Diffusion of flood damages: an application to wine sector

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Introduction

When an area is affected by a flood, do the links between economic agents matter to spread out the damages along the economic network? if so, can those effects be persistent over time or, on the contrary, do they vanish immediately?

Several major flood disaster has been occurring in Europe in last years —four of them in France— at a great, and increasing, economic and environmental cost. According to the European Environmental Agency, population growth and wealth, together with the occupation of flood prone areas for socio-economic activities seem to be in the root of the phenomenon. In Europe, since the publication of the Flood Directive in 2007, a more integrated flood risk management has been implemented. It shaped a new framework where prevention, protection and preparedness should be the axis of the new flood management plans. Precisely in those axis is where the questions here presented are relevant.

The main aim of the paper is to contribute to improve knowledge on how impacts on economic systems spread out in economic networks, and affect agents in successive rows. Diffusion of damages in economic networks is possible because of the inter-linkages of the economic system [Dziubiński and Goyal, 2013], [Goyal and Vega-Redondo, 2005]. Those inter-linkages favor the existence of trigger mechanisms that broaden the effects of floods in time and space. These indirect costs associated with floods have traditionally received less attention than direct ones [Merz et al., 2010], however their understanding leads to a better understanding of vulnerabilities in the systems. Therefore better plans and strategies can be done and followed.

To describe the system and tunning the agent's behavior, helping to capture diffusion from the bottom up we propose to use Agent-based models [Gilbert, 2008], [Bonabeau, 2002]. Using them, we work with a collection of observable agents linked in local interactions. These interactions feed back those same agents with information that can affect their behavior and interacting patterns, therefore the emerging results and regularities.

The consequent trade off between micro and macro levels is particularly useful to analyze, at the same time, global outputs and particular damages to every agent.

Economic evaluations of flood damages context-dependent [Merz et al., 2010]. Thus, based on information from the Aude department, located in southeastern France, I propose an Agent-based model for the wine sector. That particular location has been already impacted by flash floods in the past [Vinet, 2003]. Therefore valuable information can came from interviews to the main actors involved.

The model, although simple, strives to represent the main elements of the studied problem. It shows how, when a flood comes, the configuration of the network provokes side effects on the agents that are not directly impacted. Also how the decisions of the agents can modify these indirect effects.

Model

The model's aim is to capture the main features of the wine sector in the Aude river, based on the info we have collected in the area. We create a virtual sector that works following the same main rules, where two main agents operate: farmers and cooperative wineries. These agents present several links among them.

Cropland. Each farmer owns croplands. Each cropland is defined by: *distance to the river* (which induces a certain risk of flooding), *productivity*, *extent* and *age* of the plants. The three last variables altogether determine the amount of harvest, while age by itself determines whether the cropland is productive or not.

Farmer's choices. Each farmer is associated with a cooperative. Thus, all of a farmer's croplands belong to just one cooperative. Croplands are kept with different agents, which has two different consequences: one, there is rotation in crops; two, the production is variable and lower than the potential.

Damages in those croplands (soil and planting structures) as well in plants (vineyards in this model) are covered by a public insurance system called *Calamité agricole*. However the potential damages on the the harvest are not covered and is the farmer the one who chooses whether or not to get insurance over this issue. This non trivial choice is essential in a context of potential bankruptcies derived from unpredictable natural catastrophes.

Cooperatives. The cooperative wineries once they receive the grapes, process the wine and sell it in the markets. Their technology to produce wine can be different one from to each other (and we can consider it fixed since it cannot be easily modified in the short term) as well their commercial strategy: some are specialized in producing just one kind of wine while others produce several kinds with different qualities.

We distinguish two different kinds of production costs for cooperative: fixed costs (divided among participants to the cooperative) and variable costs (linked to the quantity of grapes). Both of them are divided proportionally among the members of the cooperative.

They can be expressed like:

$$B_i = pq_i - TC_i = pq_i - \left(\frac{F}{\sum_{i=1}^{n} q_i} + v\right)q_i = \Big(p - f - v\Big)q_i, \quad (i = 1, 2...n)$$

where B_i is the benefit of the farmer i; q_i is the production of the farmer i; p is the price paid per unit; CT_i is the total cost paid by unit; v is the variable cost by unit in the cooperative; $\frac{F}{\sum_{i=1}^{n} q_i}$ or simply f is the fixed costs paid by unit in the cooperative; and $\sum_{i=1}^{n} q_i$ is the total production of the cooperative winery);

Economic environment and process overview. For this two types of agents, prices for their inputs and outputs, as well as the flood scenario are exogenous to the model. Prices are determined in the market and the agents do not have power to influence them. The flood scenario in every simulation generates independent flood events. Each time the simulated flood covers different extent of the territory around the place were the river would be located. To set an element (farm, cropland and wineries buildings) affected by a flood, location is the only criterion used in the model. Therefore every element located in the territory that has been flooded is considered affected directly by the flood.

The direct damages and associated costs are different depending on the season and the element involved, ranging from some reparations to whole production losses. Cooperative wineries would have to face damages in their buildings and physical capital independently of the season but they would not be able to receive the grapes if the flood affects them in autumn, nor to produce wine if it happens in winter. Farmers would have to face costs from different sources. Firstly they would have to face damages in their machinery and buildings, as well as cooperatives, independently of the season. If the flood occurs during Autumn they also would not be able to harvest. Second, they own the croplands and these ones have three different ways of being affected: damages over the infrastructures, damages over the yield (they can suppose to lose the whole harvest) and damages over the plants, both of two last ones linked to the season.

Propagation of losses. The existing links in the system make indirect effects to emerge.

1. Damages in cooperative wineries will affect the farmers members of the cooperative/s affected: they would have to finance the reparations and, depending on the season, could not process their grapes nor produce their wine. Therefore the income of the farmers is affected indirectly by damages in the cooperatives. As a result, financial imbalances, even bankruptcies, can appear.

2. Damages over farmers' buildings and machinery, depending on the season, can make farmers unable to harvest the grapes. They will therefore lose the production and receive no revenues from the cooperative. As a result the relative production of other farmers in the bosom of the cooperative is altered, as well as the share of fixed cost the pay. This situation leads to financial imbalances for all the farmers (not only the ones flooded).

3. Damages over croplands, affecting directly or indirectly the amount harvested, mod-

ify the relative productions of farmers in the cooperative. Therefore the share of the cost, affecting financial balance of all the farmers. The persistence of the financial imbalances is linked to severity of the damages over the plants.

Simulations and results

Different scenarios with different vectors of flood seasons, flood extent and numbers of farmers per cooperative (size of the cooperative) are simulated. As floods are independent phenomena, the agents cannot have any information about the ex ante probability of flood's occurrence. Therefore agents choose blindly their choices, like cost sharing sharing rules in cooperatives.

Once obtained, the different damages are classified using Brémond et al. [2013]. The results show, first, that the rule chosen in the cooperative to share the costs matter. Second, that, depending on the rule chosen for each cooperative, the transferability of costs from those impacted to those not impacted varies and, third, that those with a high grade of transferability of damages penalize more those farmers whose production is relatively bigger. This way, farmers that, even being impacted, have the biggest relative production, will pay a bigger share than if there would not have been a flood.

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