Toward an IO ABM model to evaluate the impact of climate shocks

An application to originally denominated wine

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Motivations

- Climate shocks are expected to dramatically affect agriculture and food production in the very next years
- Input-output based models are a natural framework to study such effects due to the network based structure of nowadays economies
- However, classic, mainstream and sequential approaches to modelling suffer from different (sometimes overlapped) issues $\rightarrow$ level of aggregation of inter-sector/inter-territories relations, hypotheses about input substitutability, geographical lenses used to examine phenomena, lack of attention to firm heterogeneity and market structures, the timing of economic production, etc..

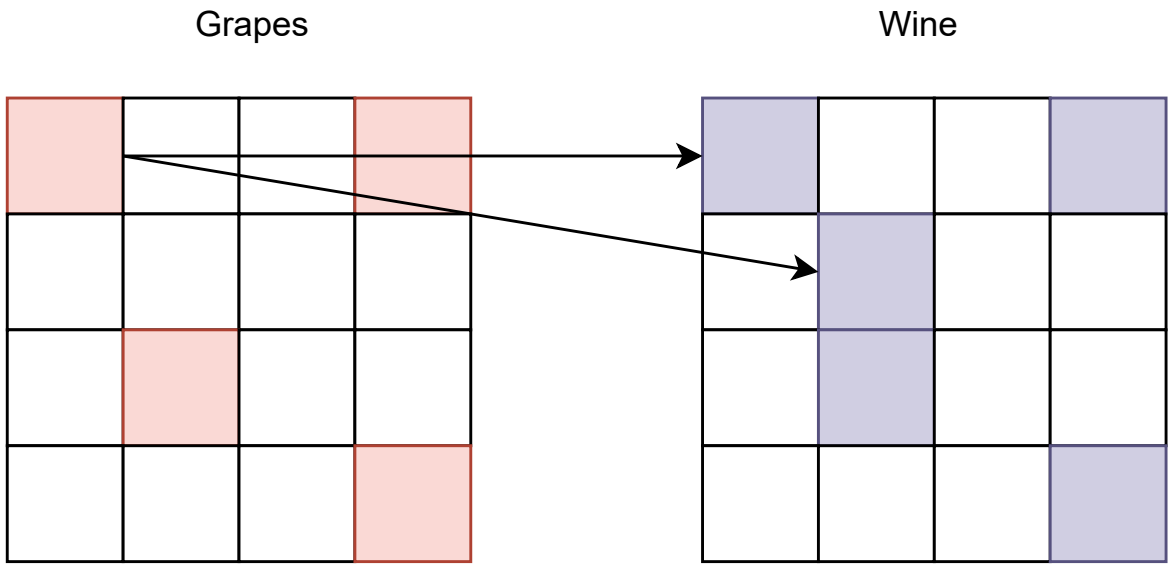
In this work

- We start from the idea that the producers of some local final goods (e.g., wine) cannot substitute for the lack of specific local inputs (i.e., grapes) and simulate the impact of climate shocks hitting specific zones of a region highly specialized in such kinds of production (i.e., Tuscany)
- We do that in a data-driven spatial input-output framework augmented with both product and firm heterogeneity (multi-product input-output ABM)
- We demonstrate how the model can be used to simulate the impact of disasters over the supply chains serving originally denominated wine production

Motivations (strike back)

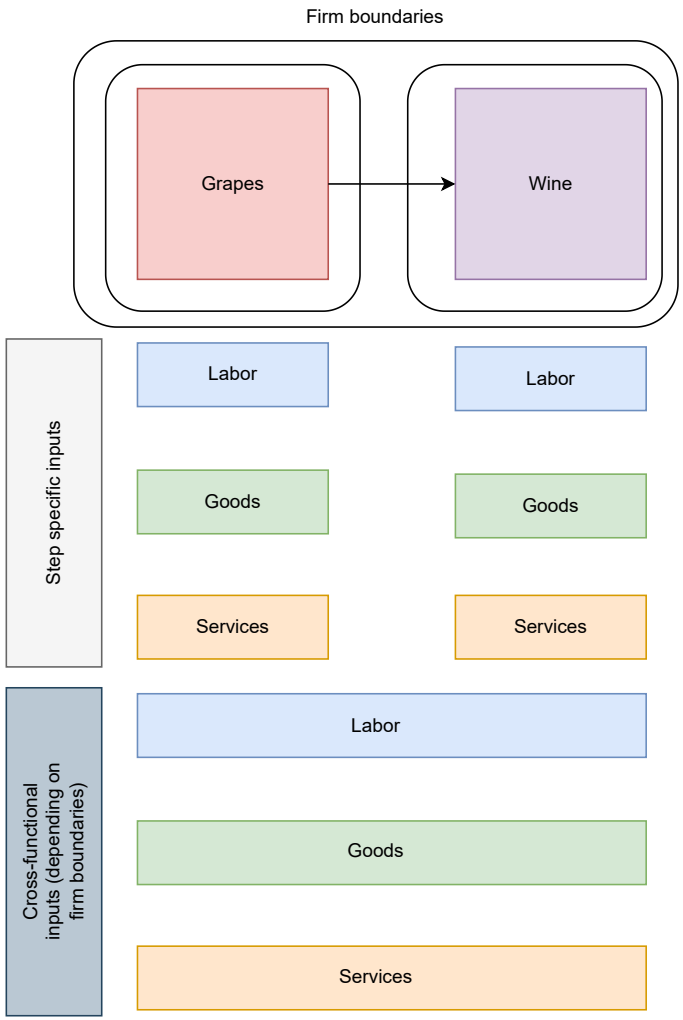
- As to wine, climate change is expected to affect both quantity and quality of the raw material and, in turn, of the final product (see, e.g., Ashenfelter and Storchmann, 2016)
- Wine (with olive oil) production is the main specialization of the Tuscan agri-food value chain
- Non substitutability of the main production input among raw materials: grapes
- Production involves the interaction between producers of the raw material and those of the final product: interesting market to study the so-called farm income problem in a value chain perspective

A spatial input-output framework..



Producers need locally cultivated grapes in order to produce wine. Both grape and wine producers are distributed in space. Moreover, there is a certain degree of correspondence in the location of suppliers of the raw material and final producers.

..in an ABM structure



- Beyond the technical requirements, wine production organization also depends upon firm boundaries
- Indeed, there might be wine producers which also cultivate grapes
- Moreover, firm boundaries can also be overcome by ultimate ownership

The model

- In order to produce a final good z, downstream consumption good firms need labor, capital and intermediate inputs, one of which (w) cannot be substituted for $\rightarrow y_z = min(\alpha L, \gamma w, \omega K)$
- The price of z will also be affected, among other things, by the "quality" (λ) of $w \rightarrow p_z = f(.., \lambda_w, ..)$
- Both w and z are assumed to be heterogeneous. Moreover, firms have to be considered as bundles of tasks $\rightarrow$ $f(w_1, .., w_i, z_1.., z_i)$
- A climate shock is thought as a two dimensional event (χ_1, χ_2) impacting both w and λ_w
- Firms set prices based on lagged prices and quality of current production (implicit demand rule)

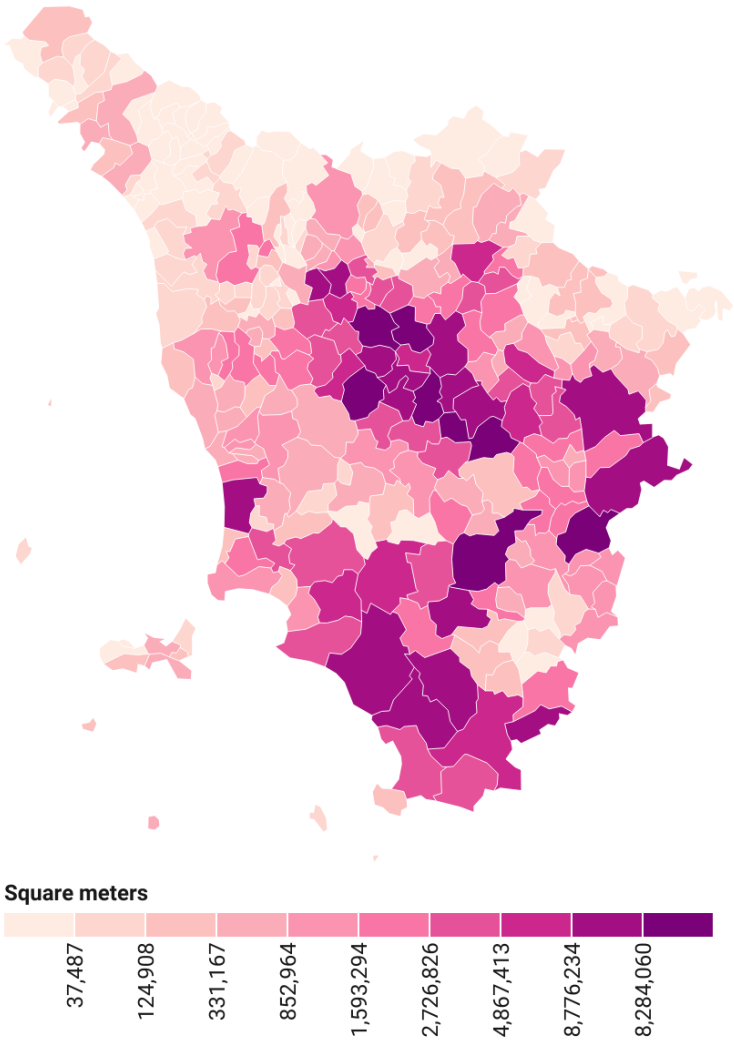
Timeline of events

1. Firms in the agricultural sector start production of the local intermediate inputs
2. The place-specific climate shock impacts the regional economy and determines quantities and baseline expected prices for the final goods
3. Firms in the agricultural sector hire workers to harvest and set the price of intermediate inputs based on lagged prices and quality of raw materials
4. Firms in the downstream sector start the production of the local final goods and set the price of the final goods based on lagged prices and quality of raw materials
5. Firms make profits/losses depending on whether the realized prices are able or not to cover unit costs

Data

- We start from spacial distribution of grape cultivations (`https://dati.toscana.it/dataset/artea-piani-colturali-grafici-annualita-2021`)
- We distribute wine producers in space (Istat data)
- We add data about (cross)ownership, balance sheets, employees (`www.bvdinfo.com`, Istat data, Firm tax declarations)
- We also collect spatial macro data about yearly production (tonnes and prices) of differentiated final products (`https://www.ismeamercati.it/flex/FixedPages/IT/VinoCertificato.php/L/IT`)

Localizing grape production in Tuscany

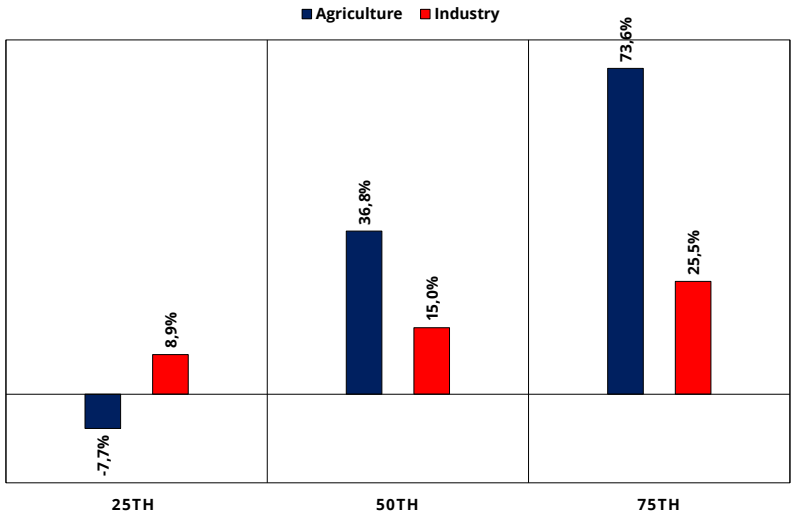


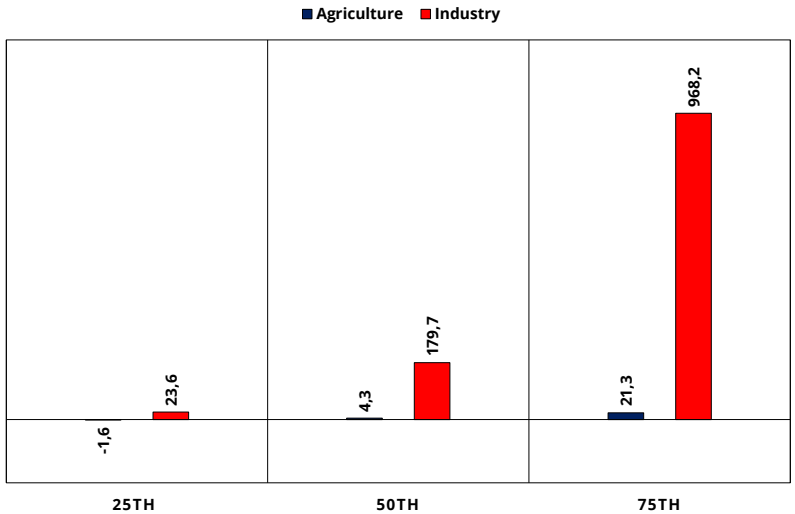
- Starting from Piani Colturali Grafici we find 60 thousands hectares devoted to grape cultivation in the region and 15 thousands firms
- Chianti region, southern Tuscany and some coastal areas are those more involved in wine production
- Municipalities in Florence, Siena and Grosseto NUTS3 regions host 75% of the cultivated surface

The structure of the markets

- We match data with business register and cover 92% of the surface (60% of firms). 95% of firms are from agricultural sector. Firms in wine production are 0.1% of the total (but 5% of the surface)
- Firms characterized by cross-ownership are 1% of total but 12% of the cultivated surface
- We then collect data on firm performances from administrative and statistical sources
- We cover with balance sheet data 60% of the cultivated surface

Firm characteristics and performances





- Industrial firms do show higher profitability in absolute terms (farm income problem). Wine exporters among agricultural firms do display far more higher dispersion of performances (absolute GOP for 25th: -75 thousand euros; for 75th: 73 thousand euros)
- Firms controlling both grape and wine production: 1% of firms in the value chain; more than 50% of exports

The simulation exercise

- We assume a climate shock to a specific zone of the Tuscan region (i.e., Chianti Classico: 20% of cultivated surface)
- The shock determines a change in grape production ($\chi_1 = 0.8$)
- We look at the impact on overall regional wine production
- We look at the impact on firm balance sheets: how many firms at risk of going "under-water"

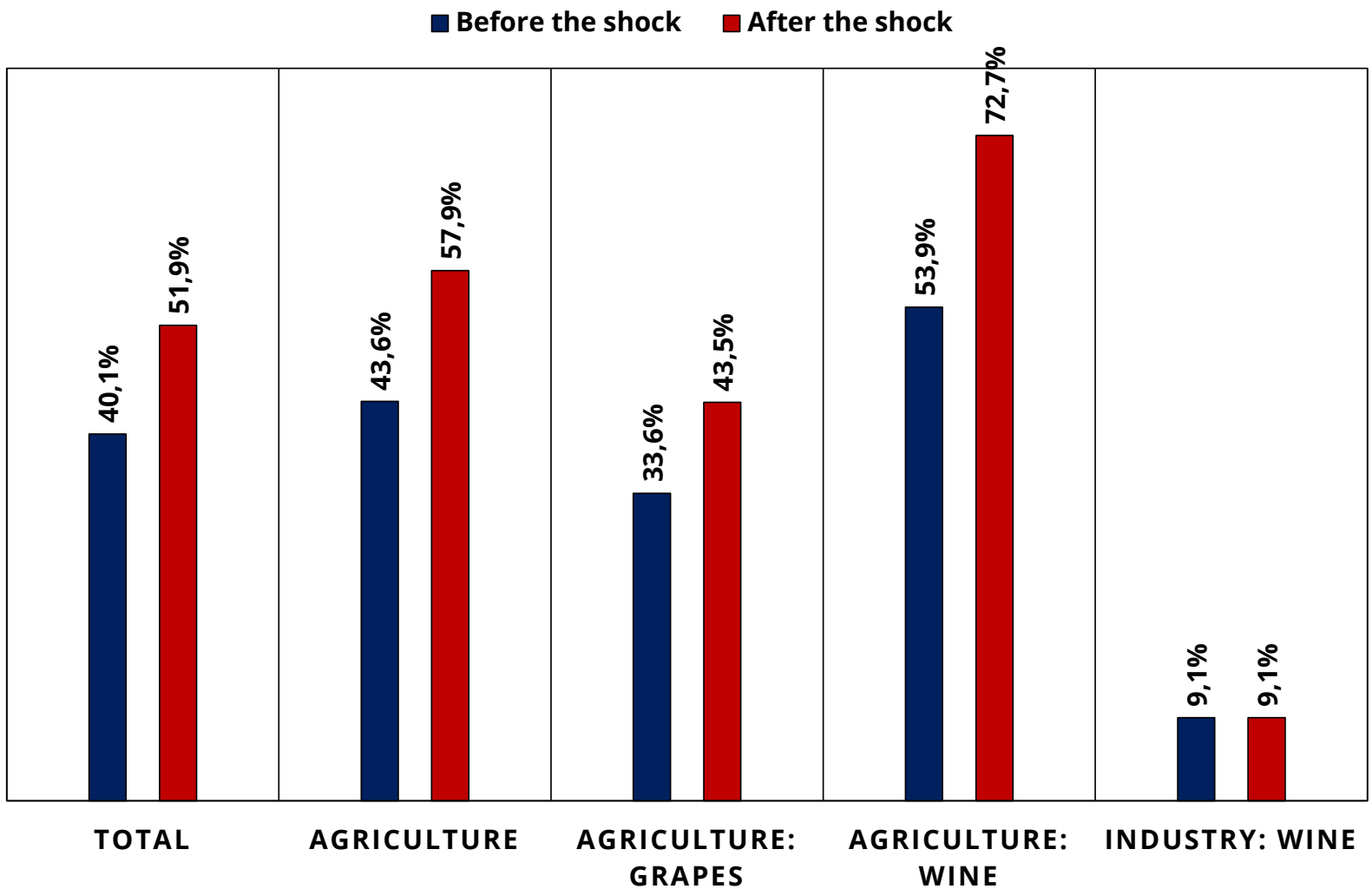
The simulation exercise (*cont'd*)

- The shock hits production in terms of litres (keep the price constant); simulated aggregate production in euros (applying lagged average prices)
- We then obtain regional aggregate production and the impact at the macroeconomic level
- Firms: those involved in grape harvest and wine production might save some costs (e.g., proportional decrease in grapes among the input costs; reduced labor force); production in the hit area is reduced proportionally
- The micro impact on balance sheets can then be recovered in terms of value added (*Output - Intermediates*) and gross operating margins (*Value added - Labor cost*)

The impact

- At the macroeconomic level a 20% decrease in grape production in the Chianti Classico region would translate in a 3.7% drop in production (in euros) of wine in Tuscany
- Firms displaying negative operating margins would increase from the 40% of the total up to more than 50%
- Firms more at risk are those in agriculture: both grape producers and wine producers
- Wine producers, among agricultural firms, are those especially at risk $\rightarrow$ they cannot substitute inputs

The gross operating margin



Discussion

This project is aiming at tackling the issue of the impact of climate change by exploiting:

- non-substitutability of specific inputs in the production of originally denominated goods
- the heterogeneous impact of climate change on firms involved in the value chain (inputs, final goods, both)

Preliminary results show that firms in the agricultural sector are those most impacted by climate shocks, as industrial firms are more capable of diversify production and input sources.
This confirms that farms are those more exposed to climate change as they are those more entrenched in local production capital.

Next steps

- Estimating some items in the balance sheets of non-observed firms
- Better estimating 'specific' costs associated to harvesting and wine production
- Timing of the shock and balance sheets effects: producing wine takes time (changes in inventories); shelf life
- Calibrating the climate module
- Multi-product firms
- Closing the model: the demand side and the macroeconomic IO inter-LMAs model