INTERACTION ROUTINES AND SELFISH BEHAVIOURS IN AN ARTIFICIAL MARKET

TRANSFERRING FIELD OBSERVATIONS OF A WHOLESALE FRUITS AND VEGETABLES MARKET INTO A MULTI-AGENT MODEL

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ABSTRACT

This paper describes an application of multi-agent systems to economics. The issue we address in our work is the actual functionning of a distributed market in terms of information acquisition for agents. We show here possible links between individual information acquisition and global results in the fluidity of exchanges. A multi-agent model has been built on the basis of field observations and interiews led at the Marseille Fruits and Vegetables wholesale market in 2002-2003. Two types of artificial agents interact, wholesale sellers and retailers, surrounded by an environment of exogenous supply and prices. Retailers can choose wholesale sellers according to two logic: either following some relational loyalty or searching for best prices (which takes time). We study the influence of the number of agents with each rationality so that to see the importance of both categories in the good supply of consumers and the limitation of garbage.

RESUME

Cet article présent un modèle multi-agents réalisé à partir d'enquêtes menées sur le marché des Arnavaux (marché de gros de fruits et légumes de Marseille) sur le sujet des habitudes relationnelles entre grossistes et détaillants. Comme il a déjà été observé sur d'autres terrains, les acheteurs professionnels utilisent ici deux types de stratégies prédominantes : soit ils font toujours jouer la concurrence du marché, soit ils sont très réguliers vis-à-vis d'un grossiste donné. Le modèle réalisé est un marché artificiel composé de grossistes et de détaillants, plongé dans un environnement défini par la probabilité d'acquérir des produits pour les grossistes et les prix de ces produits (exogénéité des prix de réserve et de l'accès à des biens). Les comportements des détaillants sont soit basés sur la reproduction d'une relation (loyal), soit sur la composition du panier le moins cher (égoïste). Ici, les simulations sont effectuées avec un monde de 10 grossistes, ayant accès à 10 produits et rencontrant 100 détaillants – les paramètres variables sont le ratio de chaque type de détaillants, la variabilité des prix et la possibilité de trouver des produits. Les résultats sont analysés de façon globale sur le marché, en terme de produits jetés et de satisfaction des besoins pour les détaillants – une comparaison est faite entre le groupe des détaillants loyaux et celui des égoïstes. Dans ce système, la variabilité monétaire n'a pas une influence majeure ; la variabilité de l'approvisionnement permet de mettre en avant l'importance de la co-présence des deux types de populations pour le bon fonctionnement du marché.

Keywords: Agent-Based Model, Multi-Agent Simulation, Market, Learning, heterogeneity, network.

Mots-clefs : Modèle orienté agent, simulation multi-agents, marché, réseaux, apprentissage, hétérogénéité

JEL : B59, C60, D49, D83, Q13

INTRODUCTION

This paper describe a multi-agent model and some elements from observations and interviews on the wholesale fruits and vegetables market of Marseille, that were used to elaborate it. The central issue for building the model is to approach complementarity of two types of behaviour on this market, which will be refered to as "loyal" and "selfish", from an economic perspective. Indeed, one can observe different attitudes which can be locally interpreted, depending on the theoretical background, as a sign of different motivations, information selection processes, norms, or interaction preferences. Globally, it is then possible to wonder how these two patterns of actions can cohabit and even have a function on a market. This research follows a previous work on the influence of different rationality and information treatment on

market dynamics (Rouchier et al., 2001).

The actual processes – from an individual point of view - that lie behind market interactions are often badly known. Even the actual process that does lead to a stabilisation of prices is not so well informed (Kirman, 2001a), although the idea that prices are formed by the encounter of offer and demand is a very basic assumption of economics. To approach a step-by-step perspective, numerous studies have already been led on that issue, focusing on the actual information processing and learning that individuals use. This includes field observations (Galtier et al. 2002; Tarrius, 2002; for examples), experimental observations (Smith, 2002, for a review) and computer based simulations (Tesfatsion, 2002 for a review). The studies in artificial systems try to stress the idea that motivations for economic actions are not necessarily close to the optimising rationality of economic theory and that it can be interesting to study the actual process of choice and learning on a market (Brenner, 1999), be it to act on the system or because the emergence of global data are really dependent on the individual actions (Janssen and Jager, 2001).

We try to take inspiration in directly gathered data, building models from observations, so that to identify the logic of actors, often based on few data, with little time to compute, and hence inducing choices that are closer to "local satisfycing" than "exhaustive optimising" ones. Our relation to the field study is related to the “companion modelling approach developed by François Bousquet and others (Barreteau and Bousquet, 2000; Bousquet et al., 1999), although we are not dealing with public good issues. First, we are more interested in producing setting that fits qualitative estimation of the system dynamics, than one that would fit to quantitative data. One reason for this choice is practical: we are in the process of gathering data, and it is not clear how exhaustive the treatment can be. People don't necessarily answer honnestly facing a question about acquaintances and credit facilities (in France money issues are often taboo), a lot of exchanges take place via unofficial networks (Tarrius, 2002), are volontarily hidden, or simply taking place by telephone or as routines that are difficult to register exhaustively. The other reason is that we want to interact in a reciprocal way with our informers, and hence produce qualitatively coherent data that they can interpet as easily as possible – artificial worlds being recognised as a good way to attain this interaction. Through that mean we wish to capture the actual mechanisms that are used by merchants and potentially be able to provide to the actors some insights on their practices. Indeed, along the modelling process, the results have been commented by our main contact on the market, which helped us to the refine the model. Indeed, the model presented is an evolution of the one presented at ESSA conference, in septembre 2003 (Rouchier and Hales, 2003).

The paper is organised in three parts: a description of the Fresh Fruits and Vegetables (FFV) wholesale market of Marseille and of interactions that induce merchant exchanges, a description of the model that was build to explore the impact of heterogenous motivations, and eventually results and a discussion of these results.

THE ARNAVAUX FFV (FRESH FRUITS AND VEGETABLES) MARKET

The wholesale fruits and vegetables market of marseille is one of the central nodes for the approvisionning of Marseille and the region in terms of fresh products. The other important network that distributes FFV are the supermarket chains, which is mainly independant. Since the 70's, this market has been seriously profesionnalised and has been established as a "Marché d'intérêt national" (MIN), National Interest Market. The market is for professionals only, who have to be registered either as supplier, seller, or retailer / restaurant owner (I’ll refer to all actors as «he », since a huge majority of them are male).. We led observations and interviews on that markets, so that to identify the mechanism of price formation by the wholesale sellers and to evaluate the influence of both their suppliers (importers and producers) and their clients (retailers).

The Arnavaux market takes place every morning apart from sundays, in the suburb of Marseille, from 3:30 until about 9:00. Sellers are localised in two areas and are designated as “producers” and “wholesale sellers”. In the main area, there are big shops with display rooms and storage rooms, where the wholesale sellers wait for there clients. They work there all day long, have a huge number of employees, buy products in huge quantities from some other profesionnals (their “suppliers” who can distribute local goods or import them). A second part is an open space protected only from the rain, where local producers come and display their own production that they bring everyday in their truck: their presence depends on the season, and they are not very numerous in winter.

Most retailers we have interviewed come everyday to get their supply, with a list in their hand. They first go to the local producers’ area, where goods are fresher and they can capture a global idea of the day prices, and then go and see wholesale sellers to complete their basket. To be able to evaluate prices and quality when they have to bargain, retailers have three main sources of information. First, there exists a

public information sheet that gives an average price for each type of product for the previous day. The information is gathered by a man who comes on the market at about 11 and asks the wholesale seller about their average prices. Apparently, on the Marseille market, this set of data is not really trusted because the man himself is not appreciated – most and retailers take into account the same information from other markets in the region. An other way to grab information is to interact with wholesale sellers - asking for the prices and choosing after a moment. Eventually, some groups of retailers can be informally organised so that to meet and share/ exchange information. Most of the time, retailers who have this practice are know for it and wholesale sellers do not necessarily appreciate and give them approximate data. The gathering of information can be very time-consuming and only retailers who have employees to install the shop can afford to stay a few hours on the market.

The relations are important for retailers for two reasons. First they get pressured by their own clients: the idea of *continuity* is fundamental for retailers who have to sell similar products all the time during the season; the *quality* aspect is also taken into account, and they have to trust a wholesale seller since quality can be judged only after a day or two. Second, they need good prices, and also short-term credit. For wholesale sellers, good relations are obviously important since they are a chance of selling goods: even if a retailer does not buy goods one day, the fact that he comes in, talks about product or about the day market is very appreciated. It means that he will come back and might buy some other day; it also shows a form of respect which is very important to exhibit in this context of male surrounding. When a retailer is well known, it usually gets the best price products and even some cheaper prices when he takes a bunch of different products. He can also get advises about purchases: wholesale sellers get permanent information about future supply and can help their retailers to organise their stock to avoid shortages or price increases.

Two patterns of behaviour can be witnessed among the retailers: either they are mainly loyal to one wholesale seller or they are behaving in a market logic, comparing all prices before choosing. These characteristics have been observed, and are consistent with other types of information on real markets, like the ones gathered and analysed in a multi-agent model by Alan Kirman on a fish market (Kirman, 2001b; Kirman and Vriend, 2000, 2001). In the domain of fruits and vegetables exchanges, these two interactions can apparently also be observed in interactions between wholesale sellers and their suppliers (Brousseau and Codron, 1998).

Among all the observed phenomena, we have reduced our model ro represent only a small part of the market activities, focussing only on the practices of retailers and wholesale sellers. The number of products that are considered is limited and available in all wholesale sellers' shops. Local producers activities are ignored; relations to suppliers are evocated as exogenous data giving supply probabilities, identical for all wholesale sellers. The reserve prices of wholesale sellers (minimum price to sell) are here exogenous: in reality they are due to the more general market mechanisms along supply chains, which are mainly governed by supermarkets. There is no element either about the retailers activity in the city. We consider that accurate information on individual wholesale sellers' stocks and prices is available to retailers if they take time to gather it. In the interactions between wholesale sellers and retailers, we only consider merchant exchanges and don't integrate credit facilities or information circulation. The logic of retailers are of two sorts: either they try and get as many goods as possible with a limited number of wholesale sellers, being first *loyal* to their main colleague; or they *selfishly* go and fetch the cheapest products they can, according to the information they gather.

We are interested in testing the impact of the ratio of loyal and selfish agents, in different environmental settings. Our observation of the market is global and linked to an idea of "good functionning", which we based on three elements: the satisfaction of retailers in terms of supply, the quantity of garbage that is produced on that market (FFV are perishable goods) and the level of heterogeneity among retailers and wholesale sellers in terms of success of supply and grabage (with a link between attitude and success for retailers).

MODEL, SIMULATIONS AND OBSERVATION

In this section, the model is described in terms of agents (wholesale sellers and retailers), environment (probability of supply for products and prices), interaction (requests and answers) and organisation (time evolution of the system). The model has been implemented using SmallTalk with the programming interface VisualWork 7.0. Sources for the program can be found at <http:// >[1]. From now on, artificial agents will be refered to will capital letter at start, whereas humans are represented with the common spelling (ie: WholesalSeller for the artificial agent).

The artificial Market is constituted of agents of two kinds: WholeSaleSellers and Retailers. The market

[1] To reviewers: this will be decided soon.

opens every day, and all retailers come and look for a given list of goods. A day is divided in 3 periods, which is the minimal unit of time for activity. At each moment, Retailers can either make requests to WholesaleSellers or gather information. Retailers make choices about the interactions they want according to their need and the informations they can gather. They send their requests to the WholeSaleSellers and get answers from them, after which they can either leave the market or carry on searching for the goods. At the end of the day, WholeSaleSellers decide which goods they need to purchase again to wait for their buyers the next day.

There are 10 different goods in the system, 10 WholeSaleSellers and 100 Retailers. Agents exchange units of goods, each unit being defined by [type of good (1 to 10), age, price].

WholesaleSellers

A WholesaleSeller is characterised by:

- his ***stock***, which is a list of units of goods. When a unit is 3-day-old, its price decreases of 20%, when it is 4-day-old, it decreases of 40%. At the end of the 4. day, a unit of good is thrown to garbage.
- his ***normalSupply***, which represents its desirable stock. The stock is a set of units of products, each characterised Every day, the WholeSaleSeller makes a request for all the goods for which the quantity he possesses does not reach his *normalSupply*. At each time-step, the Market is defined by a probability of supply for each good: if the WholeSaleSeller wins the random throw, it gets al the required need up to *normalSupply*, otherwise its stock does not change. It has an original normalSupply, which evolves in time: if a unit is thrown, the normalSupply for the product is reduced by 1; if a good is absent and asked 5 times by Retailers in less than 10 time-steps, the normalSupply is increased by 1.
- his ***prices***: for each unit bought, the WholeSaleSeller pays the price per unit. This price is given to him as a random value in a range which is the ***priceVariation*** parameter of the Market. Then he increases the value by 1.5, which gives it basic price to which he sells the unit when required. When he gives his prices as information, it is a vector of 10 prices, average over all units of each good.
- a list of regular relations: a retailer who bought on average 1 unit a day for 10 days (20% of his purchases) is considered as regular relations.
- a list of requests, each composed of a list of goods. He treats them in the order of arrival, regular relations first, and then the others, agreeing. for the transaction for each product he has in stock. The price to be paid is the sum of individual units, with a 10% discount if the retailer gets more than three goods. A regular retailer gets the cheapest units first and an extra 10% discount.
- some money that enables it to buy his goods.

Retailers

A Retailer is characterised by:

- his attitude: either “selfish” or “loyal”;
- the list of goods he must get for the day, which is randomly chosen everyday as 5 goods (one unit each), out of the goods of the market; he leaves the market after they have gathered a unit of each good or aft
- a regular WholesaleSeller.

The way agents interact and get information depends on their attitude, either loyal or selfish, and it is a step by step process:

Loyal agents:

At the first period, a loyal agent goes to visit his regular wholesale seller and asks him for the whole list he needs to gather; then if he is satisfied, he goes away. If not, at the second period, he gathers information on availability of products for 5 WholesaleSellers and chooses a combinaison of request so that he goes and sees those who can provide with the more goods in the least encounters. He then, on the third period, asks and gets answers.

Selfish agents:

A selfish agent spends the first period gathering information about prices for 5 WholeSaleSellers, and he then composes his requests to get the cheapest goods. On the second period he makes requests and gets answers, and then either leaves or stays for the third period. He then asks for a second cheapest basket on the basis of the same set of data.

Simulations

The **Prices** and **Availability** are two changing data of the Market, which are dependent, respectively, on a value called ***priceVariation*** and an interval called ***supplyProbability***. The price and availability are first calculated for the Market and then for individual WholeSaleSellers. An initial price is set for each product, and then changes from one time-step to another in the interval I defined by:

$$p - priceVariation < p' < p + priceVariation \quad (1)$$

with p being the ancient global price and p’ the new one. The diversity of prices is then given by the same equation (1) where p’ is interpreted as the individual price and p the global price. From the individual buying price is then deduced the individual basic selling price, as explain before: p’*1.5.

The *availability* of a product is chosen every day, in the ***supplyProbability*** interval, [supplyMin ;

supplyMax] which is stable for the whole simulation. Each WholesaleSeller draw a number and gets the needed goods if availability is greater to this number.

Both ***supplyProbability*** and ***priceVariation*** are considered as the definition of the environment of the Market, providing an exogenous constraint to the agents. In that representation, we mainly refer to the work by Franck Galtier (Galtier et al., 2002; Galtier, 2002). Eventually, the simulations are desing to test the impact of the ratio of each type of Retailers on the dynamics of the system. The impact is evaluated through the differences in resuts depending on the definition of the simulations.

We ran a series of 6 different simulations, where each set is reproduced for three ratio, (in bracket): the first simulation is with 50-50 agents, the second with only loyal Retailers and the third with only selfish ones.

Simulations on prices:

supplyProbability = [60 ; 80]

differences in prices = 20 (sim1,2,3);
5 (sim4,5,6);
40 (sim7,8,9).

Simulations on supply:

differences in prices = 20

probability for products = [40;60] (sim10,11,12);
[70;90] (sim13,14,15);
[90;100] (sim16,17,18).

Observation

For the Retailers, global data on:

- average age of the products that were bought,
- quantity of products found on average at each time-step,
- money earned for the whole simulation.

For WholesaleSellers, global data on:

- average number of products that end up being thrown per Wholesale Seller,
- number of products acquired on average,
- average money (to check there is no budget getting negative),
- average normalSupply (desirable stock) for the simulation,
- number of regular relations

All this given as average over the population and as minimum and maximum values to capture emergent inequalities among WholesaleSellers. For Retailers, the two last elements are compared for selfish and loyal retailers.

RESULTS AND DISCUSSION

During a simulation, Retailers go and see WholesaleSeller everyday. On the first moment, only loyal Retailers get into shops, then on the second period only selfish ones get in, and eventually on the third period all Retailers which have not fulfiled their needs do go to shops. Loyal agents spend on average more money than selfish agents when they are on the market. But loyal agents usually leave the market earlier and have led much less transactions. Those results are true when both types of agents coexist, but also when they is only one type of each. This is a logical conclusion from the model, since at each period selfish agents can go and see up to five different WholesaleSellers with an average of about 3. Even if, in this paper, we did not interpret loyalty as a solution to reduce transaction costs, it is important that our system produce a coherent setting where much more energy is use in negotiation by the selfish Retailers.

Along the time the quantity of goods that each WholesaleSeller tries to get (its normalSupply) increases up to a value that does not change too much after the 40^{th} day. On average, we consider that the system equilibrates around that time. From the dynamics, one can see that selfish Retailers have a disadvantage, in that they always get served after the loyal ones. However, with the adaptation of the WholesaleSellers through normalSupply, all Retailers have chances of getting goods after a few periods. It thus seems that the time organisation of the system does not put such a big bias on the access to goods, although it can seem to do so at first estimation.

Table 4: Values of normal supply depending on the type of simulation. The values are average numbers over 30 simulations.

	Average normalSupply	Minimum normalSupply	Maximum normalSupply
Sim1	12,7	7	18
Sim2	12,8	8	16
Sim3	12,4	9.2	14.2
Sim4	12,3	7	17
Sim5	13,1	8	20
Sim6	12,7	8.5	13.7
Sim7	12,7	8	16
Sim8	12,6	6	18.9
Sim9	12,7	8.5	20
Sim10	12,7	4	15
Sim11	21,1	12	34
Sim12	19,4	16	22
Sim13	5,2	2.5	8
Sim14	11,21	3	14
Sim15	10,46	7	16
Sim16	4,5	2	7
Sim17	8,84	6	12
Sim18	8,74	6	11

What can be observed with Table 4 is the fact that the normal supply for WholesaleSellers is dependent on the value of availability of products and that the

lower availability, the more products are purchased. The difference is mainly clear in simulations 10, 11 and 12 when the availability is really low. This is due to the fact that agents rarely get the goods thay want, then they get requests that they cannot fulfil and increase consequently their normal supply. As a consequence of this increase of normal supply, there is an increase in the quantity of garbage linked to the low availabity (Figure 2). One interesting point in that case is that the presence of loyal Retailers in parallel

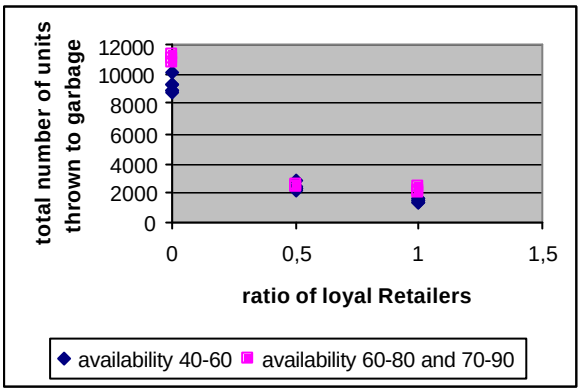

Figure 1: Total quantity of garbage for a simulation, linked to the ratio of loyal retailers in the society. Each dot represents the average value over 30 simulations (the values of Mean Square Deviation is not given for the first line, but it always shows that the average over 30 simulations is relevant).

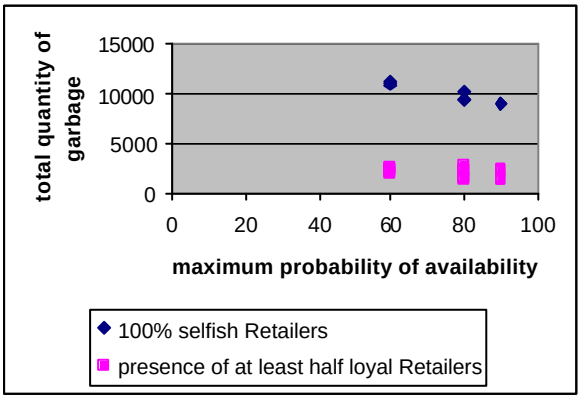

Figure 2: Total quantity of garbage for a simulation, linked to the availability in the society. Each dot represents the average value over 30 simulations.

of selfish Retailers helps the disparition of products before they are thrown away (Figure 1). This is due to the fact that loyal Retailers get the cheapest products and that the price decreases after the 3rd day of a unit: the old goods that could be thrown are eliminated by the loyal Retailers. Figure 3 also shows that the presence of loyal Retailers increases the average age of sold products.

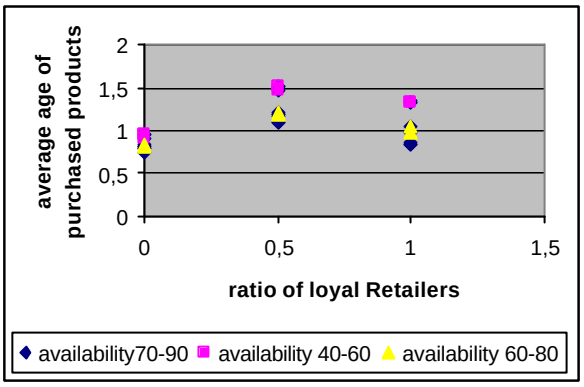

Figure 3: Average age of good sold. Each dot represents the average value over 30 simulations.

What we realise is that in our system, the difference of prices has a impact only when there are mainly selfish Retailers. This can be seen in Table 4a, where there is a significantly bigger gap between maximum and minimum supply in sim6 than in sim3 or sim9. This is an indicator that some WholesaleSellers receive more requests. When the selfish Retailers are mixed with loyal, the gap says more constant. The idea. The logic behind it is that some of the selfish agents succeed in getting cheap products, then get a lot of request and increase their normal supply. If they get again cheap products, they get even more requests, since their average price is lower than the others' average price. If they get to a huge number of cheap products that are not bought right away, they store cheaper products than the others and then have a cheaper average price. This cannot happen with such importance when there are loyal Retailers since the WholesaleSellers sell them the cheapest units first, increasing their average prices as a consequence. Even if the process is certainly different from the ones taking place in real life, it is good to get to an intuitive result of that sort, where prices don't matter so much for interactions when some loyal Retailers are in the market.

We do not consider the other data in this model, since we still have to analyse the relations between Retailers and WholesaleSellers. For the moment, we are mainly satisfied by the coherence between what

we wanted to represent and the global results we get. It is clear that, in our model, the presence of only selfish agents leads to real problems in the use of goods on the market: much more are asked for and much more are spoilt. At the same time, the systems exhibits a too specific type of global behaviour when only loyal agents are in, since the relations with an WholesaleSeller who is not a regular is very scarce, and WholesaleSellers adapt so that to fulfil a very predictable needs, their regular Retailers' ones (completely equivalent need for all products over the long run).

CONCLUSION

The paper represents an attempt to link field observations to a formal (computer) model. This field implication makes it harder to stick to a very strict theoretical context, but the modelling process offers an intermediate step between classical representation and pure description. It is also a way to describe a relationnal and lexicographic rationality that cannot be captured by linear equations. The assessment by the partner who has been interviewed and observed, is also a way to check that the model is relevant regarding the way individuals identify their practices. Our choice is indeed to try to express in a formal way the motivational aspects of an everyday life activity – which is far from one shot meetings, but also from monetary preferences, since individuals sometimes value other dimensions of their experience as it is well-known from old observations. On the MIN market, stable relations are recognised as important on both sides, and we wanted to capture this element.

To test how the local motivations could have an impact on global results, we hence built a multi-agent system in which to perform simulations. The conclusion that we can draw is of several dimensions: first, one can recognise that the individual behaviours do have an impact on the performance of individuals and on the functionning of the market as a whole. The presence of too many selfish agents pushes to a very important destruction of products. Maybe one can then understand why the wholesale seller we interviewed declared that it is a very important to push retailers to loyalty. And one can see how the degree of stability of the environment (variations of prices and of supply) can have an impact on the good functionning, as well as on a emerging heterogeneity.

Following this work a few other steps need to be reached. First, it is necessary to study the relation dynamics among agents, and even transform the rules a bit. It would indeed be interesting to conduct the same experiments with loyal Retailers who would be able to evaluate their relation to their regular, and potentially turn out to be selfish for a moment if they are not satisfied – looking for a new regular to settle with. On the other side, one could consider that the selfish agents could at some point decide to stay with one agent who could fulfil its needs in most of the case.

In any case, now that we've shown that our plateform is quite coherent with our observation and that the proportion of each type of agents has an important influence on the market movements of goods, the manipulation of this ratio will be the next step of our work.

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