Resilience bonds, green transition and complex dynamics

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Agenda

- Motivation of the research
- Our proposal
- Model's dynamics
- Model's equilibria: optimal equilibrium and poverty trap
- Comments and further research
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Motivation

Lloyd's CEO, John Neal said in 2021: âInsurers can not absorb huge losses after natural disasters especially with this trend of climate change, but the insurance industry has got 35 trillion under management, so we are part of the solution, if you like, of putting our assets at play to support green transition.

He even affirmed that there is the need of a partnership between governmental authorities and insurance companies to incentive investments by private companies for green transition.

Motivation

EIOPA. The role of insurers in tackling climate change: challenges and opportunities. 2023.

Insurers can develop innovative insurance products that incentive climate related risk prevention, for instance through offering lower premiums to policyholders implementing climate related adaptation measures.

Our proposal

In our model there is a set of firms (policy-holders) exposed to possibly catastrophic risks, which could be mitigated through the implementation of green technologies.
Let us consider a standard scenario for catastrophical risk, that is: losses lower than M_1 are covered by standard insurance, from M_1 to M_2 by Cat Bonds (or by standard reinsurance) and over M_2 by the public administration.
A reasonable assumption: if Cat Risk increases, then the rate asked by Cat Bonds investors, the insurance premiums for facing losses higher than M_1, the expected payment of public administration for losses higher than M_2 all increase.

Our proposal

Insurance companies and public administration cooperate in financing green transition and thus Cat Risk reduction.

In case some firms decide to switch towards a green transition, then companies discount the insurance premiums (and so the Cat Bond scheme switches into a Resilience Bond scheme) and the public administration decides to decrease M_2, to balance the reduction of premiums earned by the companies.

Our proposal

This way a dynamical interaction takes place, involving the bonds interest rate and the share of green firms. We will illustrate two main scenarios of the system:

- In one all the trajectories converge to an optimal equilibrium, where all the firms adopt green technologies and the rate (or spread) of the Resilience Bonds is minimum

- In the other scenario, instead, a "poverty trap" appears, meaning that the trajectories starting in that region (poverty trap) converge to a sub-optimal equilibrium, where the share of green firms is lower than 1 and the Resilience Bonds interest rate is not minimum.

Model's dynamics through a discrete time system

The discrete time dynamics takes place in a rectangle R, where $x \in [0, 1]$ is the share of green firms and $r \in [r_0, r^*]$ is the Resilience Bond interest rate (or spread).

$$\begin{cases} x(t+1) = \exp\left[(x(t)-1)\, f\left(x(t), r(t)\right)\right] \\ r(t+1) = r(t) g\left(x(t), r(t)\right) \end{cases} \tag{1}$$

"Natural" assumptions for f and g

f and g are positive functions, for which we assume.

Dynamics of x.

Assumption 1) When $x = 1$ it remains so, i.e. $x(t) = 1$ implies $x(t+1) = 1$.
When the green transition is completed, it remains so.

Assumption 2) $\frac{\partial}{\partial r} f(x, r) > 0$ for any $x \in [0, 1]$ and any $r \in [r_0, r^*]$
Assumption 3) $\frac{\partial}{\partial x} f(x, r) < 0$ for any $x \in [0, 1]$ and any $r \in [r_0, r^*]$
f is decreasing with respect to x (decreasing risk) and increasing with respect to r (increasing risk).

"Natural" assumptions for f and g

Dynamics of r.

Assumption 4) $g(1, r_0) = g(0, r^*) = 1$.
When the green transition is completed or null, the Resilience Bond interest rate is stable (at its minimum or maximum level).

Assumption 5) When $g(x, r) = 1$, $\frac{\partial}{\partial x} g(x, r) < 0$.
When the interest rate is stable and the proportion of green firms increases, then g decreases.

A coherent proposal

We propose possible shapes of the functions f and g.

$$f(x,r) = \lambda P_v$$
$$g(x,r) = (xp_1 + (1-x)\,p_2)\left(\frac{r^*-r}{r^*-r_0}\frac{1}{p_1} + \frac{r-r_0}{r^*-r_0}\frac{1}{p_2}\right)$$

where P_v is the insurance premium paid by green firms, on which depends $f(x,r)$, the impulse for the proportion of green firms x.

The impulse for the interest rate, $g(x,r)$, is proportional to the current "average risk", given by the current "mixture" of green and no-green firms. Moreover, when x and r are both low, r tends to increase; viceversa, when x is close to 1 and r is high, r tends to decrease.

A coherent proposal

Insurance premiums for no-green and green firms (we can consider the typical charge of insurance premiums, so it could be higher than the expected loss)

$h, k, \lambda > 0$ are expressed in monetary amounts (we have to choose a monetary unit)

p_1 the probability that a green firm contributes to the catastrophe

p_2 ($> p_1$) is the probability that a no-green firm contributes to the catastrophe

hp_2 is the insurance premium paid by no-green firms

A coherent proposal

We assume that P_v, the premium paid by green firms, is expressed by

$$P_v = hp_1 - k\,(r^* - r)$$

with $p_1 = a - bx$ being the probability that a green firm contributes to the catastrophe.

Specifically a $(< p_2)$ is the probability that a single green firm contributes to the catastrophe (technological improvement effect) while a "sinergy" effect is given by the level x multiplied by a "sinergy" intensity b $(< a)$.

Premium discount

The discount $k\,(r^* - r)$ applied to the green firms premium is assumed to be a function of the current interest rate level r and of the upper bound r^*: the lower is the current rate, the higher is the discount.

The intensity of discount k is a parameter controlled by the insurance system.

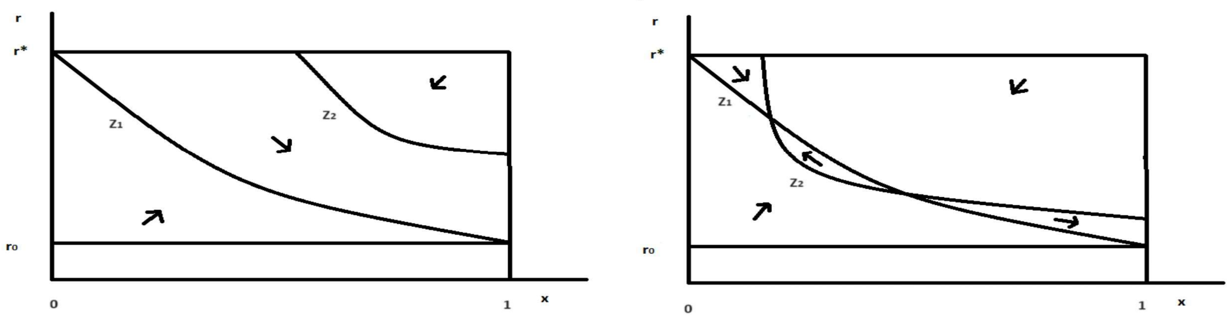
Local analysis

Along the curve $g(x,r) = 1$, in R, the interest rate is stable.

Along the curve $[(x-1)\,f(x,r)] - \ln x = 0$, the proportion of green firms is stable.

The number of intersections of these two curves is generally even. We consider the cases when it is zero or two.

Local analysis



Actually the dynamics is discrete, but the arrows give an idea of dynamical directions in the various regions bounded by the two curves.

Global analysis

In order to proceed to a full investigation of the global dynamics we introduce a further assumption.

We assume $p_2 < \frac{2+r_0}{r_*}a$ and $b < \frac{1-r_0}{2+r_0}a$

Such assumption poses bounds to the benefits of green technology and its diffusion, grossly speaking:
- the risk caused by no-green technology is no more than the double of that caused by green technology;
- the risk reduction due to the diffusion of green firms can at most halve the risk caused by the green technology.

Equilibria of the model

Taking into account the previous assumptions, we are able to illustrate the dynamics in the two main scenarios of the system.

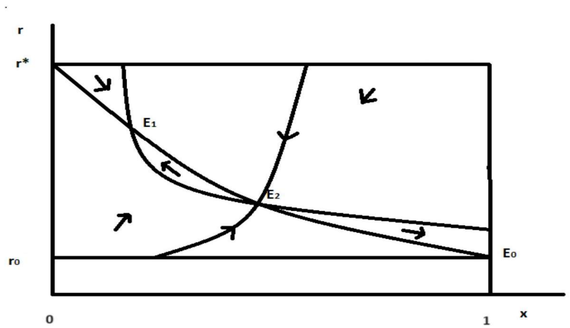
- In case the two curves have no intersection, we have the only equilibrium E_0. Then E_0 is a global attractor in R.

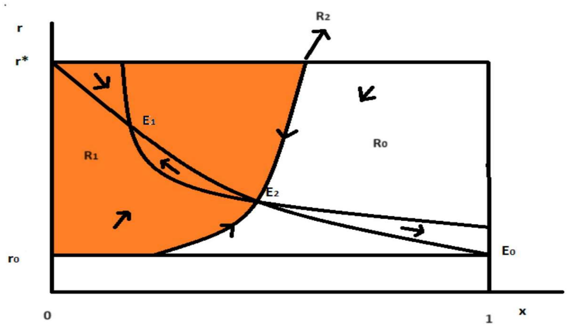
- In case the two curves have intersections, we suppose the equilibria are three: E_0, E_1 and E_2.

Then R contains two regions, R_0 and R_1. In R_0 all the trajectories converge to E_0, whereas in R_1 all the trajectories converge to E_1. R_0 and R_1 are separated by an invariant curve R_2 containing E_2.
Thus, $R = R_0 \cup R_1 \cup R_2$.

The poverty trap

Observation. We can refer to R_1 as a "poverty trap", since trajectories lying in R_1 tend to a sub-optimal equilibrium.





Remark on the assumption

The previous assumption establishes upper bounds for $\frac{p_2}{a}$ and $\frac{b}{a}$. However, when p_2 increases and/or b approaches a, the green transition will be, obviously, favored.

Hence, it is quite reasonable to conjecture that in regions containing E_0 all the trajectories will converge to such equilibrium, without assuming bounds on $\frac{p_2}{a}$ and $\frac{b}{a}$.

Remark on the assumption

The case might be different as far as trajectories lying in a poverty trap are concerned.

Namely, if the assumption is significantly relaxed, there might appear oscillatory, or even chaotic, behavior , in the poverty trap R_1.
That would not change, however, the main consequence of our analysis: when a poverty trap exists, there are initial conditions from which the resilience bond policy cannot achieve the goal of a full green transition.

Comments

We can think of a cooperative role by the public administration, both in terms of paying the exceeding loss respect to the threshold M_2 and in terms of a contribution for the insurance premiums discount.

Let us observe that when $x = 1$ (or x is "close" to one) the companies would collect only discounted premiums, so that in these scenarios the public administration increases its contribution to premiums discount and reduces the expected payment for losses exceeding the threshold M_2.

Comments

Let us recall the formula of the premium for virtuous firms

$$P_v = hp_1 - k\left(r^* - r\right)$$

in which a crucial role is played by the parameter k, the intensity of discount. This discount has to be provided by a sinergic action between insurance companies, which renounce to some expected gain, and the public administration.

Further research

We are developing an application to flood Cat Risk, searching for the best fitting of model parameters with respect to real data relative to actual damages, risk mitigation cost and risk reduction.

ACRI (Actuaries Climate Risk Index) is an index developed, on the wake of ACI (Actuaries Climate Index), by the North-American Actuarial Society (others local actuarial association, e.g. Australia, France, Spain are working on their Countries indexes) which provides the current level of climate risk for insurance business.
This kind of indexes could be a sort of proxy for Cat and Resilience Bond interest rates dynamics.

Main references

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