Trade, Invasive Species and the Spatial Insurance Hypothesis

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A project in progress ...

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Motivation

The Millenium Ecosystem Assesment: ecosystems provide services which are valuable.

Ecology: more diverse ecosystems provide more services, and reduce the variability of these services. Application: Baumgartner (Natural Resource Modelling, 2007).

Economics: distinguish what is collectively good, and what is individually beneficial.

Can we use insights from both fields ?

Trade and Invasive Species

Invasive species: dramatic economic and ecological effects.

Ecology: easier to invade an ecosystem when it has low biodiversity.

Ecology and Economics: Trade is an important vector of invasions. Perrings, Mooney, Williamson ("Bioinvasions and globalization", 2010).

Economics: trade is collectively good, because of specialization (the law of comparative advantages).

So trade leads to specialization, and specialization makes ecosystems more vulnerable to invasive species that migrate thanks to trade ...

A simple model of trade and invasive species

Begin by the case of a single country.

This country hosts a population of humans, and different ecosystems. (Key example is agriculture).

Humans manage ecosystems so as to exploit services that allow them to produce consumption goods.

Because humans enjoy consuming different goods, they end up managing diverse ecosystems.

Inside this country each good (consumption goods and labour) has an equilibrium price that equates supply and demand. A market economy works perfectly well.

The case of several countries

Trade occurs because of price differences between countries.

Because countries are different, each ends up specializing in the production of a consumption good.

Economics: this is efficient, and good for all countries. But ...

... Ecology: each country now has a low biodiversity, and this makes invasions more successful.

In our model: humans allocate labor between fighting invasions and managing ecosystems for production.

So free trade can be collectively inefficient ?

Some intuitions

One can indeed show, in a formal model, that free trade can be collectively inefficient – a justification for trade tariffs.

- In the absence of trade, there is no externality between agents in the same country: so ecosystems are efficiently managed.
- Under free trade, those agents that decide to import a good only consider prices, and not the possibility of an invasion: market failure.
- This is an externality. It should be corrected by an appropriate taxation: trade tariffs. (... Margolis and Shogren, Environment and Resource Economics, 2012)
- So far a simple, static model. What about dynamics, resilience, ... ?

The Spatial Insurance Hypothesis

Loreau, Mouquet, Gonzalez (PNAS 2003): a simple dynamic model of species dispersal among M "countries".
In each country j, specie i evolves according to

$$\dot{N}_{ij}(t) = [b_{ij}(t)R_j(t) - m_i]N_{ij}(t) + \frac{a}{M-1}\sum_{k\neq j} N_{ik}(t) - aN_{ij}(t)$$

where $R_j(t)$ is a resource stock, with its own dynamics impacted by consumption by species in country j, and $b_{ij}(t)$ has a stochastic component (the environment: climate, ...).

Simulations highlight the role of parameter a: natural dispersal.

But humans manage ecosystems; and trade favors natural dispersal.

Introducing management decisions and trade

In each country j, a single good is produced from species $i = 1 \ldots S$. Specie i population evolves according to

$$\dot{N}_{ij}(t) = [b_{ij}(t)R_j(t) - m_i]N_{ij}(t)$$

$$+ \sum_{k \neq j} [M_{jk}(t)N_{ik}(t) - X_{jk}(t)N_{ij}(t)] - Z_{ij}(t)$$

where M, X are imports and exports of the consumption good, and Z is the management decisions by humans.

The ecological model is now coupled to an economic model that determines imports, exports, and management decisions.

The economic model also determines a measure of performance (expected welfare of humans).

Research questions

More trade means a more diversified consumption: good for welfare.

More trade means more specialization: bad for alpha-biodiversity, good for gamma-diversity.

More trade means more dispersal. This can be good or bad for ecosystem services production.

More trade also impacts management decisions: $Z < 0$ if one wants to fight invasions or control pests, $Z > 0$ if one wants to favor a productive specie.

In progress ...

Analytic results: lots of externalities. Those that favor a specie for productive reasons also favor dispersal of this specie. Same for intermediaries that export and import.

Optimal trajectories (social planner) vs. decentralized trajectories (market economy).

Simulation results under progress (dynamic optimization, multiple state variables, ...), for the optimal trajectories.

First type of output: social value of biodiversity, of a specie, insurance value, ...

Second type of output: general results on the interactions between humans and ecosystems.