\frac{a_1(w_2+T_2d_2)}{a_2(w_1+T_1d_1)}\right]^{\frac{a_2}{a_1+a_2}} \qquad \bar{s}_2 = \left(\frac{q^0}{a_0}\right)^{\frac{1}{a_1+a_2}} \left[\frac{a_2(w_1+T_1d_1)}{a_1(w_2+T_2d_2)}\right]^{\frac{a_1}{a_1+a_2}}$$

- The optimal location can not be calculated analytically
- Then, for a set of parameters values, we compare profit and environmental functions for l=0; l=a and l=b.

Concluding remarks

- In the case of complementary goods,
  - unimodal transportation mode : carbon tax unusefull.
  - optimum for both functions.
  - Otherwise, improvement of the green location (double efficiency)

- In the case of substitute goods,
  - The firm has to locate near one supplier or near the final market.
  - There exists example for which a tax will not be profitable to environmental strategies.

Concluding remarks (2)

- Operational point of view
  - To generalize with K demands and I suppliers
  - To generalize with a 2-dimentionnal space.

- Economic point of view
  - To determine the GHG emissions in each part (supply and demand sides)
  - To include deman sensitivity to pollution…

- Our work is far too preliminary to make strong and specific policy recommendations. However, we believe that our results are sufficiently convincing to invite city planners and policy-makers to pay more attention to the various implications of carbon tax.