MARKET EFFICIENCY UNDER DIFFERENT DYNAMICS IN THE MALL

Valeria Secchini

University of Torino, Italy

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Contents

Introduction

The initial aim of this work was to see the behaviour of a world populated by two different types of agents: entrepreneurs and workers. The capital is given at the beginning to every agent, which, depending on its value, splits them in the two different categories. First ones have to hire workers and pay a salary to them, plus a fixed cost for every unit of product they produce. The product is the only one of the world. Then they try to sell their product making an offer that, at the beginning, is twice the total cost of production. If exchange happens, entrepreneurs will increase it to a certain value and with a certain probability. If not, they will diminish it. The same happens with salary: they try to hire, offering a certain pay. If they will, they will diminish salary, if not, they will increase it. Workers have another feature than the others, which is the "energy". Every time they buy the product, they "recharge" themselves. They accept a salary offer with a probability depending on their capital and their energy. If they still have a job, they will accept another offer only if it is higher than the one they accepted before. Under similar conditions, they will accept to buy the product (with the further limit of their capital, that could not allow them to accept an offer if it is higher than their capital).

The result we wanted to calculate was market efficiency (or total wellness) in a regime of free trade, compared to the one with an introduction of a tax.

Considering the big number of variables, we will semplify our world. At the beginning we will consider a free trade market, in particular the one of the mall. Entrepreneurs have a fixed total cost given them from the beginning, different for everyone and which remains the same (like if they hire always at the same salary). Workers buy from sellers and do not have an energy, only a maximum price they are disposed to pay, which can vary (and can be seen as their availability derived by their capital and need). Both agents do not have directly the variable of capital. Practically, we eliminate the dynamics of working and hiring. That implies we are not talking about entrepreneurs and workers anymore, but about sellers and buyers with certain limit that can be referred (in a simplified way) to maximum and minimum prices.

In our model we have agents with a strategy: buyers decrease (increase) the

maximum price they want to spend if they manage in buying (they do not). Sellers will increase (decrease) the minimum price they are willing to gain if they manage in selling (they do not).[1] We will see that the mean price and wellness reach a costant value till we have simmetry in increasing and decreasing prices. It can be seen as the case in stock market. In particular, in Stigler model [2]: till all agents act completely random, mean price of exchanges is random too and always happens within a fixed interval (it is the case of *zero intelligence* [3]). Putting at least 50% of agents with a precise strategy (every buyer or seller puts its order on best price of bid or ask) interval closes and mean price reaches a costant value [4]. Then, in both cases, if some agents act conforming to the requests of market, mean price (and in the following case also wellness) is stabilized. In case of asymmetry, in particular when buyers are not able to increase their maximum price as they have to decrease it, there will be crisis in which mean price and wellness go periodically to zero. In this case we will introduce a tax to make market stable again.

Dynamics in the mall

In particular, we assume the realistic case in which buyers >> sellers. As explained before, first ones have got a maximum price (P_{max}) they are willing to spend and the second ones have got a minimum price (P_{min}) they are willing to gain. P_{max} (P_{min}) is chosen randomly for every buyer (seller) at the beginning. P_{max} in the interval $[100, 50]$, P_{min} in $[55, 10]$. Mean total cost (mTC) for every seller is fixed as

$$TC_M = \frac{P_{min}}{2}$$

When they meet, the exchange happens only if

$$P_{min} < P_{max}$$

and they exchange at the value of P_{min}, which will be memorized as the price of exchange P_{ex} (we are in the mall, which means that the price is exposed and fixed by the seller).

We will use an agent simulation. Sellers will move only at the beginning and put themselves in all different patches (like if they are fixed shops). On the other hand, buyers will move randomly from the moment in which sellers are all established. The buyer chooses one of the sellers in a radius of three patches and buys as explained before.

0.1 The mall in free trade

Every time a buyer buyes, it will decrease its P_{max}

$$P_{ex} + Perc(P_{max} - P_{ex})$$

If not, it will increase it to

$$P_{max} + Perc(P_{min} - P_{max})$$

(where P_{min} is referred to the latest price it refused). The $Perc$ is a random %. We can fix its maximum value (for example it can randomly go from 0 to 100% or to 50% or to 20%). Both changes of threshold will happen with a probability of $Prob_B$.

If the seller manages in its aim it will increase the P_{min} to

$$P_{min} + Perc(P_{min}/3)$$

if it does not, it will diminish it to

$$P_{min} - Perc\frac{(P_{min} - TC_M)}{3}$$

Both with probability $Prob_S$.

Every time an exchange takes place, two quantities will be memorized:

- The *BuyerWellness* which is $W_B = P_{max} - P_{min}$
- The *SellerWellness* which is $W_S = P_{min} - TC_M$

They will be used to calculate the market efficiency.

0.1.1 Large change of price with same probability for buyers and sellers

At first, we consider the case in which $Perc$ goes till 100% and $Prob_S = Prob_B = \frac{1}{3}$. We obtain a situation in which both the medium price and wellness have a peak and then fall to a value and remains constant. In particular, wellness goes around 2000.

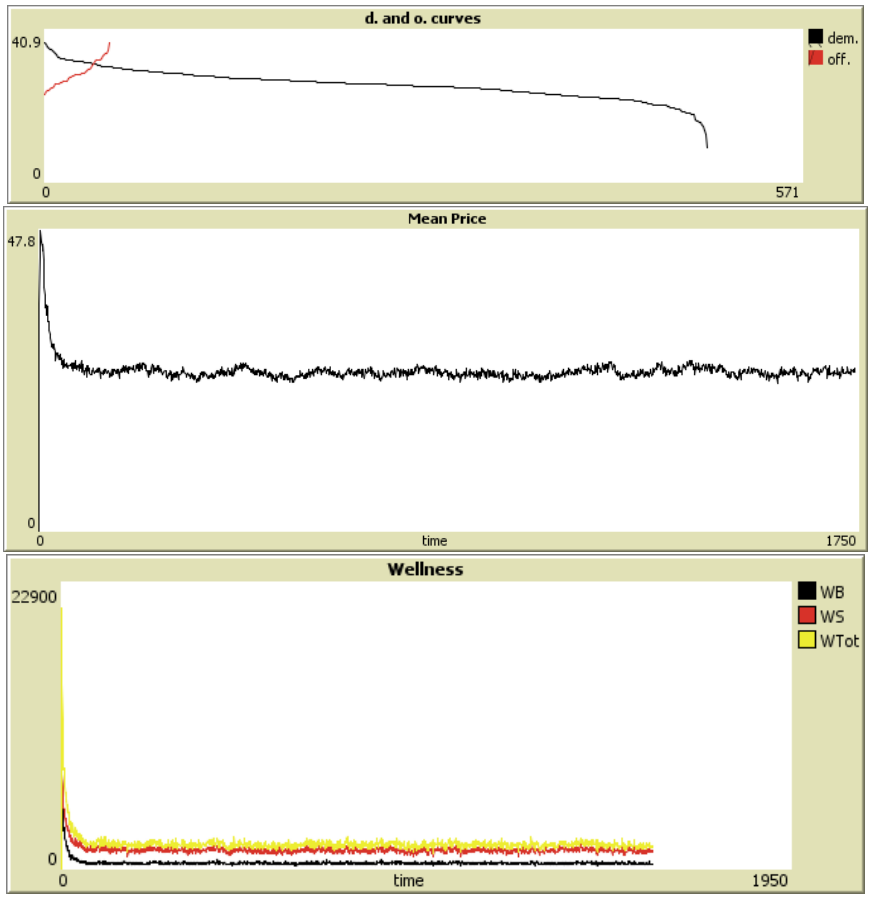

Figure 1: Case with same probability of changing P_{min} and P_{max} and a percentage of variation up to 100%. After a peak, mean price and Wellness go to a constant value

We can se a very high peack due to our choices of P_{min} and P_{max} intervals at the beginning. Infact, if we reverse the intervals (we choose P_{max} in the interval $[100, 50]$, P_{min} in $[55, 10]$), we obtain the same constant trend, without any peak at the beginning.

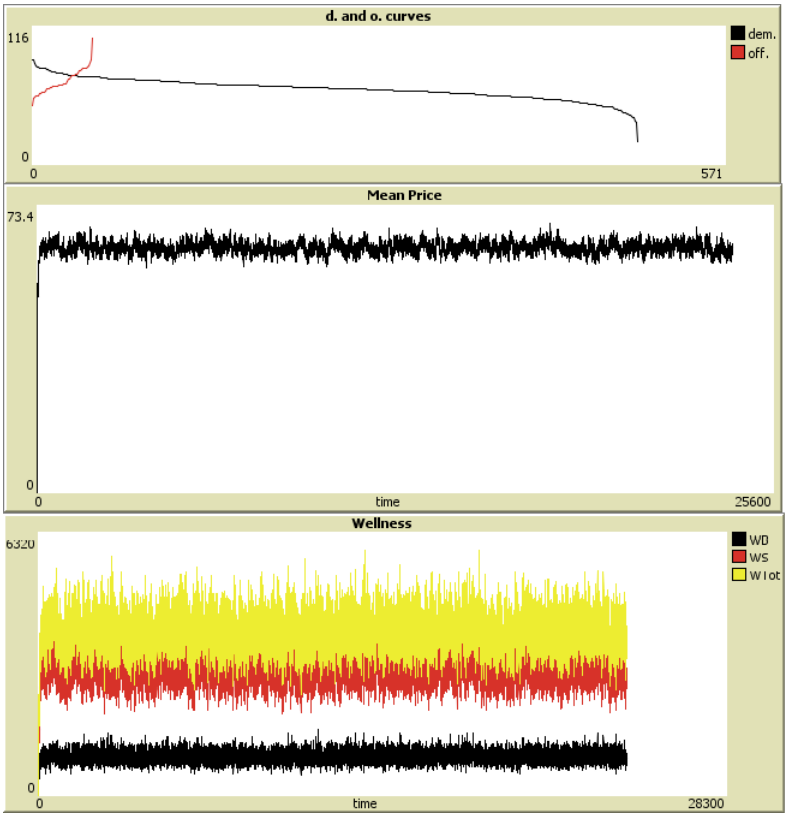

Figure 2: Case with same probability of changing P_{min} and P_{max} and a percentage of variation up to 100% and reversed intervals. Mean price and Wellness go to a constant value without any peak at the beginning

To better see the mean price and wellness trend in the first case, we focuse on the curves when they reach their mean value, beginning to store values after the peak. We will do it for every plot from now to the end.

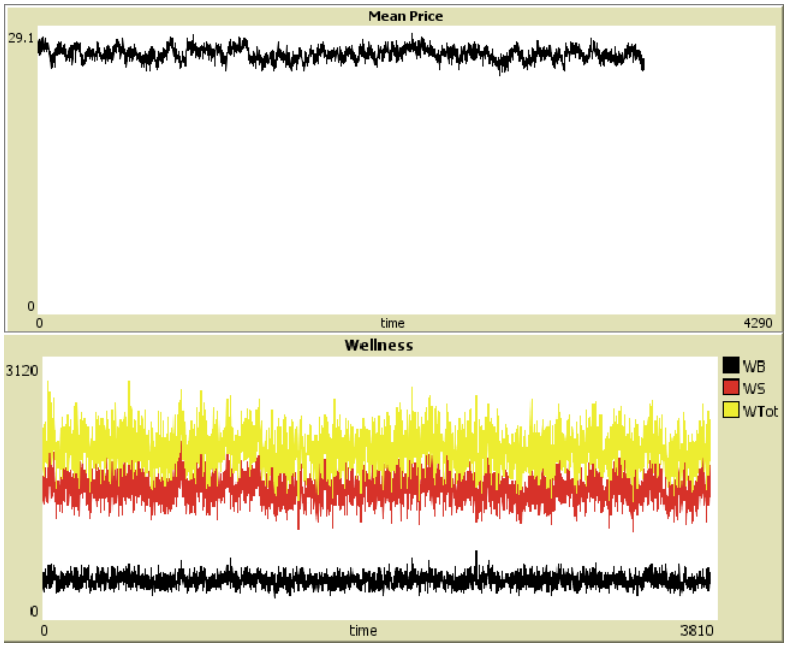

Figure 3: Case with same probability of changing P_{min} and P_{max} and a percentage of variation up to 100%. Mean price and Wellness remain constant and both the sellers and the buyers curves follow the same constant trend.

0.1.2 Behaviours with different values of $Perc$, numbers of agents and $Prob$

So, we try to change the probability of exchange. Because we fixed buyers >> sellers (in particular the buyers are 10 times the number of the sellers), we will consider the $Prob_S$ $\frac{1}{10}$ than $Prob_B$. (The seller thinks that it has more chances to

sell at the price it has decided because of the elevated number of buyers, it is the case of "sticky prices"). Anyway, result does not change, there are only few more fluctuations.

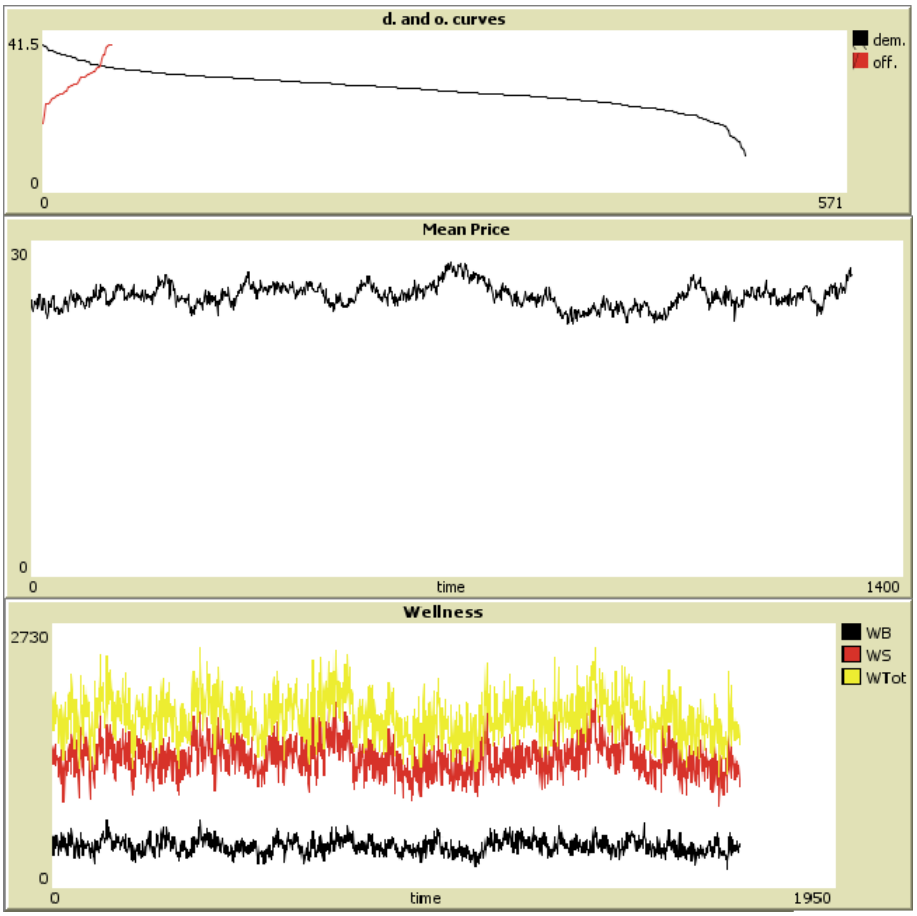

Figure 4: Case in which $Prob_S = \frac{1}{30}$ and $Prob_B = \frac{1}{3}$ and a percentage of variation up to 100%. Mean price and Wellness follow constant values

Making the $Prob_S$ even more "sticky" ($Prob_S = 0.0003$), fluctuations are bigger, but nothing happens to the trends.

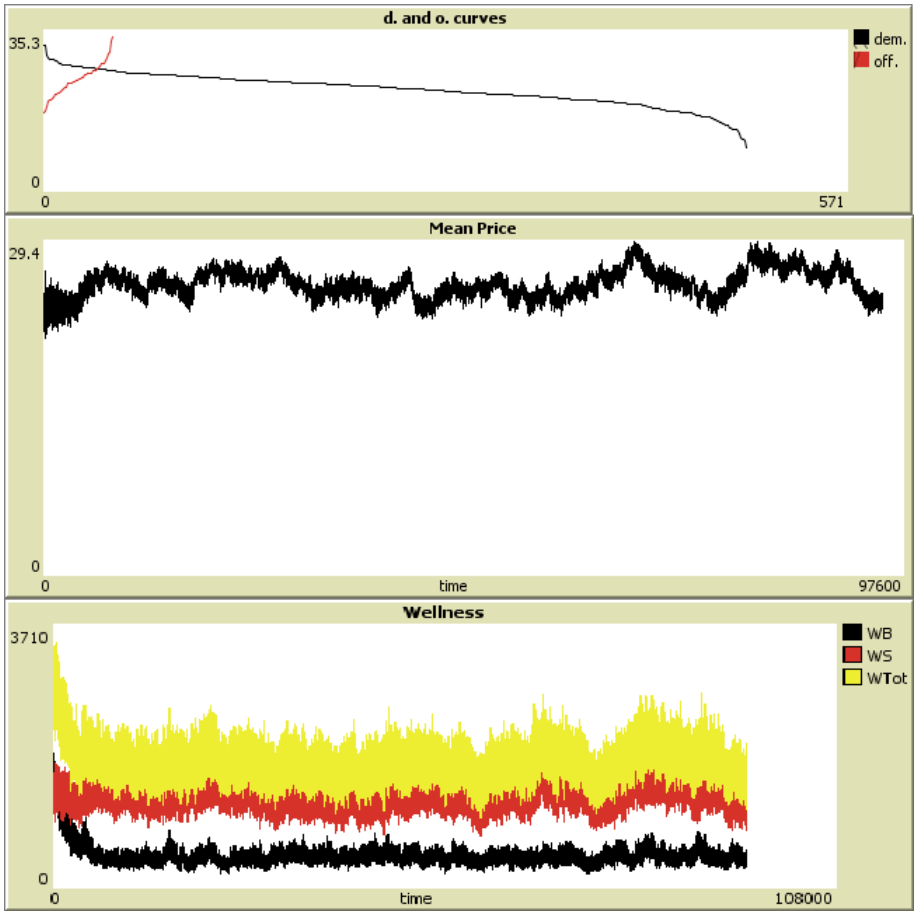

Figure 5: Case in which $Prob_S \simeq 0.0003$ and $Prob_B = \frac{1}{3}$ and a percentage of variation up to 100%. Mean price and Wellness go to a constant value. Fluctuations are more visible

Now we will change $Perc$, making it smaller (from 0 to 20%). We can see that the situation changes radically. In particular, even if total wellness remains constant, sellers wellness grows up to total wellness and buyers one falls to zero. Total wellness is smaller than the previous one. Mean price tends to grow slowly, instead of remaining constant, until sellers welleness grows. We will show all different situations, leaving $Perc$ as said before:

- $Prob_B = Prob_S = \frac{1}{3}$
- $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{30}$
- $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{3000}$
- $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{3000}$ and number of buyers two times the one of sellers

- $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{3000}$ and the same number of buyers and sellers

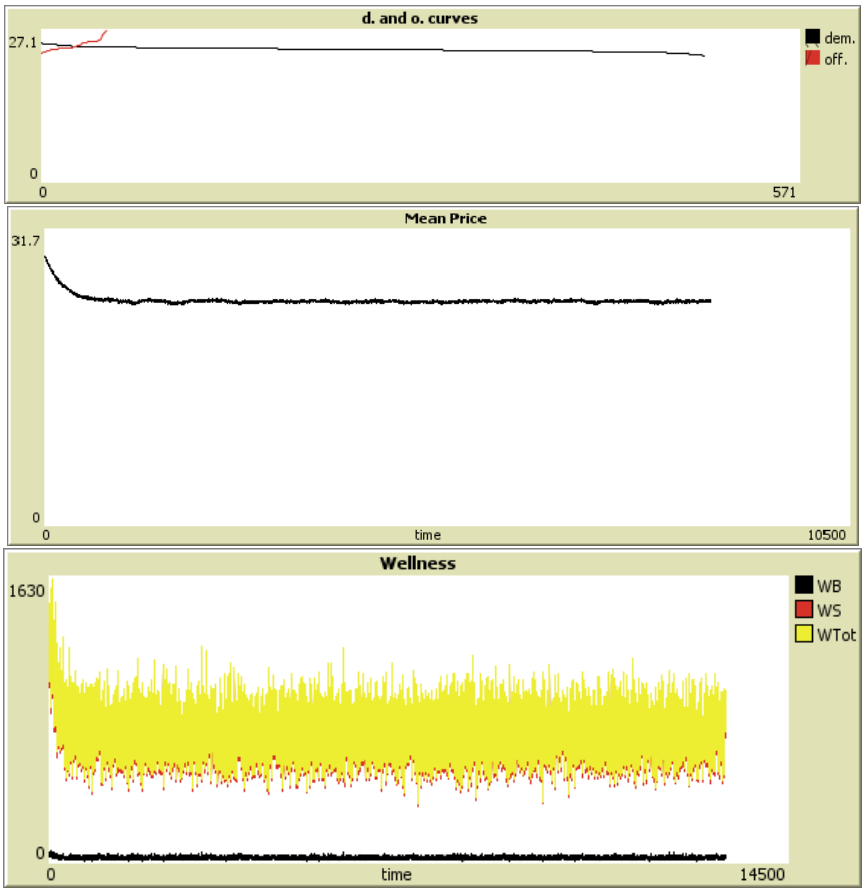

Figure 6: Case with same probability of changing P_{min} and P_{max} and a percentage of variation up to 20%. Wellness goes to a constant values, but buyers wellness falls to zero. Medium price grows

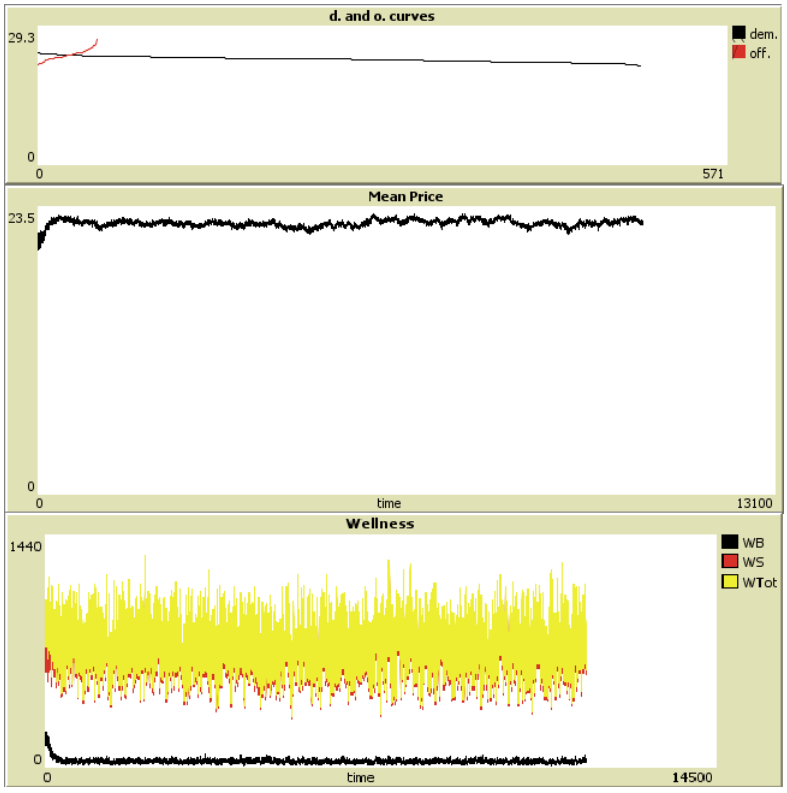

Figure 7: Case with $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{30}$ and a percentage of variation up to 20%. Wellness goes to a constant values, but buyers wellness falls to zero. Medium price grows

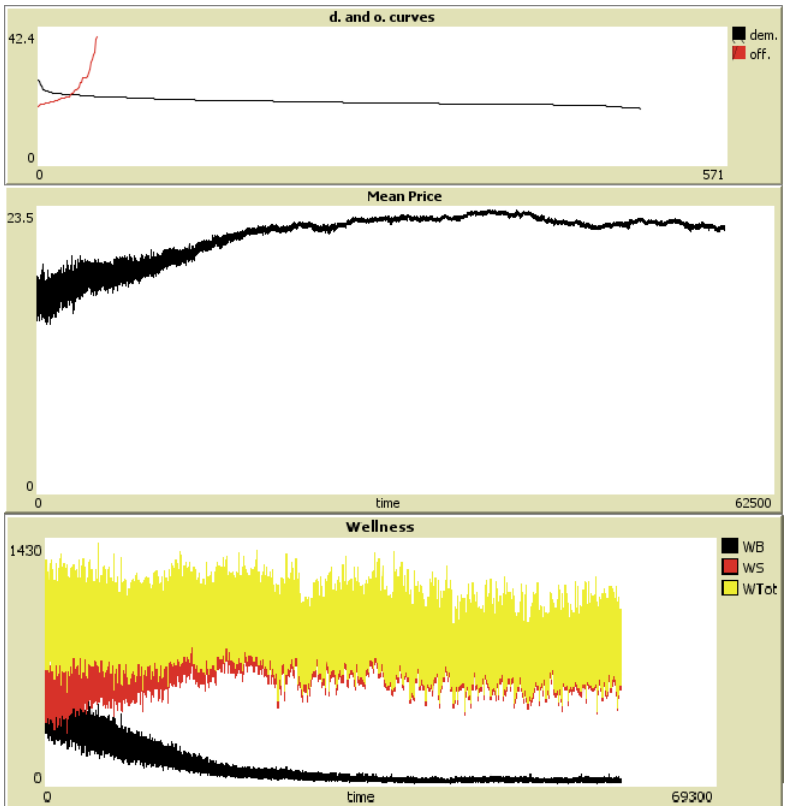

Figure 8: Case with $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{3000}$ and a percentage of variation up to 20%.Wellness goes to a constant values, but buyers wellness falls to zero. Medium price grows

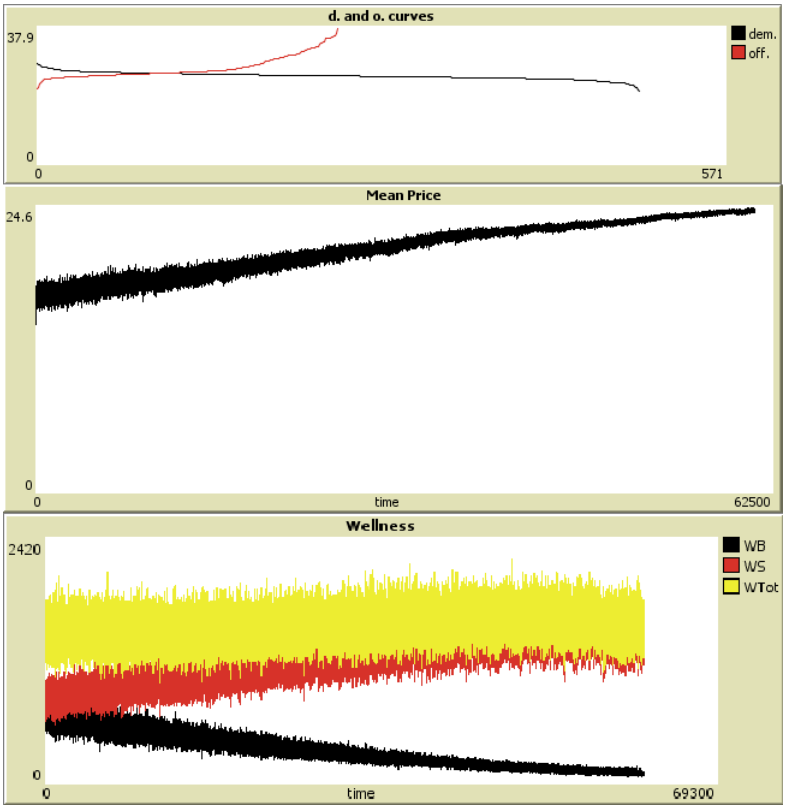

Figure 9: Case with $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{30}$. Number of buyers two times the one of sellers. Percentage of variation up to 20%. Wellness goes to a constant values, but buyers wellness falls to zero. Medium price grows

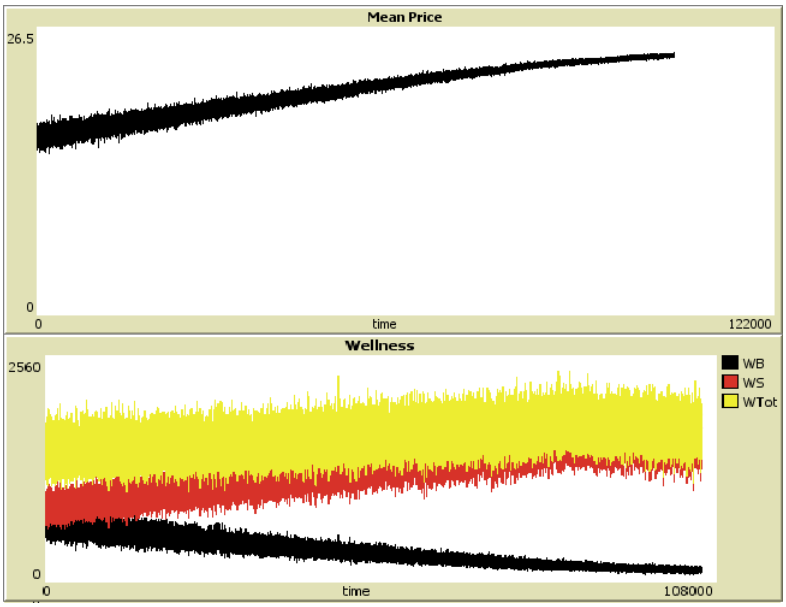

Figure 10: Case with $Prob_B = \frac{1}{3}$ and $Prob_S = \frac{1}{3000}$. Number of buyers equals the one of sellers. Percentage of variation up to 20%. Wellness goes to a constant values, but buyers wellness falls to zero. Medium price grows

We can see that, even if the buyers wellness falls slower with the growing number of buyers and stickyness of sellers prices, the trend is always the same and total wellness remains slower than the one with $Perc$ up to 100%. We can also see the evolution in time of bid and ask curves. We choose the one with same number of buyers and sellers because changes are more visible. The big initial area among them (related to the peack of wellness at the beginning) is due to the initial choises of P_{max} and P_{min}. It rapdly gets smaller and buyers curve tends to diminish its slope.

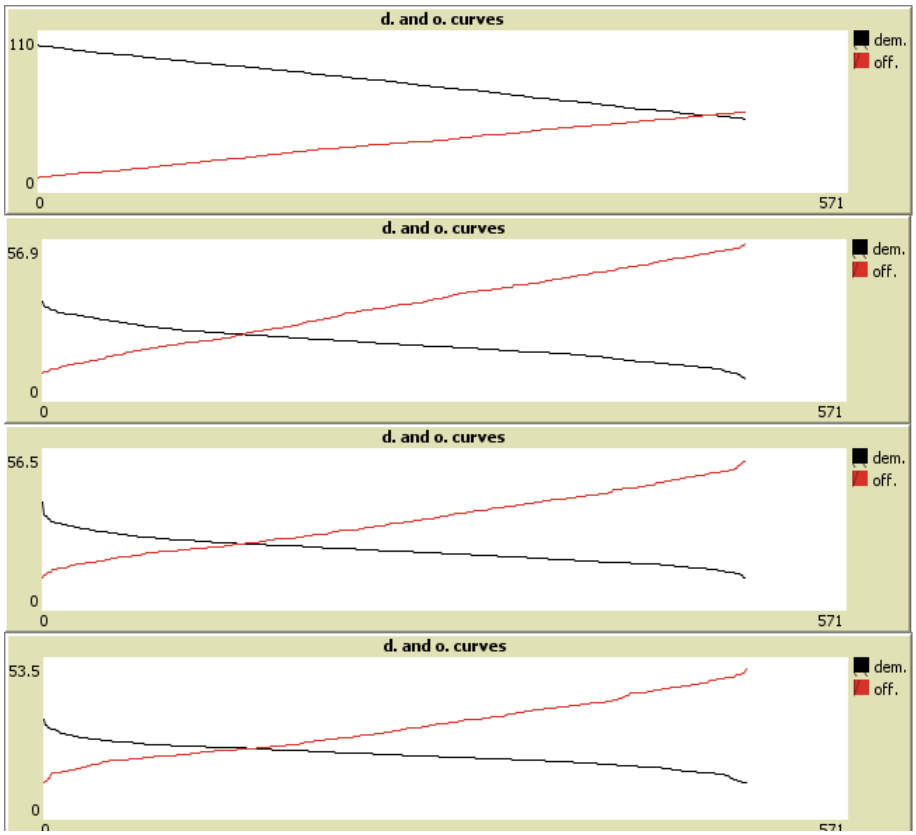

Figure 11: Evolution of bid and ask curves with $Perc$ up to 20%, $Prob_B = \frac{1}{3}$, $Prob_S = \frac{1}{3000}$ and same number of buyers and sellers. The big initial area among them (the peack of wellness) rapdly gets smaller and buyers curve tends to diminish its slope

This means that diminishing the interval of changing price, is predominant in respect to all other parametres. Probably because of asimmetry in the probability of increasing and diminishing sellers price (in increasing, the seller looks only at the price, in diminishing, it has to consider also the total cost. The price can not go under this value). Fluctuations can not repair the difference as happens in the case with $Perc$ up to 100%.

0.1.3 Asymmetric probability of increasing and diminishing prices

Infact, if we put probability of increasing seller price as $\simeq 0.0003$, the result is the opposite: we still have mean price and total wellness constant, but sellers wellness goes to zero. For sake of simplicity, we'll call $Prob_S$ of diminishing P_{min} $Prob_{S_D}$ and the one of increasing it $Prob_{S_I}$. We will do the same for $Prob_B$

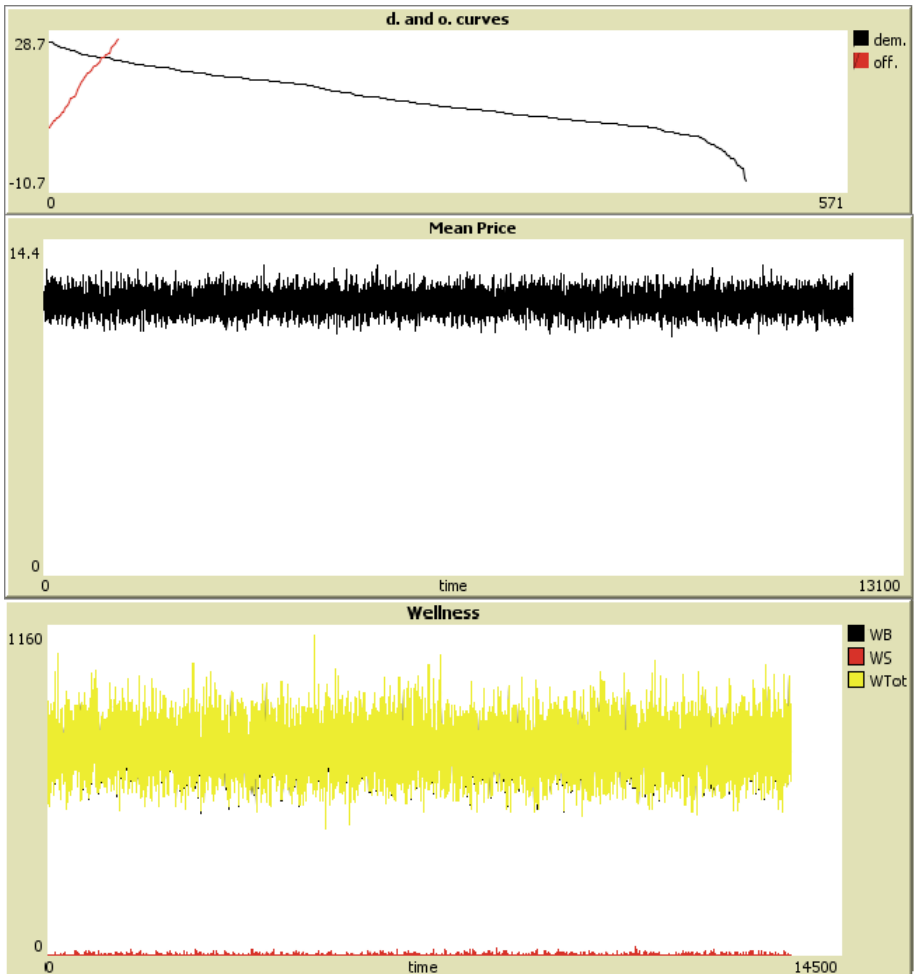

Figure 12: Case with $Prob_B = \frac{1}{3}$, $Prob_{S_D} = \frac{1}{3}$, $Prob_{S_I} = \frac{1}{3000}$ and a percentage of variation up to 100%. Wellness remains constant and both sellers and buyers curves follow the same constant trend. Sellers wellness goes to zero

On the other hand, trend changes completely if we put $Prob_{S_D} = \frac{1}{3000}$. We can see an exponential growth.

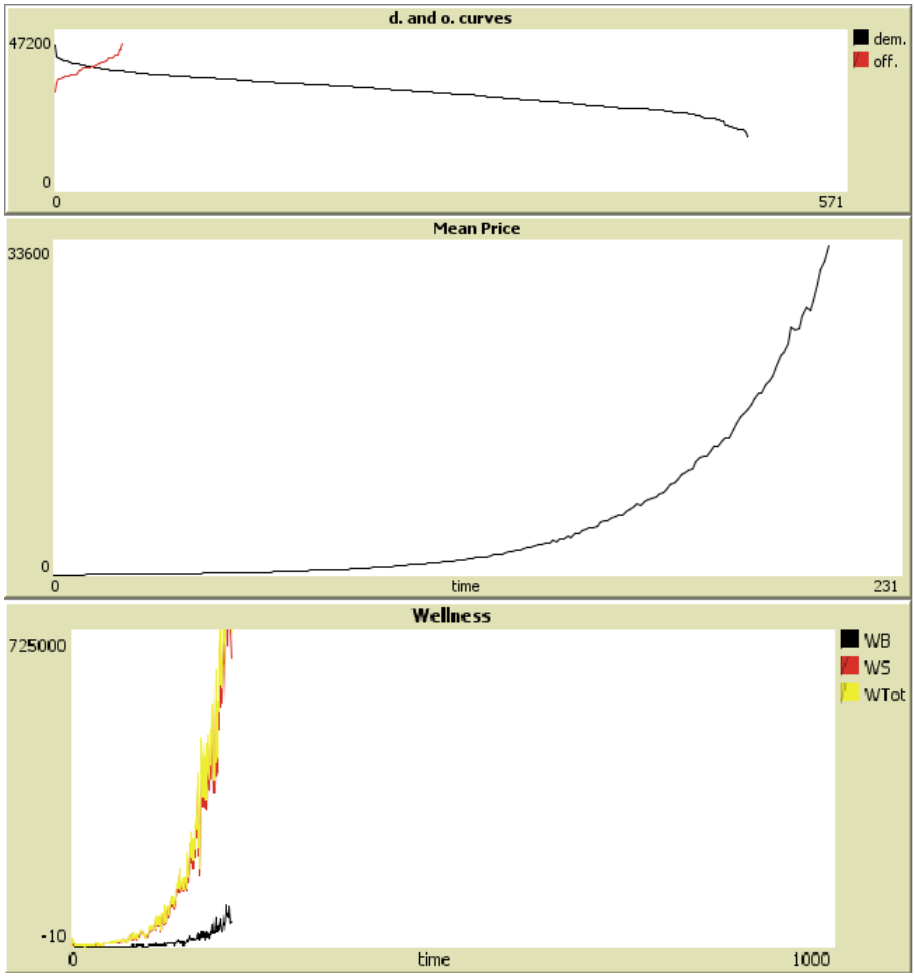

Figure 13: Case with $Prob_B = \frac{1}{3}$, $Prob_{S_I} = \frac{1}{3}$, $Prob_{S_D} = \frac{1}{3000}$ and a percentage of variation up to 100%. Both wellness and mean price have an exponential trend

We obtain a similar trend if we put $Prob_{B_D}$ very small, even if the growth is smaller. Of course, this case requires an infinite disponibility both of product (variable that we did not considered in our model) and sellers budget (which is not meant to grow with price in reality, but depends on salary and employment), which is quite unreal.

Another trend is obteined by making sticky $Prob_{B_I}$. The wellness and mean price fall to zero periodically because there are cycles in which nobody can exchange.

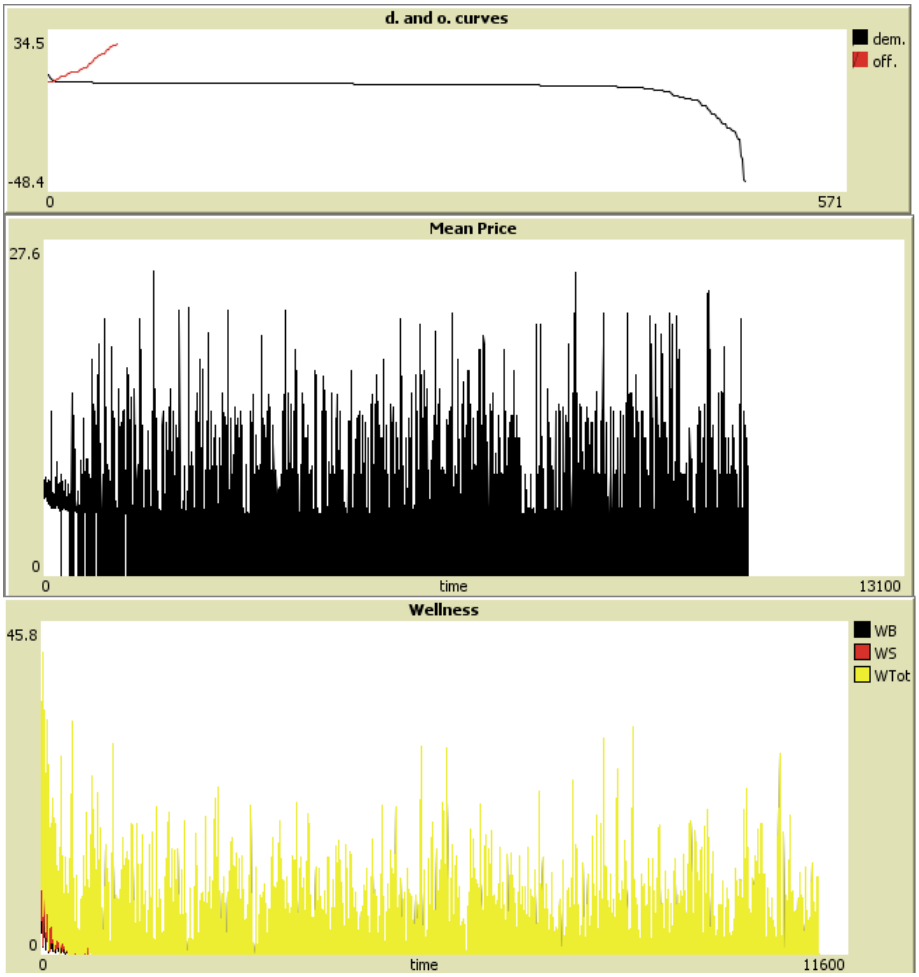

Figure 14: Case with $Prob_B = \frac{1}{3}$, $Prob_{B_D} = \frac{1}{3}$, $Prob_{B_I} = \frac{1}{3000}$ and a percentage of variation up to 100%. Wellness and mean price go periodically to zero

That means that if there is no possibility for the buyer to spend more in product, there will be periodic "crisis" (for example in case of unemployment or salary that do not increase with growing of prices).

0.2 Out of free trade: introduction of a tax

To avoid crisis, we try to add a tax on exachanges, to give an allowance to buyers who have a $P_{max} < MeanPrice$. In particular we apply a tax on the case similiar

to the one seen before. We have $Perc$ up to 100%, $Prob_B = \frac{1}{3}$, $Prob_{B_D} = \frac{1}{3}$ and $Prob_{B_I} = \frac{1}{300}$. Every time there is an exchange, seller wellness gets diminished by 15% of its value and, after every cycle (every one with is own mean price) the buyers with $P_{max} < MeanPrice$ gets their P_{max} increased by $\frac{MeanPrice - P_{max}}{2}$. We obtain

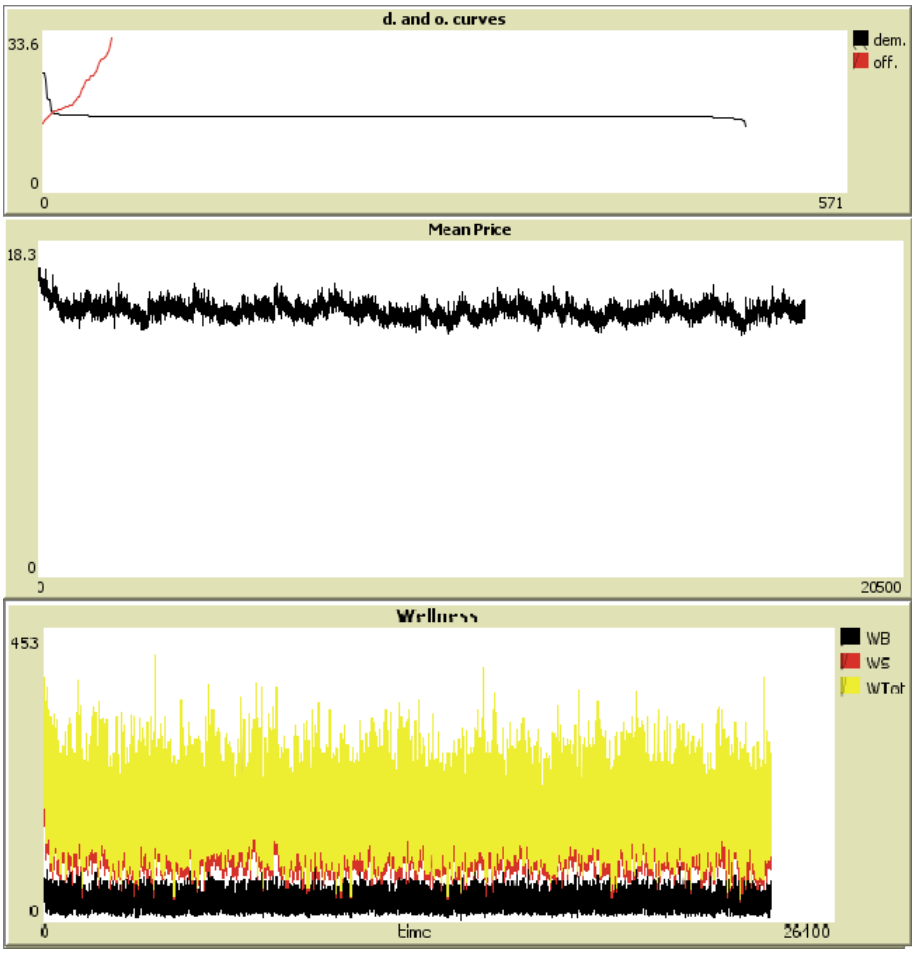

Figure 15: Case with $Prob_B = \frac{1}{3}$, $Prob_{B_D} = \frac{1}{3}$, $Prob_{B_I} = \frac{1}{300}$ and a percentage of variation up to 100%. Wellness and mean price do to a constant value different from zero

We can see how crisis do not go to zero, but they stay on a constant value and buyers wellness does not go to zero as it happened in free trade with $Perc$ up to 20%. Anyway, the ones who gain more wellness from the tax are the sellers.

Conclusions

We have seen the market in a world were agents can move and interact to buy or sell as in the mall.

In free market, in most cases mean price and wellness follow costant values in free trade. In particular, if there is symmetry in the probability of incresing and decreasing prices for both buyers and sellers. If there is a small asymmetry in how much we increase or decrease prices, total wellness follows a constant value, but buyers wellness falls to zero and mean price grows until this happens (then it follows a constant value). This is avoided if fluctuations of prices are enugh big and so buyers wellness does not fall. The most interesting case is in the asymmetry of increasing and decreasing. We founded exponential trend in cases in which buyers or sellers probability of decreasing prices was zero. Situation that requires infinite quantities of product and growing of salaries. The case in which buyers probability of increasing price is zero, creates periodic crisis.

To fix this situation we introduce a tax, going out of free trade. The tax is applied on sellers gain and allows to increase the smallest maximum prices. Market gets stable again.

Appendix

We report the code of the programmes we used [5]. The programming lenguage is NetLogo.

0.3 Code of market in free trade

Code 1: CODE CAPTION.

```
breed [buyers buyer]
breed [sellers seller]
buyers-own [maxPrice ProbB WB]
sellers-own [minPrice meanTotalCost WS]
globals [meanPrice price transactionNumber/10 Prob priceTot
             nEx HowManyS WBTot WSTot WTot ProbS i]

to setup

  clear-all

  create-buyers 500
  [set maxPrice random-float 50 + 50
     set shape "person"
     setxy random-xcor random-ycor
     ]

  create-sellers 50
  [set minPrice random-float 45 + 10
     set meanTotalCost (minPrice / 2)
     set shape "truck"
     setxy random-xcor random-ycor
     ]
  set nEx 0
  set priceTot 0
  set meanPrice 0
```

```
27    set i 0
28
29  plot_d&o
30
31    reset-ticks
32
33  end
34
35
36
37   to go
38    reset-ticks
39    moveB
40    interact
41    mediate
42    plot_d&o
43    setZero
44    tick
45  end
46
47  to moveS
48    ask sellers
49    [
50      while [count sellers-here > 1]
51      [ forward random 20
52        right random 360
53      ]
54    ]
55  end
56
57  to moveB
58    ask buyers
59     [
60     forward random 10
61     right random 360
62     ]
63
64  end
65
66
67  to interact
68    ask buyers
69    [
```

```
70      set HowManyS count sellers in-radius 3
71      if HowManyS > 0
72      [let sellingAg one-of sellers in-radius 3
73       set ProbB random-float 1
74       set ProbS random-float 1
75       set Prob random-float 1
76       let diff maxPrice - [minPrice] of sellingAg
77       ifelse diff > 0
78          [set nEx nEx + 1
79           set price [minPrice] of sellingAg
80           set priceTot priceTot + price
81           set WB diff
82           set WBTot WBTot + WB
83           ask sellingAg [set WS minPrice - meanTotalCost
84                                 set WSTot WSTot + WS]
85           set WTot WBTot + WSTot
86           if ProbB < 0.3333333333
87             [set maxPrice (price - Prob * (maxPrice - price))]
88               if ProbS < 0.3333333333
89                 [ask sellingAg [
90                  set minPrice (price + (Prob * (price / 3 )))]
91                  ]
92             ]
93
94          [if ProbB < 0.00033333333333
95            [set maxPrice (maxPrice + ( (-1) * Prob * diff )) ]
96             if ProbS < 0.33333333333
97              [ask sellingAg [
98               set minPrice ( minPrice -(Prob *
99                           (minPrice - meanTotalCost) / 3 ))]
100              ]
101         ]
102
103     ]
104   ]
105   set i i + 1
106 end
107
108 to mediate
109   set Prob random-float 1
110   if nEx > 0
111   [set meanPrice priceTot / nEx]
112
```

```
113 end
114
115
116
117 to plot_d&o
118
119   set-current-plot "d. and o. curves"
120   clear-plot
121   set-current-plot-pen "dem."
122   foreach reverse sort [maxPrice] of buyers plot
123   set-current-plot-pen "off."
124   foreach sort [minPrice] of sellers plot
125   if i > 200
126  [set-current-plot "Mean Price"
127   plot meanPrice
128
129   set-current-plot "Wellness"
130   set-current-plot-pen "WB"
131   plot WBTot
132   set-current-plot-pen "WS"
133   plot WSTot
134   set-current-plot-pen "WTot"
135     plot WBTot + WSTot]
136
137 end
138
139 to setZero
140
141   set meanPrice 0
142   set nEx 0
143   set HowManyS 0
144   set priceTot 0
145   set WBTot 0
146   set WSTot 0
147
148 end
149 to exportInterface
150
151 export-interface word date-and-time
152             " interactingBuyersAndSellers.png"
153
154 end
```

0.4 Code of market with tax

Code 2: CODE CAPTION.

```
1
2
3  breed [buyers buyer]
4  breed [sellers seller]
5  buyers-own [maxPrice ProbB WB]
6  sellers-own [minPrice meanTotalCost WS]
7  globals [meanPrice price transactionNumber/10 Prob priceTot
8               nEx HowManyS WBTot WSTot WTot ProbS i]
9
10 to setup
11
12   clear-all
13
14   create-buyers 500
15   [set maxPrice random-float 50 + 50
16      set shape "person"
17      setxy random-xcor random-ycor
18      ]
19
20   create-sellers 50
21   [set minPrice random-float 45 + 10
22      set meanTotalCost (minPrice / 2)
23      set shape "truck"
24      setxy random-xcor random-ycor
25      ]
26   set nEx 0
27   set priceTot 0
28   set meanPrice 0
29   set i 0
30
31 plot_d&o
32
33   reset-ticks
34
35 end
36
37
38
39  to go
```

```
40    reset-ticks
41    moveB
42    interact
43    mediate
44    plot_d&o
45    setZero
46    tick
47  end
48
49  to moveS
50    ask sellers
51    [
52      while [count sellers-here > 1]
53      [ forward random 20
54        right random 360
55      ]
56    ]
57  end
58
59  to moveB
60    ask buyers
61     [
62     forward random 10
63     right random 360
64     ]
65
66  end
67
68
69  to interact
70    ask buyers
71    [
72      set HowManyS count sellers in-radius 3
73      if HowManyS > 0
74      [let sellingAg one-of sellers in-radius 3
75       set ProbB random-float 1
76       set ProbS random-float 1
77       set Prob random-float 1
78       let diff maxPrice - [minPrice] of sellingAg
79       ifelse diff > 0
80          [set nEx nEx + 1
81           set price [minPrice] of sellingAg
82           set priceTot priceTot + price
```

```
          set WB diff
          set WBTot WBTot + WB
          ask sellingAg [set WS minPrice - meanTotalCost
                                        - (minPrice * 0.15)
                                set WSTot WSTot + WS]
          set WTot WBTot + WSTot
          if ProbB < 0.3333333333
            [set maxPrice (price - Prob * (maxPrice - price))]
              if ProbS < 0.3333333333
                [ask sellingAg [
                 set minPrice (price + (Prob * (price / 3 )))]
                 ]
            ]

         [if ProbB < 0.00033333333333
           [set maxPrice (maxPrice + ( (-1) * Prob * diff )) ]
            if ProbS < 0.33333333333
             [ask sellingAg [
              set minPrice ( minPrice -(Prob * (minPrice -
                    meanTotalCost - (minPrice * 0.15)) / 3 ))]
              ]
         ]

    ]
  ]
  set i i + 1
end

to mediate
  set Prob random-float 1
  if nEx > 0
  [set meanPrice priceTot / nEx
   ask buyers [
                       if maxPrice < meanPrice
                         [set maxPrice maxPrice +
                             ((meanPrice - maxPrice) / 2)]
                     ]
]

end
```

```
126 to plot_d&o
127
128   set-current-plot "d. and o. curves"
129   clear-plot
130   set-current-plot-pen "dem."
131   foreach reverse sort [maxPrice] of buyers plot
132   set-current-plot-pen "off."
133   foreach sort [minPrice] of sellers plot
134   if i > 200
135  [set-current-plot "Mean Price"
136   plot meanPrice
137
138   set-current-plot "Wellness"
139   set-current-plot-pen "WB"
140   plot WBTot
141   set-current-plot-pen "WS"
142   plot WSTot
143   set-current-plot-pen "WTot"
144     plot WBTot + WSTot]
145
146 end
147
148 to setZero
149
150   set meanPrice 0
151   set nEx 0
152   set HowManyS 0
153   set priceTot 0
154   set WBTot 0
155   set WSTot 0
156
157 end
158 to exportInterface
159
160 export-interface word date-and-time
161            " interactingBuyersAndSellers.png"
162
163 end
```

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