The Real Effect of a Financial Market: an Agent-Based Model

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Abstract

It is well known how people, in these very days, despise the financial world in general, blaming all the causes of the crisis on it: quite a few have started to propose a complete elimination of it, probably thinking things would get better in this way. But to what extension this is true? How much financial markets, especially secondary ones, affect real markets and real world? Can be they really discarted from the economic world? Or is this renewal grudge towards speculators and brokers brought on by a substantial, and obviously justifiable, ignorance of people? The aim of this study is to simply show how financial markets affect real ones, stressing on the crucial point of information, both public and private.

Keywords: NetLogo, Financial Markets, Agent-based models

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1 Introduction

The purpose of this study is to analyse a simple model in which two different kinds of markets, financial and real, affect one another. Recalling the ideas of Bond *et al.* [2011], in fact, very few theories have included so far the effects that a *secondary financial market* has on a real one. These are due to three causes:[1]

- Real decision makers learn new information from secondary market prices: not only are traders usually more informed than firms' managers (because they aggregate information from different sources), but they can have also access to both internal and external information, which is more difficult for the managers. In any case, both RDMs (managers) and speculators (traders) learn from prices, which are considered to be a reliable source of information.
- Managers' compensations are often tied to firm's share price, making them less reluctant to follow financial markets.
- On the subject of behavioural finance studies, RDMs use prices as an anchor, often following them irrationally.

What is evident is the fact that for all the causes prices are thought to be *efficient*, i.e. they reflect at every istant the real behaviour of that particular firm. But if the RDM or manager can learn and modify her strategy according to firm's stock price, the notion of *price efficiency* has to be rethought.
What Bond *et al.* [2011] suggest[2] is two different notions of price efficiency:

1. *Forecasting price efficiency*: does the price of a security accurately predict the future value of that security?
2. *Revelatory price efficieny*: does the price reveal the information necessary for real efficiency, i.e. for decision makers to take value-maximizing actions?

What is immediate is that a lack of RPE leads to real inefficiency; by contrast, FP inefficiency leads to real inefficiency only if it is related to RP inefficiency. Bond *et al.* [2011] propose different explanations of how RPE can fail: the interesting point for our model is the fact that RPE is crucial only if prices are actually used in making decisions. In other words, once a DM relies on prices, she cannot help using them for her decisions, which should be hopefully always value-maximizing.

There is also another way by which prices can affect the real market, and it is called *incentives channel*.[3] According to this, since manager's remunerations are tied to firm's share price, decision makers have an obvious incentive to improve firm's performances: thus, the more RPE, the more the DM is willing to opt for an efficient action; in the learning channel, instead, RPE had the duty of revealing to the DM what the efficient action was, influencing her ability to take efficient decisions. If prices truly reflect manager's actions, she has a greater incentive to take desiderable ones.
Finally, even if this channel does not comprise a learning feature for managers/decision makers, there is still someone who is pleased to learn from the market: the shareholder, who actually pays the manager according to the stock price, reflecting the firm value (classic price efficiency).

Having introduced the bases to understand how a financial market can affect a real one, we can now move on to few examples of mutual influence.[4]

[1] Cfr. Bond *et al.* [2011], pagg.3-5.
[2] Cfr. Bond *et al.* [2011], pag. 9.
[3] Cfr. Bond *et al.* [2011], pag. 13.
[4] Cfr. Bond *et al.* [2011], pagg. 15-22.

- **Manipulative short-selling**. With *short-selling* we are referring to a speculators' behaviour, whose purpose is, by selling a large amount of stocks, to decrease the price itself. A learning chain has been suggested: if the speculator goes short, even without information, she makes the firm's manager cancel a possible investment,[5] reducing firm value and allowing the speculator to profit from her short position. The opposite, i.e. long position, is not valid.

- **Survival of irrational traders**. Traditionally, traders who trade on irrational considerations only, i.e. whose actions are unrelated to firm's fundamentals, should lose money and then disappear from the market. But if we consider prices' affection on firm's cash flow, it might happen that these traders make a profit by non-fundamental considerations, which might affect firm's cash flow, and then the trade itself.

- **Runs in the financial market**. With *run* we are referring to the typical behaviour of traders who start selling only because their colleagues do so: it is difficult to explain with the standard models, because if someone sells the price should go down, making someone else buy the stock. However, if we consider a capital provider whose actions depend on stock prices, she will not finance a financially dwingling firm, making it downsize itself.

- **Optimal disclosure policy** An important point worth bearing in mind is how much a firm should disclose its private information to the market: it can happen, in fact, that not only does the firm learn from market, but also the other way round. Should the company disclose parts of information which speculators do not have access to, they would trade on them more aggresively, making firm's learning process more efficient. However, there is always a tradeoff of sorts: the disclosure of the firm, in fact, discourages traders from producing their own information, this being a disadvantage for the firm.

Along with these theoretical examples, there are also empirical evidences. A typical learning situation, in fact, can come up when a manager reveals an acquisition intention and the market reacts negatively: in this case, the market and the speculators are supposed to have more information than the manager, who relies on prices' informativeness and cancels the acquisition. This phenomenon has been proved to occur with a statistical significance.[6]
On the subject of investments, it has been showed that *Tobin's Q*, i.e. the sensitivity of investment to price, is stronger when the private information, included in the price, has a relevant position:[7] the manager wants to learn from the price because it is a remarkable source of information otherwise unavailable to her.

2 Presentation of the model

In order to model the effect a financial market can have on a real one, it is necessary to simplify our system. Two types of agents are considered: *traders* (split into **companies** and **consumers**) and *shareholders* (split into **buyers** and **sellers**). Traders can buy (consumers) and sell (companies) goods according to the rules described in Subsection 2.1; shareholders can buy (buyers) and sell (sellers) stocks according to the rules described in Subsection 2.2.

The number of companies, consumers, buyers and sellers is fixed *a priori* and cannot be changed during the simulation; moreover, not every company is going public.

The key of the model presented here is the effect of *information*. We distinguish two types of information: **public information** and **private information**. The first one is related to the price settled during a

[5] The manager has learnt from the financial market.
[6] Cfr. Bond *et al.* [2011], pag. 23.
[7] Cfr. Bond *et al.* [2011], pag. 23.

bargain between two traders; the latter, instead, is different for any agent and influences the willingness to buy or sell stocks. The purpose of this study is observing the influence of a financial market (stock market) on a real one (trade market): the real market affects financial one thanks to public information, i.e. the price settled during a bargain, whilst shareholders change traders' behaviour buying and selling stocks of that particular trader, i.e. company.

2.1 Buying and selling goods

Every trader, both consumers and companies, has a *reservation price*: consumers want to spend at most their reservation price, companies want to earn at least their reservation price. In other words, when a consumer and a company meet, the trade occurs only if the reservation price of the consumer is higher than company's one. If so, the settled price depends on the kind of bargain dynamic decided by the user: either the settled price is a random number between the two reservation prices, or is close to one of them, according to a specific external parameter.[8] Once the trade has occurred, the consumer buyes a unit of product sold by the company, which normally[9] products two of them at every time step.

Reservation prices of both traders are adjusted if they exceed an *a priori* decided bounder: consumers are going to spend less (resp. more) if they have (resp. not) enough, companies are going to decrease (resp. increase) their desidered earning if their stocks are (resp. not) full.

2.2 Buying and selling stocks

Stock exchange and trading goods resemble each other in terms of reservation price-based dynamic: as in Subsection 2.1, the exchange occurs only if buyer's price is higher than seller's one, but not when a buyer meets a seller. Instead, shareholders decide how many quoted company's stocks they want to trade, fixing their prices as follows. These prices will be then inserted into the logs referred to the quoted company, which will sort them from the highest to the lowest, for buyers' log, or the other way round, for sellers' one. If the first element of the buyers' log is higher than the first one of sellers' log, the exchange occurs and the price is settled equal to either seller's price or buyer's one, with the same probability.

The cost of a stock, i.e. seller's and buyer's basic reservation price, depends firstly on the average of companies' settled price at that specific moment and the one at the previous iteration they traded: in this way, if the company is economically flourishing (resp. dwindling), i.e. its average settled price is increasing (resp. decreasing), the cost of the stock should increase (resp. decrease) as well. The average is what we have called public information.

Private information owned by a single shareholder is a uniform random number in the interval $(-p, p)$, where p is the bounder to maximum private information available to agents:[10] this number will be added to shareholder's reservation price, defining the final price of a bargain.

To sum up: shareholder's reservation prices are formed by public information (quoted company's economical state) and private information (random number, different for buyers and sellers).

2.3 Financial market's effect

Thus far we have only implemented the influence of real market on financial one, i.e. public information. The are many ways to do the other way round. What has been chosen is to affect the production level of companies.

[8] See Subsection 3.1 for further details.

[9] See Subsection 2.3 for the definition of "normally".

[10] The user can actually choose the percentage p, which will be transformed into the bounder.

Every company produces two units of product at every time step, but if its stocks are increasing (resp. decreasing) in price, i.e. settled one after a bargain between shareholders, the company should have more (resp. less) credit and thus produce more (resp. less). Modelling speaking, if the settled price of its stock is greater than the one at the previous iteration it traded, the company produces three units; if it is lesser, it produces only one unit; if it is equal, it still produces two units.

3 NetLogo implementation

In this section all the procedures shown in the previous Section will be presented, particularly stressing on tradings and stock exchanging.

3.1 Trading implementation

As explained in Subsection 2.1, when a consumer meets a company, she tries to spend at most her maximum reservation price, whereas the company is willing to earn at least its minimum reservation price. Only companies with at least one unit of product in their stocks will be considered, and only one of them a bargain. The coding procedure is thus:

```
to trading
    ask consumers [
        let numberOfTrials 0
        while [numberOfTrials < consumerTrials and count companies-here with [Q > 0] [
            let aCompany one-of companies-here with [Q > 0]
            let diff maxPrice − [minPrice] of aCompany
            if diff >= 0 [
                if tradePrice = "random price settlement" [set price (maxPrice - random-float diff)]
                if tradePrice = "closeness to" [set price ([minPrice] of aCompany + tradeClosenessTo *
diff)]
                set settledPrice price
                set Q (Q + 1)
                ask aCompany [
                    set Q (Q − 1)
                    set settledPrice price
                    if quoted = "true"[set publicCost ((settledPrice + settledPrice-1) / 2)]
                ]
            ]
            set numberOfTrials (numberOfTrials + 1)
        ]
    ]
end
```

Roughly put, a consumer chooses one of her neighbour companies with enough products. The bargain occurs *consumerTrials* times: at every trading the price is settled according to either *"random price settlement"* method or *"closeness to"* one, the latter establishing the price close to consumer's reservation price (when the parameter is close to 1) or company's one (when the parameter is almost 0). *publicCost* is the basic cost of the stock for the quoted trading company and is simply the average between the price settled at that bargain and the one settled at the previous iteration the company traded.

3.2 Stock Exchange implementation

This is the core engine of the whole model: both public information and private one are included.

```
to exchanging
    if (any? companies with [publicCost != 0]) [
        buyersInLog
        sellersInLog
        ask companies with [quoted = true] [
            if (not empty? logB and not empty? logS) and (item 0 (item 0 logb) >= item 0 (item 0 logS)) [
                ifelse (random-float 1.0 < 0.5)
                    [set price item 0 (item 0 logS)]
                    [set price item 0 (item 0 logB)]
                set stockPrice price
                set diffStock (stockPrice − stockPrice-1)
                ask buyer item 1 (item 0 logB) [set settledPrice price]
                ask seller item 1 (item 0 logS) [set settledPrice price]
                set logB but-first logB
                set logS but-first logS
            ]
        ]
    ]
end
```

As shown, this method recalls other two methods (only one is presented here, the other is the same but for the sellers).

```
to buyersInLog
    ask buyers [
        let placement 0
        while [placement < nb-stocks-to-buy] [
            let aQuotedCompany one-of companies with [quoted = true]
            while [[publicCost] of aQuotedCompany = 0] [
                set aQuotedCompany one-of companies with [quoted = true]
            ]
            let bounder ((privateInformationPercentage * [publicCost] of aQuotedCompany) / 100)
            let privateBuyerInformation 2 * bounder * (random-float 1.0) − bounder
            ifelse ([publicCost] of aQuotedCompany + privateBuyerInformation) > 0
                [set maxPrice ([publicCost] of aQuotedCompany + privateBuyerInformation)]
                [set maxPrice ([publicCost] of aQuotedCompany)]
            let tmp[]
            set tmp lput maxPrice tmp
            set tmp lput who tmp
            ask aQuotedCompany [
                set logB lput tmp logB
                set logB reverse sort-by [item 0 ?1 < item 0 ?2] logB
            ]
```

```
            set placement (placement + 1)
        ]
    ]
end
```

In the last method private information is added to public one: the user can choose *privateInformationPercentage*, which becomes the bounder for the real private information. The procedure is repeated a number of times equal to *nb-stocks-to-buy*, so a single buyer can buy more than one stock per company.

4 Results

In this section different results given by the model will be presented. Since too many parameters are present, it is necessary to focus on the most important ones only: in Subsection 4.1 the effect of trading price correction will be analysed; in Subsection 4.2 the two different dynamics, *random price settlement* and *closeness to*, will be shown; finally, in Subsection 4.3, the most important feature of this model will be introduced and explained, the private information.

Bear in mind that sometimes, during the study, few parameters will be fixed or changed, according to the purpose of the Subsection.

4.1 Trading price correction

In this Subsection we will focus only on the effect of the trading price correction. *privateInformation* is fixed equal to 0 and *tradePrice* is settled to *random price settlement*.

As exposed in Subsection 2.1, companies and consumers may change their reservation prices depending on the amount of product they have. Specifically, the user can choose, with an external parameter *deltaPrice*, the percentage of maximum correction to the reservation prices: for consumers, if the amount of products is higher than *consumerDesideredStock*, another external parameter, the maximum reservation price is diminuished thanks to a random number in the interval $[0, \mathit{deltaPrice} * \mathit{maxPrice}/100)$; if it is lower, instead, it is increased with the same technique. The same is valid for companies, *companyDesideredStock* being the external parameter.

The results are very curious: tendencially, consumers increase their reservation price, companies are not effected by any change. If the first phenomenon requires an in-depth explanation, the second one is easy to prove. For the companies, in fact, if the reservation price falls below the half of their initial *minPrice*, it is automatically set to this value: in other words, no company would sell below cost.

Consumers, instead, put up their *maxPrice*, no matter what the user decides.

As shown in Figure 1, few iterations are required to assist to an exponential growth of the mean of consumers' reservation price, in blue. The explanation for this pattern may be this one: since the number of consumers is far greater than the number of companies, many agents of the first class would not trade in a single time step. This would immediately force, because of continuous consumption of products, the consumers to change their price, putting it up.

Is then natural asking if the pattern changes inverting the situation, i.e. having the number of companies far bigger than the number of consumers. The answer can be nothing but affirmative: although strong fluctuations are present, the mean of prices tends to be stable and slightly greater than *minPrice*'s mean.

The role of *deltaPrice* is crucial to determinate the pace of prices' growth: as it can be easily imagined, the more δ, the speeder the growth, as shown in Figure 3.

Finally, it is also interesting analysing the influence of *consumerTrials*: if consumers, in fact, can buy more products per time step, the mean of reservation prices should increase less rapidly. Observing the

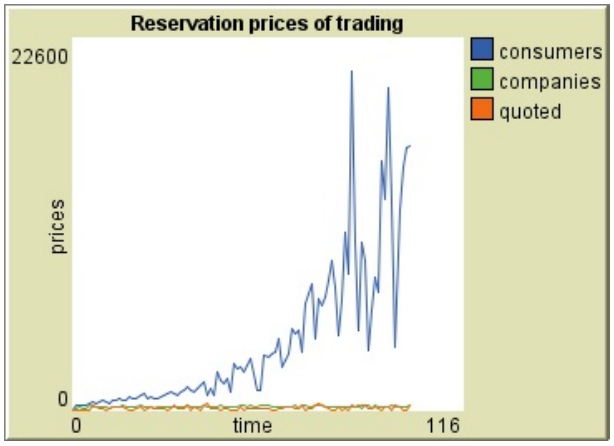


Figure 1: 200 consumers, 50 companies. Bounders for initial reservation prices for both traders set to 500. Consumer's and company's desidered product stock equal to 15. *deltaPrice* equal to 10%. Number of trading trials equal to 20. The means are computed on agents who have traded at that time step only. The simulation lasts 100 iterations.

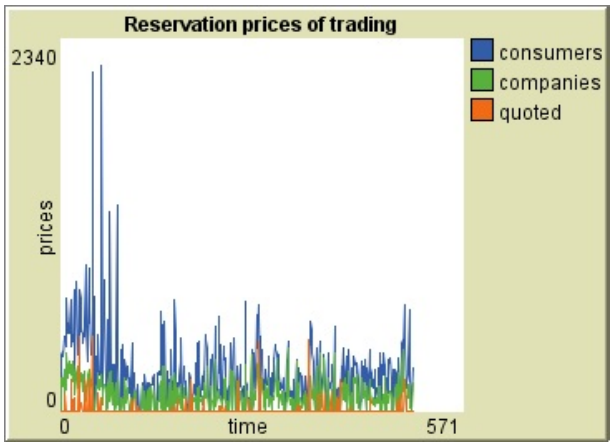
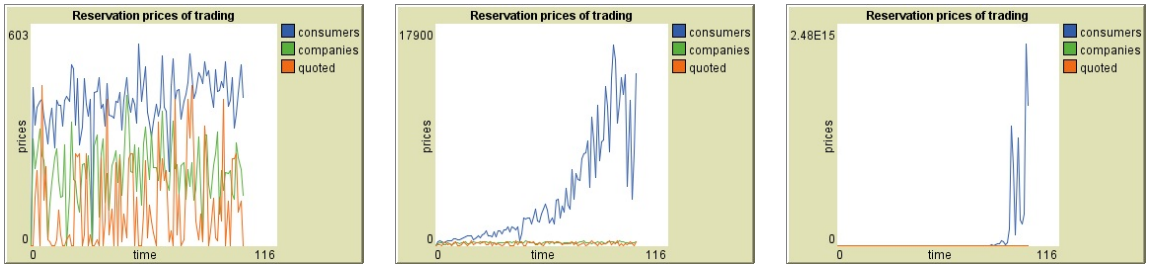


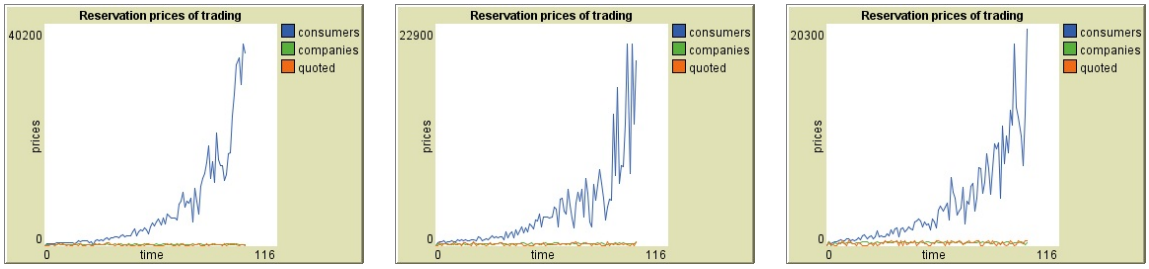
Figure 2: 50 consumers, 200 companies. Bounders for initial reservation prices for both traders set to 500. Consumer's and company's desidered product stock equal to 15. *deltaPrice* equal to 10%. Number of trading trials equal to 20. The means are computed on agents who have traded at that time step only. The simulation lasts 500 iterations.



$\delta = 1\%$ $\delta = 10\%$ $\delta = 75\%$

Figure 3: 200 consumers, 50 companies. Bounders for initial reservation prices for both traders set to 500. Consumer's and company's desidered product stock equal to 15. *deltaPrice* varying. Number of trading trials equal to 20. The means are computed on agents who have traded at that time step only. Every simulation lasts 100 iterations.

Figure 4, however, this is not so evident: although the mean strongly fluctuates, it reaches high values in few time steps, as in Figure 1. It can mean nothing but the role of the number of trials is not as important and crucial as we originally thought: the dynamic of agents, i.e. the possibility of moving in the grid, wins over the number of products they have, because of their constant consumption.



trials = 1 trials = 50 trials = 100

Figure 4: 200 consumers, 50 companies. Bounders for initial reservation prices for both traders set to 500. Consumer's and company's desidered product stock equal to 15. *deltaPrice* 10%. Number of trading trials varying. The means are computed on agents who have traded at that time step only. Every simulation lasts 100 iterations.

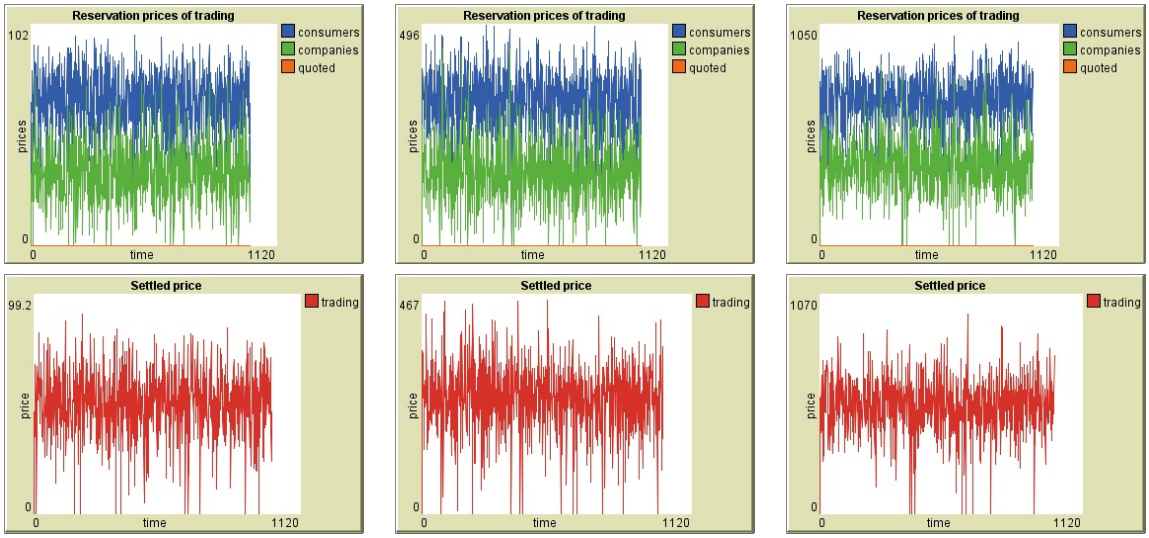
4.2 Price settlement

In this Subsection the two different trading dynamics will be studied. Private information is set to 0 and traders cannot change their reservation prices (making the number of trials irrelevant).

As explained in Subsection 2.1, the settled price changes according to two dynamics:

- *Random price*: calling M consumers' price and m companies' one, the price of a bargain is a random number uniformly drawn in the interval $[0, (M - m))$.
- *Closeness to*: price is set equal to $m + c(M - m)$, c being an external parameter, called *tradeClosenessTo*, in the interval $[0, 1]$. If $c \approx 0$, the price is close to the minimum price of the company, if $c \approx 1$, it is close to maximum price of the consumer instead.

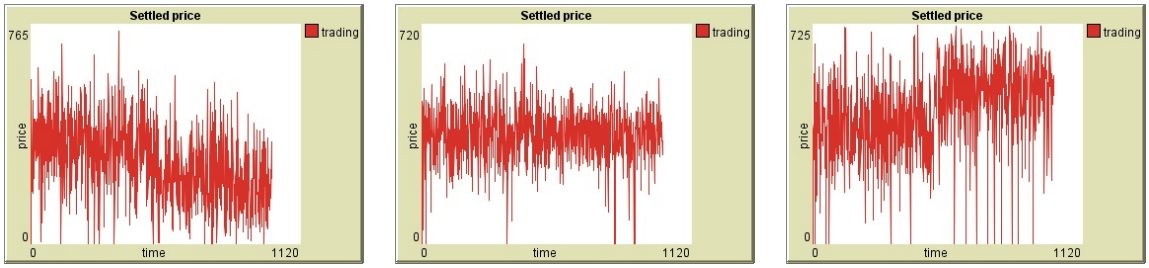
The first dynamic is surely less interesting than the second: prices just follow a random walk, without any drift, which depends on the bounders for initial reservation prices, as shown in Figure 5.



bounders = 100 bounders = 500 bounders = 1000

Figure 5: 200 consumers, 50 companies. Bounders for initial reservation prices varying. *Random price settlement*. The means are computed on agents who have traded at that time step only. Every simulation lasts 1000 iterations.

The results of the second method are quite obvious too: if we get close to consumer's (resp. company's) price, the settled price tends to increase (resp. decrease), as shown in Figure 6. The importance of this



$c = 0.0$ $c = 0.5$ $c = 1.0$

Figure 6: 200 consumers, 50 companies. Bounders for initial reservation prices for both traders set to 750. *Closeness to*. The means are computed on agents who have traded at that time step only. Every simulation lasts 1000 iterations: the first 500 are run with *random price settlement*, the last ones with the other method.

dynamic, however, will be striking in the next Subsection.

4.3 Private information

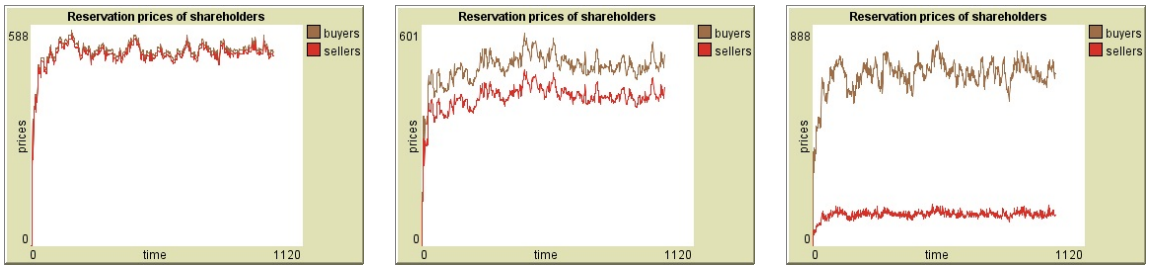
In this Subsection private information will be finally considered, along with all the other characteristics depicted thus far. The bounders for the initial reservation prices of traders is set, for both, equal to 750. No price correction, depending on the amount of product, is considered.

Firstly, it would be appropriate beginning with focusing on the effect of private information only. In Figure 7, as predictable, the curves of buyers and sellers coincide, because there is no private information: both prices are equal to the public cost of the stock.

The situation changes drastically, however, varying the percentage p of private information, as shown in

Figure 7: 250 buyers, 250 sellers, 50 quoted companies, *nb-stocks-to-buy* = *nb-stocks-to-sell* = 1. Private information set equal to 0%. The simulation lasts 1000 iterations. Notice how the two curves, representing the mean of reservation prices of the trading shareholders, perfectly coincide.

Figure 8. The more the private information, the bigger the gap between the two averages.[11] Not only does



$p = 1\%$ $p = 10\%$ $p = 75\%$

Figure 8: 250 buyers, 250 sellers, 10 quoted companies, *nb-stocks-to-buy* = *nb-stocks-to-sell* = 1.The simulations lasts 1000 iteration.

the spread become greater, but it is also evident another effect: consumers' price tends to fluctuate much more than sellers' one. This seems to be the first strinking result of the model, because it is substantially unexplainable: even increasing the total number of buyers we observe no significant shake-up.

As exposed in Subsection 2.3, our financial market can affect the real one, in terms of production's levels. In Figure 9 we observe in green the percentage of "stable" companies, which products two units per time step, in blue the "flourishing" companies, whose production is increased up to three units, and in red the "dwingling" companies, whose financial problems have made them product one unit a time only.

For the first 500 iterations the percentage of stable companies is more or less equal to 100%: the small fluctuations are due to the fact that stock exchanges occur also when seller's and buyer's prices are equal, and therefore are more frequent. If the exchanges happened only when buyer's price is strictly greater than seller's one, with no private information we would not see any oscillation in the three different percentages. An increase in the number of quoted company, however, would lead to stronger oscillations, for each of the three indicators.

The second part of the curve should not be frightening. With the addition of private information, reservation

[11] Bear always in mind that all the curves are drawn with respect to the agents who have actually traded in that time step, i.e. whose *settledPrice* is different from 0.

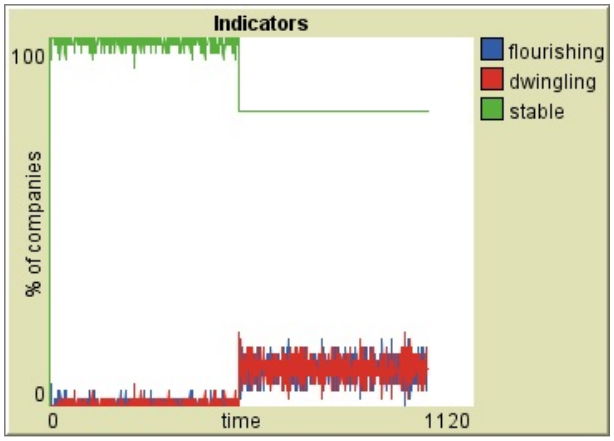
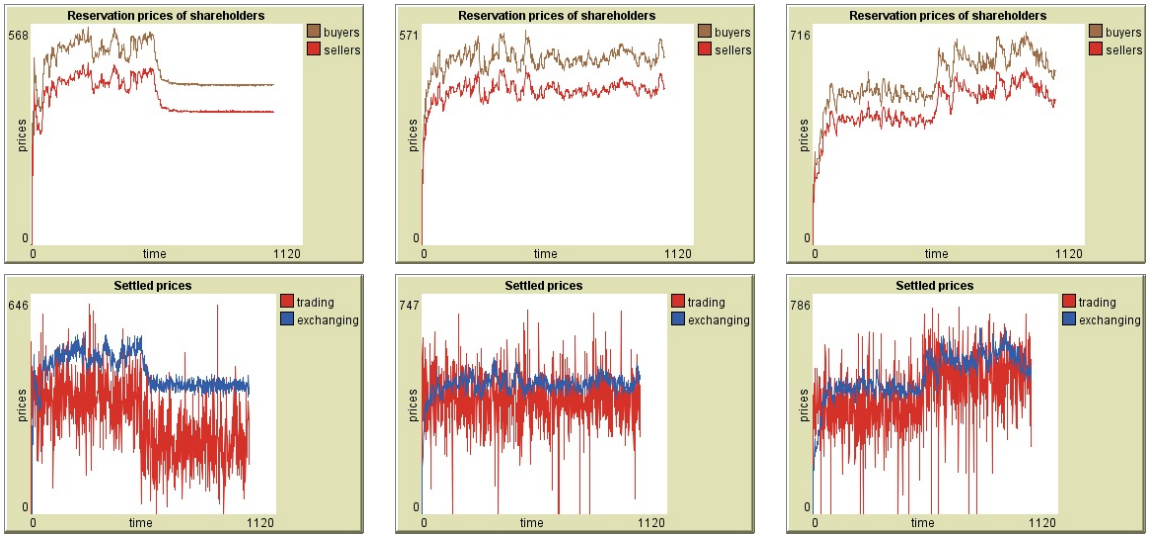


Figure 9: 250 buyers, 250 sellers, 50 companies (10 quoted), *nb-stocks-to-buy* = *nb-stocks-to-sell* = 1. For the first 500 iterations the private information is null, then it is set to 10%. The simulation lasts 1000 iterations.

prices of shareholders are always different from one another: in this case stock exchanges are less frequent, but more effective. In other words, the only stable companies are the non-quoted ones, whilst flourishing and dwingling ones alternate each other in a random walk.

The two different methods of setting prices in a normal trade, i.e. *random price settlement* and *closeness to*, have an impact on the financial market too. Observing Figure 10, in fact, it is immediate to see how the shareholders' reservation prices, even with private information, tend to follow traders' ones.

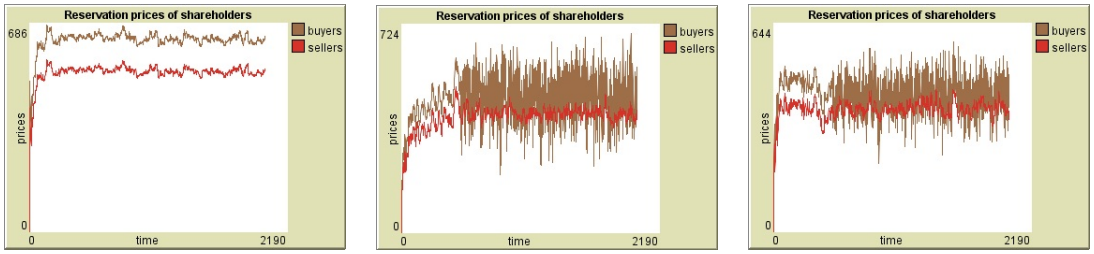


$c = 0.0$ $c = 0.5$ $c = 1.0$

Figure 10: 250 buyers, 250 sellers, 10 quoted companies, *nb-stocks-to-buy* = *nb-stocks-to-sell* = 1, $p = 10\%$. In the first 500 iterations trade prices are correct with *random settlement price*, in the last 500 with *closeness to*, with different c. The simulations lasts 1000 iterations.

Finally, we consider the most interesting feature of this part of the model, i.e. the number of stocks which can be bought or sold at every time step. Let us fix, for example, the number of sold stocks and vary the other one, as shown in Figure 11. What is incredible is that, as predictable, the oscillations of the

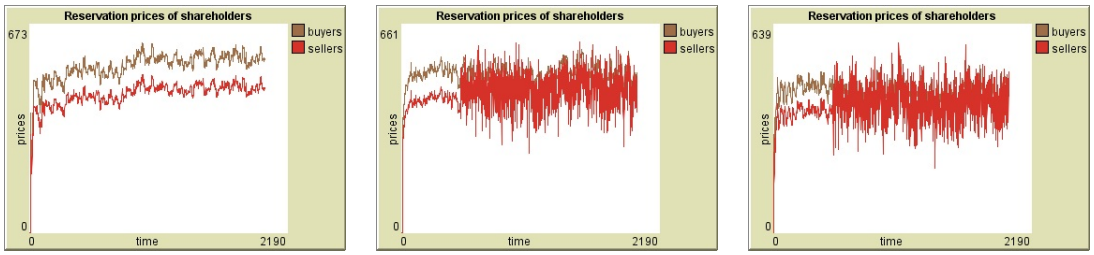
line tend to increase, but not monotonically: when the number of buyings is equal to the number of public companies it seems to appear an internal averaging effect, which shortens the range of the oscillations.



Nb = 1 Nb = 3 Nb = 10

Figure 11: 250 buyers, 250 sellers, 10 quoted companies, *nb-stocks-to-buy* varying, *nb-stocks-to-sell* = 1, p = 10%, *random price settlement.* In the first 500 iterations the total number of bought stocks is fixed equal to 1. The simulations last 2000 iterations.

However, this behaviour is not observed when we change the number of sold stocks, instead, as can be easily seen in Figure 12. In other words, though the number of buyers and sellers is the same, buyers show,



Nb = 1 Nb = 3 Nb = 10

Figure 12: 250 buyers, 250 sellers, 10 quoted companies, *nb-stocks-to-buy* = 1, *nb-stocks-to-sell* varying, p = 10%, *random price settlement.* In the first 500 iterations the total number of bought stocks is fixed equal to 1. The simulations last 2000 iterations.

again, a more interesting dynamic and seem to be the real "market regulators".

5 Conclusion

Bond *et al.* [2011]'s work and our model resemble each other in different aspects: first of all, the NetLogo simulation uses the double characterisation of information, public and private, and shows the effect of the financial world on goods trading. Despite this, the differences are frequent. Prices do not aggregate pieces of information from different parts of the market, they are simply the real market's tendency itself: in this way, all the FPE role is ruled out, in favour of a complete RPE interpretation. Speculators[12] consequently do not really learn from the market, as they were used to according to the article: they passively get known of companies' economic status and modify their willingness to trade, which is their exhanging prices, with the private information.
In this way, neither learning nor incentives channel are present, because there is actually no decision maker: the situation is more static than in the article, everyone is bound to trade or exchange stocks.

[12]Managers no longer exist or, in other words, are thought to be the companies.

FPE is inserted again with the financial market's effect on real one: the price becomes forecasting in terms of companies' level of production. However, no cash-flow, and then no primary financial market, is considered, which can understimate the complexity of this mutual dependence.
In fact, by far the biggest flaw of this model is the "constraining linearity": since only two kinds of classes are considered (traders and shareholders), and because of their static behaviour (to buy/sell or not), no complex pattern arises. The only interesting result is the unexpected leading role of buyers, who actually control the market according to their desires: if these agents were to be given some learning feature, making them real decision makers, complexity might well come up.

Another possible interesting feature to insert is a third agent, such as a bank, which would affect both influence processes. As market regulator, in fact, it would change stock prices, aggregating different pieces of information (and then modifying price efficiency as we know it, which has been perfect and completely revelatory thus far); as capital provider it might lend or not money to the financially flourishing/dwingling companies, changing again the role of FPE.

Despite these faults, the model may teach something interesting. Firstly, going public gives more or less a fifty percent of probability of flourishing or dwingling: this is not surprising, because also in real financial markets there is only one certainty, which is the risk; the only decision making procedure is the reservation price process: in this way, every agent is supposed to be rational and willing to maximize her revenue: our real economic and financial situation, however, has shown how this assumption is often false; the number of agents is crucial: it is known that complexity rises when a large number of agents is present, so this might be another way to reproduce complexity.

To sum up, the possible extensions may be:

- Enlarge the number of agents.
- Divide FPE (financial effect on real market) from RPE (public cost of stocks) by adding a third agent.
- Enable agents to learn from the market, by adding irrationality and another agent such as a manager, whose actions are bound to companies' economic and/or financial status.

References

BOND, P., EDMANS, A. et GOLDSTEIN, I. (2011). The real effects of financial markets. Working Paper 17719, National Bureau of Economic Research.