Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 2, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

CONCURRENCY AND DISTRIBUTION IN ECONOMIC MARKETS: MODEL DESCRIPTION

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Abstract

Economic markets can be modeled using a system-based approach. In an economic system, agents have complex behavioural patterns, two of the most important being concurrency and cooperation. In this paper, we present a model of an economic system that integrates the dual characteristic of economic system. On one hand, the concurrent characteristic is modeled using Petri nets and focuses on determining the agent behavioural patterns in the system related to the resources distribution and market share. On the other hand, the cooperation characteristic is related to the determination of an agent that can influence the market behaviour, using a model based on Leader Election. In this matter, the concurrency between agents is integrated with market coordination, useful in contexts as quality standard establishment or collective issues. The context of the model related to distribution can be further developed, especially related to agrifood chains in economic markets, by establishing a classification of the agents of the economic market, useful for a vertical integration of the market.

Key words: *economic market, concurrency, cooperation, model*

INTRODUCTION

Mathematical modeling and information systems are important scientific tools which could offer solutions for economic development in many fields of activity [1, 6, 12].

Economic markets are dynamic and complex systems that involve the interaction of various agents, each with its own unique behavioral patterns [11, 15].

Concurrency [16] and cooperation [18] are two fundamental aspects of these systems, influencing the dynamics of resource distribution [3, 7], market share [8] and overall market behavior [13].

In this paper, we propose a novel approach to modeling economic markets using a system-based methodology.

Our model integrates the dual characteristics of economic systems by leveraging two key modeling techniques: Petri nets [2, 14, 5] and Leader Election [9, 10].

The approach is not novel, but it is based on the particular nature of local and European agrifood chain structure.

Petri nets are utilized to capture the concurrent nature of economic activities, focusing on understanding the behavioral patterns of agents in relation to resource distribution and market share dynamics.

On the other hand, Leader Election is employed to model cooperation among agents and determine influential actors that shape market behavior.

By combining these approaches, we aim to provide a comprehensive understanding of how concurrency and cooperation interact

within economic systems.
Furthermore, our approach is not limited to the economic domain, but can be adapted and applied to a variety of other contexts, including team management and education, to better understand the dynamics of interactions and decision making in these domains.

MATERIALS AND METHODS

The first important step of the study run in this paper was considered to be the development of a bibliographic study related to agrifood chain modelling. In this matter, the bibliographic study was created using the Dimensions.ai scientific database [4] as the search domain and the VOS Viewer software [17] as the mapping instrument.

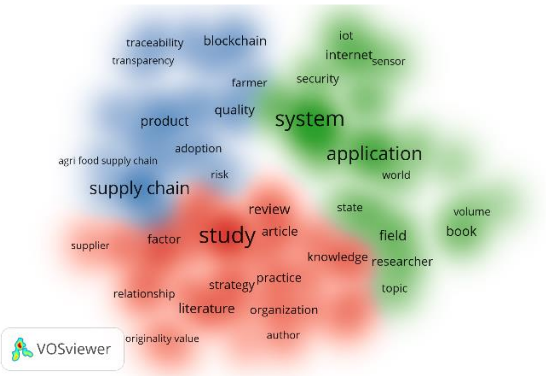


Fig. 24. Graphical representation of the most relevant research terms
Source: Own results.

We can observe that the main directions of research in the literature were delimited related to the scientific method (red cluster), the economic aspects (blue cluster) and technology-based approaches (green cluster). In this matter, the most relevant terms related to technological-based approaches were selected and are shown in Table 1.
The main technology-based approaches were determined to be close to the instruments used for modelling, such as machine learning, blockchain technology and artificial intelligence, but also related to the agrifood chain characteristics, such as traceability, transparency and relationship. Finally, the practical aspects of technology implementation in the agrifood chain were determined, delimited by terms such as IoT, sensor or Internet.

Table 1. Term list related to the research subject with the occurrences and relevance scores

No.	Term	Occurrences	Relevance score
38	machine learning	118	2.4417
33	Iot	254	2.4195
32	Internet	321	2.1962
62	Supplier	145	2.0693
55	Sensor	167	1.9687
72	transparency	147	1.9468
71	traceability	204	1.804
70	Topic	232	1.3377
10	blockchain technology	224	1.2626
49	relationship	237	1.2559
7	artificial intelligence	213	1.2151

Source: Own results.

Now, in order to establish the main conceptual aspects of the model, we will take into consideration the main two ideas related to the economic model: concurrency and cooperation. This paper extends an approach of establishing an economic map [1] which uses a graph-based approach and graph algorithms to model the structure and functionality of an geographical economic map. This paper focuses on the development of a model which deals with two of the most important aspects of an economic market within an agrifood chain, as mentioned above. The market will be modelled based on two components
-the enterprise (E), defined as a node within a network;
-the relationship between the enterprises (R), defined as a link between two nodes. A relation is defined as a transaction between a provider E (EP) and a client E (EC) and can be approached based on two characteristics: existence and intensity.
The model of enterprises and relations can be seen in Fig. 25.

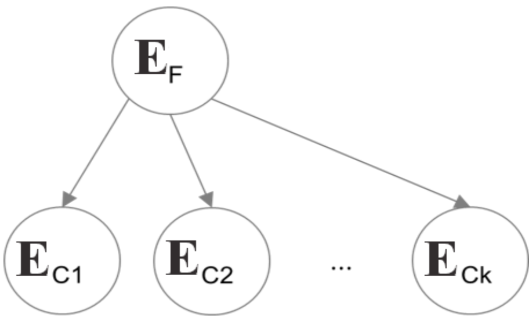


Fig. 25. An example of modelling relationships between enterprises
Source: Own conception.

The enterprises are grouped alongside the agrifood chain, forming in this matter clusters based on its components.

Agrifood chains are complex systems with various stages, from production and processing to distribution and consumption.

Within the agrifood chain, several key stages can be identified:

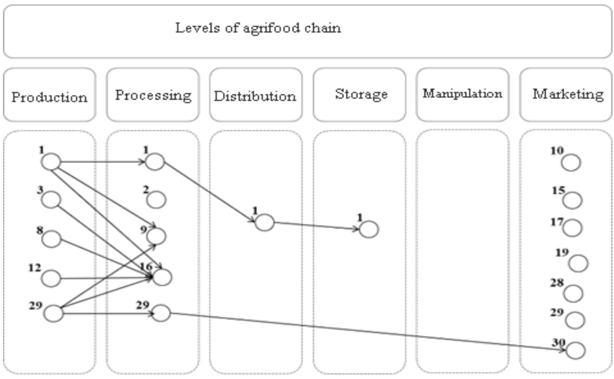
(1)*Food Production*: This stage encompasses factors related to agricultural activities, such as growing crops or raising livestock.

(2)*Processing:* Here, raw materials from production are transformed into refined food products through various processes.

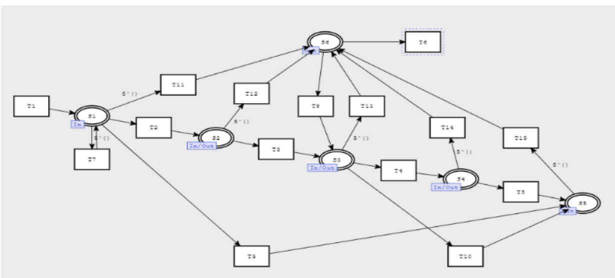
(3)*Logistics*: This stage involves the efficient movement and handling of food products throughout the chain, from producers to processors and then to distributors.

(4)*Distribution:* This step brings the food closer to its final destination - the consumer - by making it readily available through various channels.

(5)*Marketing to consumption*: Finally, the food reaches its ultimate purpose - being consumed by the end user.



(a)



(b)

Fig. 26. Examples of models related to agrifood chains: (a) graph-based approach; (b) Petri net approach
Source: Own conception.

A pictorial view of the organisation of the enterprises on the agrifood components organisation can be seen in Fig. 26.

The first approach (a) is based on graph theory, being a result of an implementation on a geographical economic map of a village. The second model (b) presents the clusters on the agrifood chain and the waste management alongside it.

Thus, we can observe that relations are established based on the place of the enterprise within the agrifood chain and several other characteristics.

In this paper, the main characteristics taken into consideration are:

-the enterprise turnover, which defines the economic power of an enterprise, used in the cooperation model;

-the situation of the enterprise in the agrifood level as a classifier operator. Usually, the enterprises are situated automatically alongside the agrifood chain by their NACE code, but, for simplification reasons, the enterprises are classified manually with the correspondent agrifood level identificatory (1 to 5). It is used in the concurrency model.

The considered agrifood system may be represented as a Petri net PN, which is considered to be a quintuple $PN = \{ S, T, A, F, M_0 \}$, where:

$S = \{S_i | i = 1, n\}$ is the set of places, which will model the enterprises;

$T = \{T_i | i = 1, m\}$ is the set of transitions, which will model the transactions;

$A = \{(T_i, S_j) | i = 1, m; j = 1, n\}$ is the set of arcs (edges), which will represent relationships between enterprises;

$F = c \times S_i \xrightarrow{T_k} p \times S_j, i, j = 1, n; k = 1, m$ is the arc function, which will delimit the requirements for a transaction to be made;

$M_0 = \{S_l | S_l \mathit{is\ in\ the\ final\ agrifood\ component}\}$ is the initial state of the Petri net, delimited by the leader of the market.

This model uses an arc function to account for waste within the agrifood chain. This function acts like a multiplier, determining the power of an enterprise at each stage.

A variable, denoted by c, represents the minimum number of tokens required in state S_i for transition T_k to activate. When the transition fires (representing a stage in the chain), state S_j produces p tokens. In this matter, an inverse path related to agrifood chain flow could be used, in order to use the arc function properly.

Concurrency model

The concurrency model aims to study the network based on the competition between the enterprises situated at the same level in the agrifood chain. The methodology of concurrency model design comprises the following steps:

S1.The identification of the net components: in this matter, the states will be modelled as the enterprises, the transitions will be transactions between them, arcs will be relationships between them and the function would be related to the turnover ratios between the enterprises.

S2.The definition of the conditions used for the transition firing: in this matter, a transition will be made whether the client enterprise (EC) will reach a threshold of tokens related to the provider enterprise (EP), where a token can be represented as a turnover unit (e.g., thousand lei).

S3.The Petri model build: the net is implemented using specific instruments. For this purpose, a Python implementation for the generation of the network, the Orange software for visualisation and the CPN software for modeling were used.

S4.The simulation of the model: the results, as configurations of the market, are obtained after the simulation of Petri nets.

Cooperation model

The main purpose of the cooperation model is related to the determination of the leader enterprise of the market in order to establish several aspects such as quality standard establishment or common approaches for collective issues.

The cooperation model is obtained using a Leader Election algorithm. The phases of the development of the cooperation model are:

S1.The identification of the net components: in this matter, the states will be modelled as the enterprises, the transitions will be transactions between them, arcs will be relationships between them and the function would be related to the turnover ratios between the enterprises.

S2.The selection criteria establishment: for the current implementation, the selection criteria for the leader is selected to be the turnover.

S3.The implementation of the Leader Election algorithm: the implementation is made using a Python script.

S4. The integration with the concurrency model: this step will be accomplished by marking the leader as the main node in the Petri net, with consequences related to the market dynamic.

S5. Simulation and analysis of leader behavior and its impact on the economic system: this may involve evaluating the leader's performance and effectiveness under various input scenarios and conditions.

The two models are then integrated in order to facilitate market coordination, enabling effective decision-making processes in contexts such as establishing quality standards or addressing collective issues.

RESULTS AND DISCUSSIONS

The results were determined for a randomly-generated network of 10 enterprises for which the turnover and the place in the agrifood chain were considered.

The agrifood chain components were encoded with 1 to 5, according to the list presented in the previous sections. The characteristics of the enterprises are presented in

Table 2 and Fig. 27.

Table 2. The characteristics of the generated enterprises

No.	Enterprise	Turnover [lei]	Agrifood chain place
1.	Enterprise 1	3,579,258	1
2.	Enterprise 2	4,854,139	2
3.	Enterprise 3	8,587,311	2
4.	Enterprise 4	8,075,937	1
5.	Enterprise 5	7,735,355	5
6.	Enterprise 6	6,156,748	3
7.	Enterprise 7	1,315,977	4
8.	Enterprise 8	3,141,598	4
9.	Enterprise 9	8,487,998	3
10.	Enterprise 10	8,351,205	5

Source: Own results.

We can observe that the randomly-generated

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 2, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

data has a close resemblance with a real unsimulated environment. The next figure shows the graphical view of the characteristics.

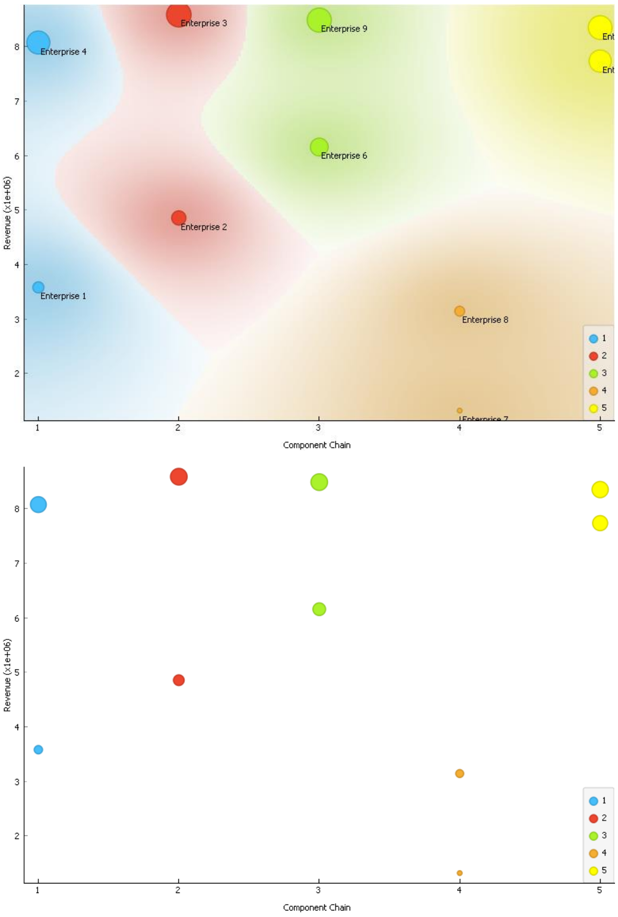


Fig. 27. The characteristics of the generated enterprises
Source: Own results.

In Fig. 27, the enterprises were plotted on a scatterplot graph, where x-axis represented the component of the agrifood chain and the y-axis the turnover of the enterprises. This graph shows more clearly the distribution of the enterprises by agrifood chain component (vertically) and by turnover (horizontally). The enterprises are balanced related to their turnover, showing a potential well-balanced network of enterprises, as well as for the number of enterprises per agrifood chain component. Further, the network of enterprises is presented in Fig. 28. The relationships between the enterprises were determined based on a hybrid implementation, which used both random and turnover-based requirements between the enterprises. The random approach simulated a real-life scenario, where relationships are not entirely based on aspects such as the turnover.

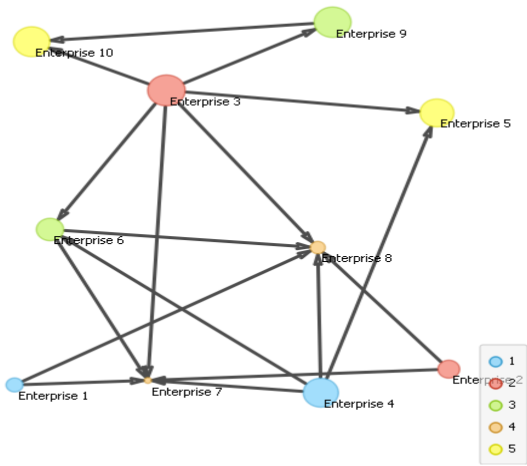


Fig. 28. The generated network based on the requirements
Source: Own results.

In Fig. 28, the enterprises network shows a potential configuration of the network, taking into account the economic power (turnover). In order to apply the model to the given example, a Petri net was considered. In this matter, the obtained result is shown in Fig. 6.

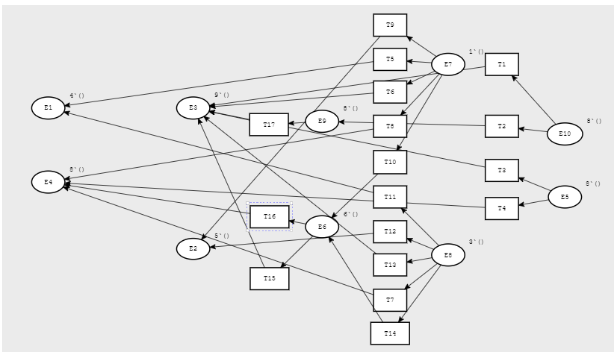


Fig. 29. The correspondent Petri net obtained for the generated network
Source: Own results.

As observed, the net represents the economic concurrency and the main aspects related to the economic power of the enterprises at each level of agrifood chain. After the simulation run, the less powerful enterprises were established as the ones with the lowest turnover (E7 and E8) and the highest were established E3 and E4. On each level, the results showed that:
-for level 5, the most powerful enterprise was E10;

-for level 3, the most powerful enterprise was E9;
-for level 2, the most powerful enterprise was E3;
-for level 1, the most powerful enterprise was E4.

For level 4, the enterprises had not established forward relationships with level 5, due to the low turnovers.

As for the cooperation within the network, the Leader Election algorithm was established. The algorithm was implemented using the Python library Network X. In this example, the election of the leader is done using the betweenness centrality algorithm, available in the library. This algorithm evaluates nodes based on how often they are passed through on the shortest paths among all pairs of nodes in the network.

Furthermore, related to power character of the nodes, we added the weight='revenue' (turnover) parameter to the library specific function to weight the entire centrality with revenue. Thus, nodes with a higher turnover will be more influential in choosing the leader.

After the run of the algorithm, the leader enterprise that respected the conditions described above was found to be E1.

CONCLUSIONS

In conclusion, our approach to modeling economic markets using a system-based methodology provides a new and holistic perspective on how economic agents interact within these complex systems. By integrating the dual characteristics of economic systems, namely competition and cooperation, we have succeeded in developing a robust framework for analysing the behaviour of markets and their dynamics.

The use of Petri nets allowed us to capture the competitive nature of economic activities, emphasizing the understanding of agents' behavioural patterns in terms of resource distribution and market share dynamics. On the other hand, the model based on Leader Choice was effective in modeling the cooperation between agents and in determining the influential actors that shape market behaviour.

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