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Market Exchange Modelling Experiment, Simulation Algorithms, and Theoretical Analysis^{*}

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Résumé

Ce papier propose, sous forme d'un ensemble de logiciels, une analyse critique des modèles théoriques agrégés. Il s'agit de construire un modèle totalement désagrégé, lequel est ensuite validé par expérimentations, puis d'effectuer une comparaison entre les simulations agrégées et désagrégées. Le modèle désagrégé repose en effet sur un algorithme totalement analogique des comportements individuels ce qui rend possible sa validation par expérimentation. L'application présentée ici porte sur la formation des prix en concurrence imparfaite (absence de transparence) et l'expérimentation est proposée dans un contexte scolaire. Enfin, l'implémentation informatique de cette analyse permet, d'une certaine manière, de relancer le débat Mises-Hayek-Lange à propos du socialisme de marché.

Summary

The purpose of this paper is, through a system of software, to analyze some theoretical aggregate models. We suggest to build a disaggregated model to compare its results with these of the aggregated one. The disaggregated model uses an analogical mechanism of the individual behaviors so that a validation of it by experiments is possible. We apply the system to the mechanism of prices and we do experiments at school, which enable the Mises-Hayek-Lange debate to be reconsidered through the computer implementation of its system.

Mots-clés : Économie expérimentale, Modélisation, Simulation, Marché, Logiciels économiques

Key Words : Experimental Economics, Modelling, Simulation, Market, Economic Softwares

JEL Classification : B53, C15, C88, C90

0 - Introduction

Experimental method in economics is often presented as a complementary method for the econometric one. We don't use econometric one here, but we try¹ to combine three complementary analysis levels - see Fig.#1. At the first level we found an aggregated theoretical model, a disaggregated model is at second one. The third level is an experimental one (we built an exchange software)². Our purpose is to compare the results of a disaggregated model, which would be chosen by experiment, with the results of an aggregated one.

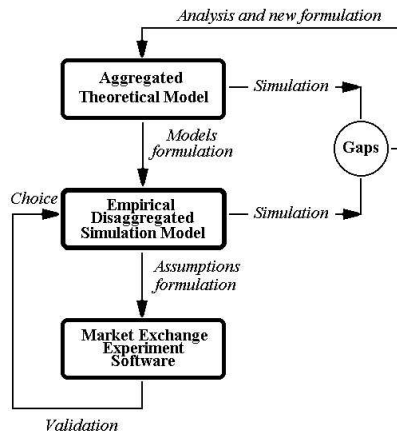


Fig.#1 - Theoretical, empirical, and experimental system

Because our disaggregated model is built according to an analogical process of exchange behaviors, we think that experimental methods are able to validate it³. Experiments help us to choose the right disaggregated model among a lot of potential one. When we examine general literature about algorithms⁴ (simulation or optimization one), we can observe that an analogical process is seldom used. If we except the commercial traveller, queue or dynamic programming algorithms, the differential criteria of the optimiza-

¹ - In a preliminary working paper for a macroeconomic Doctorate thesis (R.Buda, 1997), we examine the difficulties of the behavior equations and our temporary conclusion was that we have to formalize analogical equations. So, we have considered the aggregated level was not compatible with such a formalization.

² - We have built all the system with the language Turbo-Pascal 7.0.

³ - This reflection is born during the redaction of our Doctorate thesis (the main purpose of this thesis was to build a macro-econometric modelling software for multi-dimensional models, and so to study the relationship between algorithms and real behaviors in the markets). The idea was reinforced too by some teaching experiments in high school (R.Buda, 1998).

⁴ - The H.Scarf (1967) algorithm belongs to aggregated algorithms, but it is more applied than others one. It opens the way for Computable General Equilibrium Models.

tion algorithms (gradients, etc.) don't indeed describe the behavior of the economic agents.

We have applied here our method to the price mechanism. We assume a market with only one good (in the disaggregated model, but eight in the market experiment) without any production - agents are consumers, sellers, or dealers only⁵. In this paper, we'll describe the stages of the building of the system and some applications of the disaggregated model, but not experimental results yet⁶. We'll then be able to examine some theoretical problems (price mechanism, "market socialism").

1 - The Price Mechanism Theoretical Model

The new-classical model is based on the price mechanism. Under some assumptions, it describes pure and perfect competition. Here, we tried to build an algorithm to resolve an exchange problem and then, we tried to compare its results with the theoretical equilibrium results (in the case of a partial equilibrium).

Tab#1 - Total number list of buyers and sellers for each price

Total number Price	Total number of potential purchases	Total number of potential sales
P_0	A_0	V_0
P_1	A_1	V_1
P_2	A_2	V_2
\vdots	\vdots	\vdots
P_n	A_n	V_n

1.1 - Theory and Price Mecanism

The assumption we particularly examine, is the transparency one. Consumers and sellers are supposed rational. That means each consumer and

⁵- We'll have to leave this assumption, and we'll have to resolve a programming difficult ; with this assumption we are not able to consider the substitutions effect between goods.

⁶- The experiment with pupils at high school was delayed because of troubles with our network system.

seller (resp.) knows his maximum purchase price and minimum sale price (resp.) - we speak about "psychological price" in commercial management. They have access neither concerning difficulties nor costs, to the information necessary for their transactions. According to static analysis⁷, we assume that an auctioneer announces some prices until the number of demanders is equal to the suppliers on - "equilibrium". We often read in literature, that at each price some of them make a contract, but in the same time some others break their previous contract. Such a contract process is not right from a legal point of view⁸. Well, in the experimental method we consider the role of institutions. The behavior of auctioneer is one of "tâtonnement", that means he increases or decreases (resp.) the prices when he observes an excess of demand or supply (resp.). We assume we can obtain the level of each side of the market (Demand and Supply) by aggregation (with a simple addition). In fact, such an assumption implies that each agent is able to meet all the others.

1.2 - Price Mechanism and Algorithm

According to the new-classical model, we have built a first algorithm to calculate the equilibrium point of a market with one good. Our algorithm is simulating a kind of auction.

```

Inc:=Inc0;
MinDiff:=1.0E+30;
Price:=0.0;
i:=0;
Repeat
  i:=i+1;
  Price:=Price+MinPrice+Inc;
  Diff:=Abs(Supply[i]-Demand[i]);
  if (Diff<MinDiff) Then
    Begin
      Rank:=i;
      EquPrice:=Price;
    End;
Until (Price>=MaxPrice);
EquQuan:=Inf(Supply[Rank],Demand[Rank]);

```

Fig.#2 - Price mechanism algorithm

We don't keep the behavior pattern which we described at § 1.1 (increase and decrease movements with which auctioneer obtains equilibrium). We consider the auctioneer regularly increases ("english auction") prices from a

⁷- We don't speak about dynamic analysis (i.e. Cobweb algorithm), even if we can explain some cyclical phenomenon.

⁸- In fact, who's breaking contract must pay damages to the other side, because it is an unilateral breach - see by e.g. E.Gaudemet, *Théorie générale des obligations*, Paris, Sirey, 1937.

"bottom price". At each price, algorithm compares the number of demanders to the number of suppliers. In fact, we are not always able to reach perfect equilibrium (equality of the both sides total numbers). Hence, our algorithm considers that equilibrium is the point where the market minimizes the difference between both numbers - see Fig.#2⁹.

In fact, the market holds intrinsic social information - see Tab.#1. The new-classical model of pure and perfect competition asserts that this information is revealed by an auctioneer process (auctioneer, advertising, etc.), so that no transaction can take place outside the equilibrium. We know, with the result of experimental economics, there are a lot of transactions outside equilibrium point without any auctioneer process. Moreover, there are two grounds on which to consider a disaggregated scale of analysis. First, the conditions of validity of the Brower theorem (the continuity of the functions) are not filled - there is not always a price between two successive prices. Secondly, the Sonnenschein's theorem about the aggregation restriction¹⁰ lead us to examine the market mechanism before any data aggregation.

2 - An Empirical Disaggregated Model - SINGUL

SINGUL is a imperfect competition market (without any auctioneer process) price and quantity calculation model. Its algorithm is analogical because it is built from the most realistic (as possible) behavior of the agents of a market. Our model simulates the meeting between the agents. Each agent is able to meet a limited number of other agents¹¹, and doesn't know the whole information about his market¹². He is able, in a price interval, to negotiate prices to make them increase or decrease (resp.) if he sells or buys (resp.) the good.

⁹- Where $Inc_0 = \text{Price Increment between MinPrice and MaxPrice}$. $Diff = \text{Absolute difference between Supply and Demand at the } i\text{th rank}$. We keep temporary the price in EquPrice (Equilibrium Price) if Diff is less than MinDiff. As soon as we reach MaxPrice, the equilibrium quantity (EquQuan) become equal to the smallest value between Supply(rank) and Demand(rank).

¹⁰- H.Sonnenschein, "Do Walras Identity and Continuity Characterize the Class of Community Excess Demand ?", *Journal of Economic Theory*, N°6, 1973.

¹¹- Even if agent uses new communication tools, this number of contacts is not proportional to the size of the market - see M.Polanyi (1951, in french edition 1989, pp.148-77). The limitation is not a technical one but a physiological one.

¹²- See F.A.Hayek (1976, in french edition 1981, pp.129-59).

2.1 - Description of the Basic Model

SINGUL is a very short period model with only one good. The agents can't stock quantity of this good over the level they indeed need. So, they can't speculate. SINGUL simulates the behavior of the N total number of agents. For each agent SINGUL calculates¹³ the initial patrimony (1), initial present stock (2), wished stock¹⁴ (3), "mind price"¹⁵ - it's a kind of hidden price : if the agent wants to buy the good, he won't pay more than a maximum price ; if the agent wants to sell the good, he won't to be paid less than a minimum price - (4) and (5), and the negotiation margin which determines the interval of transaction.

$$Patrim_i^t = \overline{Patrim_i^0} \quad (1)$$

$$Stock_Courant_i^t = \overline{Stock_Courant_i^0} \quad (2)$$

$$Stock_Desire_i^t = \overline{Stock_Desire_i^0} \quad (3)$$

$$Prix_Max_i = \overline{Prix_Max_i} \quad (4)$$

$$Prix_Min_i = \overline{Prix_Min_i} \quad (5)$$

$$Marge_i = \overline{Marge_i} \quad (6)$$

The i -th agent meets a total number of P_i other agents. Their ranks are selected by random choice among $N - 1$ ranks. The i -th agent negotiates the price of one unit of the good. At the beginning of the simulation, if the difference $\Delta_i^t = Stock_Courant_i^t - Stock_Desire_i^t$ is negative, positive (resp.) then the agent is seller, buyer (resp.). When the difference becomes equal to zero, then the agent leaves the market.

During the negotiation (9,10) between the two agents i -th and j -th, they won't be motivated with the same strength. One of the both agents, who has got the greater difference (Δ^t), will accept the price condition of the other agent more easily. But the conclusion of transaction happens only if the price belongs to both negotiation intervals (12 to 17). Neither agent knows the negotiation margin of his partner.

$$\Delta_i^t = Stock_Courant_i^t - Stock_Desire_i^t \quad (7)$$

$$\Delta_j^t = Stock_Courant_j^t - Stock_Desire_j^t \quad (8)$$

$$\alpha_{i,j}^t = \frac{|\Delta_j^t|}{|\Delta_i^t| + |\Delta_j^t|} \quad (9)$$

¹³- We use sometimes pseudo-random procedures.

¹⁴- It's a kind of cardinal utility index. For J.C.HARSANYI (1956), cardinal utilities are better than ordinal one, in the bargaining mechanism analysis.

¹⁵- Each agent is exclusively buyer or seller during a simulation session.

if

$$Prix_Max_{Acheteur} < Prix_Min_{Vendeur}$$

then

$$Prix_{i,j}^t = \alpha_{i,j}^t \cdot Prix_i^t + (1 - \alpha_{i,j}^t) \cdot Prix_j^t \quad (10)$$

else

$$Prix_{i,j}^t = \psi \cdot Prix_i^t + (1 - \psi) \cdot Prix_j^t \quad (11)$$

$$\psi = 0$$

or

$$\psi = 1$$

$$Prix_i^t \cdot (1 - Marge_i) \leq Prix_{i,j} \quad (12)$$

$$Prix_j^t \cdot (1 - Marge_j) \geq Prix_{i,j} \quad (13)$$

$\Delta_i < 0$ (i buyer) and $\Delta_j > 0$ (j seller)

$$Prix_i^t = Prix_Max_i \quad (14)$$

$$Prix_j^t = Prix_Min_j \quad (15)$$

$\Delta_i > 0$ (i seller) and $\Delta_j < 0$ (j buyer)

$$Prix_i^t = Prix_Min_i \quad (16)$$

$$Prix_j^t = Prix_Max_j \quad (17)$$

We have considered too that, sometimes the price order was not a normal order - i.e. the minimum price of the seller is less than the maximum price of the buyer. In this case, we assumed that only one of the two agents (he is randomly chosen) understands that the price order is abnormal. So he agrees with the price condition of the other, because it's more interesting for him than his own. This case could lead us to examine later the negotiation under the ultimatum game point of view¹⁶.

Thus, in the basic model, the agents try to reach a "level aim", (increase or decrease their good stock level) under constraints (BuyerMaxPrice, Seller-MinPrice and NegotiationMargin)¹⁷. During a simulation session, we assume

¹⁶ There is a relationship between negotiation and discrete representation of agent in an economy - see J. Neumann (Von), O. Morgenstern, *The Theory of Games and Economic Behavior*, New Jersey, Princeton UP, 1944. About experimental games and ultimata, see J. Ochs et A. Roth (1989).

¹⁷ We have replace the program *MaxU* under income constraints with the program *Min|S_c - S_d|* under income constraints - *S_c* and *S_d* (resp.) for present stock and wished stock (resp.). M. Abdel-Fadil (*La planification des prix en économie socialiste - essai méthodologique*, Paris, PUF, 1975) used level stocks information in a centralizing program because prices didn't exist on the supply side. For a price model survey, see R. Courbis (1977) too.

one agent can meet enough other agents to reach his aim and to leave the market - see algorithm in Fig.#3.

```

i:=0;
Repeat
  i:=i+1;
  Initializing;
  Patrimony;
  WishedStock;
  PresentStock;
  SellerMinPrice;
  BuyerMaxPrice;
  Status (Supplier vs Demander);
  NegotiationMargin;
Until (i>=Total_number);

Time:=0;
Repeat
  Time:=Time+1;
  i:=0;
  Repeat
    i:=i+1;
    Partner rank choice;
    j:=0;
    Repeat
      j:=j+1;
      Partner:=Partner[j];
      Compatibility Test (Supplier vs Demander);
      If (Compatibility) Then Negotiation of price;
      If (Price belong to margin) Then Conclusion;
    Until (Partner[j]>=Max_Partner);
  Until (i>=Total_number);
Until (Time>=Horizon);

```

Fig.#3 - Random transactions calculation algorithm

2.2 - Some Variants of the Basic Model

If we leave the level aim assumption, we can admit that the i -th agent tries to choose the best partner (the cheapest seller or the most generous buyer) among all of the P_i agents he has met. The agents try to reach a "price aim". In such a case, we need more periods of simulation than in the first one.

During simulation, i -th agent meets P_i partners (their rank is selected by random choice) and he makes a classification from the best to the worse¹⁸. If the j -th agent is selected by i -th, the transaction will be concluded only if in the mind of the j -th agent, the i -th agent is his best partner too¹⁹. We have to consider a symmetric relationship (i, j) and (j, i) to avoid being paradoxical : with a total random procedure we would obtain that i would meet j but j wasn't met by i . So we have used a contiguity matrix²⁰ - see Fig.#4. That

¹⁸- In *Production of Commodities by Means of Commodities* (Cambridge UP, 1960), P.Sraffa assumed through a new-ricardian analysis, that consumers make classification of the sellers.

¹⁹- The have to simulate a symmetric relationship We have used a contiguity matrix to record the relationship (i, j) and (j, i) to organize comparisons on the both sides.

²⁰- Such mathematical tool is used in regional economics to respect borders constraints - see J.R.Boudeville, *Aménagement du territoire et polarisation*, Paris, M.T.Génin, 1972, pp.46-54, or H.Jayet, *Analyse spatiale quantitative*, Paris, Economica, 1993, pp.7-9.

matrix is used to keep classification too. So prices are reservation prices ; they become real prices if the couple (i, j) is optimal for both sides. Then both agents leave the market temporarily during the other negotiations.

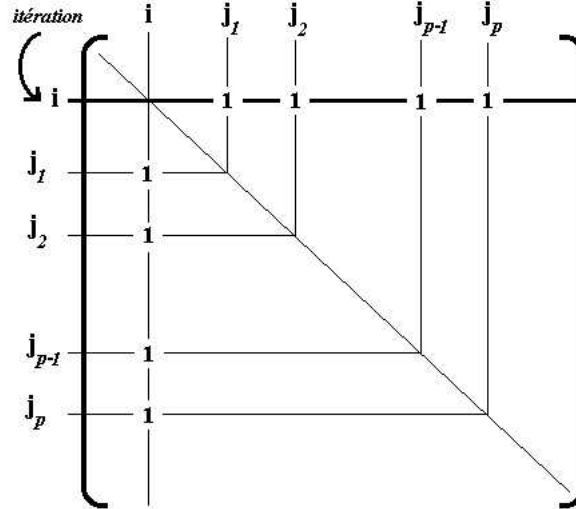


Fig.#4 - Contiguity and transactions matrix structure²¹

The exchange system is solved at the first level, when all the couples of agents i and j , who have drawn up contract are so that i has chosen j at first and j has chosen i at first. We write the couple is a $(1,1)$ one. But we can solve the exchange system on a second level too. That means that we keep first all the couples $(1,1)$, and then all the couples $(1,2)$ & $(2,1)$. We solve the exchange system on a third level, when we keep the $(1,1)$, then $(1,2)$ & $(2,1)$, and at last the $(1,3)$, $(3,1)$, $(3,2)$, $(2,3)$, $(3,3)$ couples. We can solve the system until the P_{i^h} level, but the agents who drawn up contracts at such a level are less useful than those who have found partners at the first level²².

The following equations of the model are :

$$Prix_{i,j}^t = \inf_{P_{i-r}}^{h=1} (Prix_{j,h}^t) \quad (18)$$

$$Prix_{j,i}^t = \sup_{P_{j-r'}}^{k=1} (Prix_{i,k}^t) \quad (19)$$

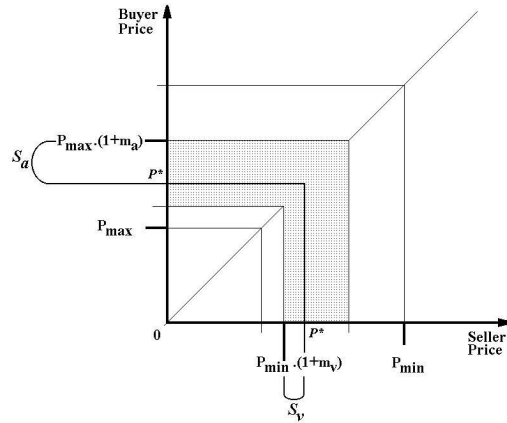
²¹- As we select the rank of the P_i partenaires of the i -th agent, we put the number 1 at the row of the partner at i -th line and, in the same time, we put the number 1 at the i -th row at the partner line. We put the number 0 elsewhere.

²²- That means too that these agents was perhaps to much demanding.

$$r = \begin{matrix} Rang(j) \\ \in \mathcal{C}_i \end{matrix} \quad (20)$$

$$r' = \begin{matrix} Rang(i) \\ \in \mathcal{C}_j \end{matrix} \quad (21)$$

where the i -th price (a reservation price) is the best that the P_i partners have proposed to him at level r (r' for seller) - i and j belong to a (r, r') couple. However, after one period, some agents don't find a partner because of their best price aim. So, we have assumed that they make their transaction conditions weak. We examine two cases : 1° - they make their negotiation margin weak ; 2° - they increase their partners number (P_i), it means they buy information - see the algorithm at Fig.#5.



Chart#1 - Satisfaction interval during price negotiation²³

To analyze the results at the end of simulation, we have tried to define a welfare index for each agent. If an agent has found a partner, we have considered that he could reach two extreme kinds of situation. We can admit the following convention. If the transaction price P^* is just at the border of his negotiation margin price - m_a or m_v (resp.) if he is buyer or seller (resp) -, then his satisfaction is minimal. If P^* is just equal to his own mind price - BuyerMaxPrice or SellerMinPrice (resp.) if he is buyer or seller (resp) - then his satisfaction is maximal²⁴.

²³- This Chart is analogous to the chart of utilities in the bargaining analysis. We can observe that this analysis was more interesting by utilities than the price movements through the bargaining mechanism - see e.g. A.Coddington (1968).

²⁴- We consider here the case of normal order prices.

when i is buyer

$$S_i = 1 - \left(\frac{Prix_{i,j}^t - P_0}{P_{100} - P_0} \right) \quad (22)$$

$$\text{with } \begin{cases} P_{100} = Prix_Max_i \\ P_0 = Prix_Max_i \cdot (1 + Marge_i) \end{cases} \quad (23)$$

when i is seller

$$S_i = \left(\frac{Prix_{i,j}^t - P_0}{P_{100} - P_0} \right) \quad (24)$$

$$\text{with } \begin{cases} P_{100} = Prix_Min_i \\ P_0 = Prix_Min_i \cdot (1 - Marge_i) \end{cases} \quad (25)$$

with $i = 1$ to N and $j = 1$ to P_i .

We have defined the Satisfaction index²⁵ S_a or S_v (resp.) of the buyer or the seller (resp.) as the difference between P_* and mind price divided by the difference between mind price increased or decreased (resp.) with negotiation margin - see Chart#1 and equations (22 to 24).

```

i:=0;
Repeat
  i:=i+1;
  Initializing;
  Patrimony;
  WishedStock;
  PresentStock;
  SellerMinPrice;
  BuyerMaxPrice;
  Status (Supplier vs Demander);
  NegotiationMargin;
Until (i)=Total_number);

Time:=0;
Repeat
  Time:=Time+1;
  Contiguity matrix building;
  i:=0;
  Repeat
    i:=i+1;
    j:=Partner_1
    Repeat
      Compatibility Test (Supplier vs Demander);
      IF (Compatibility) Then Negotiation of price;
      IF (Price belong to margin) Then Conclusion;
      j:=j+1;
    Until (j)=Max_Partner);
    Partners Classification according to the price;
  Until (i)=Total_number);

k:=0;
Repeat
  k:=k+1;
  If (rank<k for the couple (i,j)) Then
    Debut
      Conclusion;
      Exit of i and j from market;
    Fin;
  Until (k)=Partenaire_max);
Until (Time)=Horizon);

```

Fig.#5 - Best price transactions calculation algorithm

²⁵- About this point, J.Marçal (1969, pp.109–13) speaks of "rente du consommateur" (vs "producteur").

In Appendix 6.3 we can find the cohesion tests about the behavior simulation. The next part describes the method we'll want to use to validate the SINGUL model. The solution of the SINGUL model is not an aggregated one, so we have to use a disaggregated tool - the experimental one.

In fact, we consider, the theoretical modelling tries to get endogenous most variables of a phenomenon, and on the contrary, experimental method tries to get them exogenous (it's even an interactive exogenezation one).

3 - Market Experiments with the "ÉCHANGE" Software

Market experiment - as false or real situations where some agents are playing goods supplier and demander games - has existed for a long time - let's think about the financial markets, the fish market auctions, etc. The ECHANGE software we'll present now, explores the imperfect competition problem²⁶.

3.1 - The Experimental Way in Economics

The experimental method is born because on the one hand, economists attempted to abandon perfect assumptions of competition market, and on the other hand, the game theory was applied to economics and management²⁷. We can observe that experimental method has taken place in the teaching context too²⁸ - or firms game context²⁹. The background game is often a microeconomic one, but we can imagine a macroeconomic one too³⁰. With such software, the pedagogical advantage is to show the mechanism of economic models to the pupils, and the experimental advantage is to collect data about economic policy decisions³¹ (R.Buda, 1998).

²⁶- One of the main problem already examined by the experiment pioneer : E.H.CHAMBERLIN, in "An Experimental Imperfect Market", *Journal of Political Economy*, 56, 1948, pp.95-108.

²⁷- O.Morgenstern examined the problem of the experiment in economics - see A.Schotter (Ed.) (1976).

²⁸- The *Journal of Economic Education* has published some experimental teaching papers : R.B.Williams, Y.De Young & J.M.Leuthold in 1993 ; N.Netusil & M.J.Hauptert in 1995 ; M.J.Hauptert in 1996. See in French literature F.Gagey & P.Rey (1986).

²⁹- MIT has developed some management simulation softwares - see e.g. A.E.Amstutz (1967).

³⁰- By e.g., in the French literature see M.Pariset & J.M.Albertini, (*Jeux et initiation économique*, Paris, CNRS, 1980) or M.Berthot & S.Guillaumont-Jeanneney (*Trois jeux informatiques de politique économique*, Paris, Cujas, 1977) ; in the English literature see M.Binks & A.Jennings (*Macroeconomics in focus*, London, McGrawHill, 1986) who examines rational expectations.

³¹- We collect data about the question "what would you do if you were chancellor ?".

The experimental data³² has got interesting characteristics to lead a "*ce-teris paribus*" analysis, but we have to make some corrections³³ before any interpretation. It does exist an analogy but no identity between reality and experiment. It becomes possible to lead a double complementary method (econometric and experimental one)³⁴. However, in our system (see Fig.#1), there is no econometric procedure. The experimental software organizes exchanges and collects data to help disaggregated model choice.

According to V.L.Smith (1989), the choice of environment and institutions by the economists is the main advantage of experiment in comparison to the econometrics method. The experimental protocol is defined by five principles : 1° - insatiability - the utility function of each agent is a monotonous function of his gains ; 2° - prominence - the gains of each agent depend on the actions of the other ; 3° - dominance - the reward motivates each agent ; 4° - secret - each agent only knows his owns information ; 5° - parallelism - laboratory institution has to look like the real world we try to represent.

3.2 - Description of an Experimental Economics Software - "ECHANGE"

ECHANGE software can (will be able to) run under two modes on a network system. The teacher e.g., can lead the system with the pilot mode and his pupils (or students) use operator mode - see Fig.#6 - but the pilot is not an auctioneer.

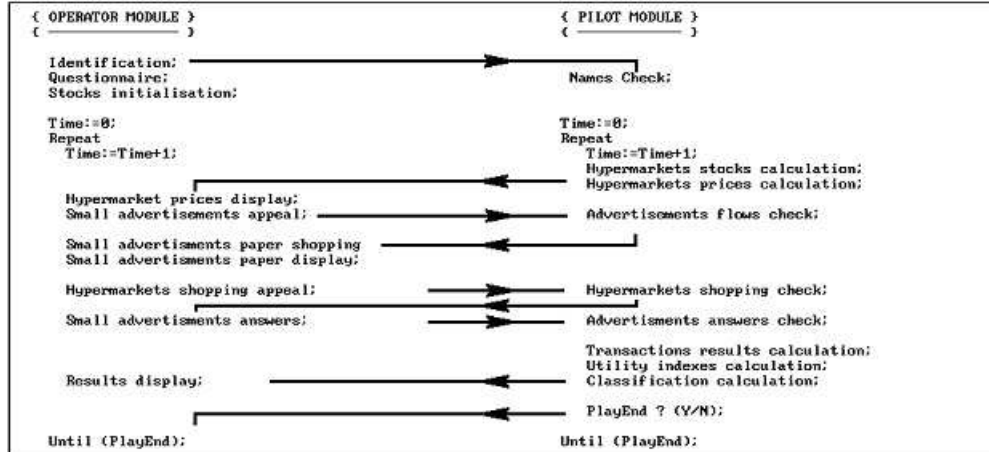


Fig.#6 - ECHANGE software algorithms

³²- The data we obtain in situ are called field-happenstance-data ; the other are the laboratory-happenstance-data.

³³- It exists some econometric procedures to obtain better data (R.Deloche, 1995).

³⁴- We can correct specification mistake. About a general point of view, see O.Morgenstern (*op.cit.*). See R.J.Lalonde (1986) too.

ECHANGE software simulates the transactions : the operator nor really buys the goods neither do these goods really exist. The exchanges take place over a short period (we assume a daily period) and the goods have been chosen among the leisure of the pupils - parallelism principle - see Fig.#7. Each operator exists for the other one through his advertisement(s). At each period, the operator can write advertisements and/or answer to one (to buy and/or sell), and/or buy goods at hypermarkets. They have to pay for information (advertisements, hypermarket prices) - principle of secret. We have used the hypermarkets to give a reference price of the goods - parallelism principle. At each period, ECHANGE simulates hypermarkets out of stock, very early - we want to avoid operators only buying at hypermarkets - principle of parallelism too. The goal of each operator (pupils) is to maximize his utility (in buying or selling some goods) with his liquid assets. Before the exchanges, each operator answers to a questionnaire to define his utility function (proportions of goods to hold at each period). Initial dotations of goods are calculated to present an excess quantity of one good, so that all operators would be sellers of one good, at least. There is no point in the operators speculating because they don't realize their periodical aim - prominence principle. ECHANGE software calculates the classification of the operators at each period - insatiability and dominance principles -, and at the end of game - it considers the final level of liquid assets too.

3.3 - The Perspectives with "ECHANGE" software

We'll are able to collect some important data (prices, levels, periodicity of some behavior, compatibility aims and decisions, information purchases, hypermarket purchases, etc.). One of the problems which could happen is the use of advertisements. The operators will think easily of writing advertisements for sales, but they don't think of writing when they want to buy. This problem would imply some difficulties collecting buyers prices. If we don't have both side's prices, the comparison with models would be impossible. It will probably be impossible to observe a "best price search" behavior, because operators are constraint to have a quantity level aim. Another problem is to allow the operator to choose among the partners who answer to him by an auction - it's just a programming problem. In a next release of ECHANGE, we could implement a free rider procedure - after a transaction, one of the operators obtains some more money. We could ask the operator what be the prices are they expect for the goods for the next period. The main goal of the interpretation of data will be to calculate the gap in the equilibrium ; it will be more difficult to estimate the "mind prices", the negotiation margins and the partners classification behaviors of the operators.

4 - Market, Planning, and Calculation: a Temporary Conclusion

When we are writing this paper, the experiment is not applied to choose a good version of the disaggregated model SINGUL. We are not able to conclude either the comparison or about the experiment but we hope from it, to know more about information search behaviors and the market coordination assumption. We know the transparency assumption is a controversial point. For new-keynesians R.W.Clower & A.Leijonhufvud³⁵, the agents make non optimal decisions because of a lack of information. For F.A.Hayek on the contrary, there is a coordination between agents in the market because nobody knows the "whole information" ; so agents look for a partner who is able to give him complementary information³⁶. However, we can present some reflections about the building of economic algorithms (especially analogical ones) and their properties in representing economic reality. When we have to build a disaggregated model, there are new problems we don't have to resolve in comparison to aggregated ones³⁷. The exactness of the method depends on the solution of such a problem³⁸.

Our system only presents exchange models (without production), but we can reconsider here the Mises-Hayek-Lange debate³⁹. With all necessary information and a very efficient computer, is a Planning administrator able to take place of each agent to calculate their optimal decisions - L.Mises explains us it's impossible and for F.A.Hayek, he is necessarily inefficient ? So O.R.Lange proposed decentralizing planning⁴⁰ which controlled only in-

³⁵- "The Coordination of Economic Activities", *American Economic Review*, Vol.65, 1975, pp.182-88.

³⁶- The coordination assumption is a controversial point even in Austrian economics school - see M. Rothbard, *The Ethics of Liberty*, Humanities Press, Atlantic Highlands, 1982.

³⁷- At the level of an aggregated firm we don't have to check all the relationships between all agents to be sure the system is coherent. We assume the necessarily relationship exist. At the disaggregated level we have to check all the relationships. In national account first, we work with aggregated data and we use some black boxes (by e.g. the "comptes écrans") to simulate the market relationship. Secondly, the national account has not got the same properties like double-entry firms accounts - see O.Arkipoff, "Importance et diversité des problèmes d'agrégation en Comptabilité nationale", in E.Archambault & O.Arkipoff (EDS), *La comptabilité nationale face au défi international*, Paris, Economica, 1990, pp.365-81.

³⁸- See the macro-account building of M.Allais (1954).

³⁹- See L.Mises (Von) (1935), F.A.Hayek (Von)(Ed.) (1935), O.R.Lange (1967) and "On the Economic Theory of Socialism", *Review of Economic Studies*, N°4(1-2), 1936-37, Reprint 1967.

⁴⁰- O.R.Lange (1970) has worked on economics control with a cybernetical point of view

intermediate goods but the real problems of planning were never resolved⁴¹. Because, without any prices, these economies can't find their optimal situation, moreover, the agent keeps the information (F.A.Hayek (Ed.) (op.cit.)) to keep their power - even with decentralized planning. In fact, sometimes, when one agent has to make a decision, his behavior depends on his environment. If something was different in his environment, perhaps he have made another decision. The fundamental problem is if we want to replace agent's behavior (with planning), we try to replace some contingent actions by a few necessary procedures. For E.Barone (1908), it's useless to calculate the exchange solution that we can obtain easily by the market mechanism without any calculation. Another point we can examine when we build algorithms is the arithmetical one⁴². Let's assume a planning administrator who has access to all necessary information - it would be not enough even if the agent gave their mind prices⁴³. Let's assume - with the SINGUL model - that the population of an economy is 1,000,000, the number of different goods is 1,000, then the number of negotiations would be 1013 (with 100 meetings for each agent), and 1021 (if each agent meets the other). Two problems occur : 1° - the calculation duration is one month (with a 1 GHz processor) ; 2° - the overflow of the twenty digits computers so we loose the accuracy of the calculation⁴⁴. We know that it's possible to correct the accuracy problem, but we use more calculation time. Moreover, it is not necessarily more interesting to organize a general meeting (each agent meets the other), because in this case the number of meetings will reinforce the bad position of the less interesting agents toward his partners (they can better make comparisons). When we'll collect and we'll analyze data and then results, we'll have to remember these last reflections. A quantitative tool, especially a scientific one, is useful as soon as we know its limits.

too. About decentralizing planning algorithms, see P.Picard, *Procédures et modèles de la planification décentralisée*, Paris, Economica, 1979.

⁴¹- Programming technicals have make progress with the work of L.V. Kantorovitch, but not the socialist planning.

⁴²- O.Morgenstern (1950) speaks about calculate accuracy, the heavy quantity of equations to formalize and to resolve exchanges just for a very little economy. L.Robbins (*The Great Depression*, London, Macmillan, 1934) speak about one million equations, F.A.Hayek (Ed.)(1935, op.cit.) about a hundred millions.

⁴³- See the conclusion of X.Freitas (1978).

⁴⁴- See our working paper about the GNOMBR software (R.Buda, 1996) - e.g. we loose accuracy from 20! calculation. we use an accuracy of 2500 digits. See M.Daumas & J.M.Muller (Eds), *Qualité des calculs sur ordinateurs - vers des arithmétiques plus fiables ?*, Paris, Masson, 1997, 164 p.

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6 - Appendix

6.1 - Check Screen of the Program "ECHANGE"

```

ECHANGE 1.0 - LOGICIEL DE SIMULATION DE MARCHÉ
-----
ELEVE      Prénom (PYRENEES)

TYPES DE LOISIRS          NOTES  OBJ  STOCK
-----
Soirées, restaurants, night club (SOI) 2 1 u 5 u
Sorties, Cinéma, théâtre, concerts (SOR) 4 2 u 6 u
Cassette, musique, vidéo, télé (MUS) 2 1 u 7 u
Jeux vidéo, multimédia, PC (JEU) 1 0 u 39 u
Radio, culture, musées, lecture (RAD) 2 1 u 8 u
Voyages, shopping, week end (VOY) 1 0 u 9 u
Mode, vêtements, lunettes (MOD) 4 2 u 5 u
Luxe, hte couture, parfum, bijoux (LUX) 2 1 u 5 u
Sport individuel ou en association (SPO) 1 0 u 7 u

DISPONIBILITES INITIALES EN LIQUIDE 15000.00 FF
-----
R.BUDA, GAMA, UNIVERSITE PARIS-X
    
```

Screen#1

```

ECHANGE 1.0 - LOGICIEL DE SIMULATION DE MARCHÉ
-----
PANNEAU DES ANNONCEURS

ACHETEUR          VENDEUR          COUT
PRIX QTE L/N DUREE  PRIX QTE L/N DUREE
-----
Soirées, res...          0
Sorties, Cin...          0
Cassette, mu...          10
Jeux vidéo, ...          0
Radio, cultu...          0
Voyages, sho...          10
Mode, vête...           0
Luxe, hte co...          0

<C>=>PASSER / A = ACHETEUR / V = VENDEUR_

ELEVE
14995.00 FF
PÉRIODE 1
-----
R.BUDA, GAMA, UNIVERSITE PARIS-X
    
```

Screen#4

```

ECHANGE 1.0 - LOGICIEL DE SIMULATION DE MARCHÉ
-----
INFORMATIONS GÉNÉRALES

VOUS ETES EN RÉGION PYRENEES
VOTRE HYPERMARCHÉ LOCAL EST "SUPER-FLUX"

BAREME DES PRIX          LOCAL  NATIONAL
-----
PUBLICITÉ HYPERMARCHÉS -          5.00 FF
JOURNAL D'ANNONCES -          5.00 FF
DIFFUSION D'UNE ANNONCE 10.00 FF 20.00 FF
RÉPONSE A UNE ANNONCE 5.00 FF 10.00 FF
FRAIS DE PORT (ACHETEUR) -          10.00 FF

VOULEZ-VOUS UN AFFICHAGE LOCAL OU NATIONAL
DES PRIX DES HYPERMARCHÉS ? (L/N) _

ELEVE
15000.00 FF
PÉRIODE 1
-----
R.BUDA, GAMA, UNIVERSITE PARIS-X
    
```

Screen#2

```

ECHANGE 1.0 - LOGICIEL DE SIMULATION DE MARCHÉ
-----
JOURNAL D'ANNONCES

ACHETEURS          VENDEURS
LOCAL  NATIONAL  LOCAL  NATIONAL
NUM  PRIX Q  NUM  PRIX Q  NUM  PRIX Q  NUM  PRIX Q
-----
SOI          002 120.00 1
SOR          002 500.00 1
MUS          002 800.00 1
JEU          004 500.00 1
RAD          005 500.00 1
VOY          006 600.00 1
MOD
LUX
SPO

LISEZ ATTENTIVEMENT PUIS TAPÉZ <Enter> SVP...

ELEVE
14870.00 FF
PÉRIODE 1
-----
R.BUDA, GAMA, UNIVERSITE PARIS-X
    
```

Screen#5

```

ECHANGE 1.0 - LOGICIEL DE SIMULATION DE MARCHÉ
-----
INFORMATIONS GÉNÉRALES

VOUS ETES EN RÉGION PYRENEES
VOTRE HYPERMARCHÉ LOCAL EST "SUPER-FLUX"

BAS NOR BRE ANV TOU ALS PRO COR ALP PYR
190 200 186 192 196 194 186 184 188 200 1 u 5 u
SOR 182 200 198 192 200 184 196 200 200 186 2 u 6 u
MOD 92 96 98 100 99 98 98 90 100 92 1 u 7 u
JEU 190 180 186 180 184 192 200 196 180 182 0 u 39 u
RAD 48 48 46 49 48 50 50 49 47 47 1 u 8 u
VOY 1140 1080 1176 1116 1200 1104 1188 1200 1104 1152 0 u 9 u
MOD 480 455 475 455 465 480 465 480 460 475 2 u 5 u
LUX 2475 2275 2350 2450 2400 2325 2425 2350 2500 2450 1 u 5 u
SPO 93 97 95 93 100 98 97 91 98 96 0 u 7 u

14995.00 FF

ELEVE
14995.00 FF
PÉRIODE 1
-----
R.BUDA, GAMA, UNIVERSITE PARIS-X
    
```

Screen#3

Screen #1 gather data about patrimonies (current inventories, liquidities) and goals (wished inventories).

Screen #2 gets information's purchase tariffs.

Screen #3 provides the hypermarket's merchandizes prices.

Screen #4 waits for the announcements.

Screen #5 displays announcements.

6.2 - Description of the Market Simulation with the "ECHANGE" software

Game session stages :

At the beginning, we ask his name and its leisures preference to each operator (we try to install in a few different rooms to avoid any trouble communications). We can then calculate good stock aim utility function and initial present stocks - see Appendix 6.1.

#1 - The some information prices (Hypermarkets advertising, transport, advertisement) are displayed (local one are free).

#2 - Operator can "write" advertisement (to buy vs sale purchases). He can keep one message during a lot of period. Price is lower than normal message, but he can't change the message until of the total of period.

#3 - Operator can buy the advertisements national paper (local one is free). After the second display of advertisements, operator has to pay.

#4 - Operator can answer to one or a lot of advertisements. Who answer do accept to pay for transport of good. When he answer, transaction is not warranted. Perhaps there are a lot of answers to the same advertisement. The first arrived is the partner.

#5 - Operator can buy the same kind of goods in hypermarkets.

#6 - Software calculates transaction results. Then results are displayed at each screen. Utility functions and new classification are calculated and possibly displayed. Some parameters in the utility are implemented to avoid the explosive classification (one operator is first and the other know they never reach him).

In the goods file we can find the name of each one, and the reference hypermarket price - see Fig.#7.

Soirées, restaurants, night club	(SOI)	200.00
Sorties, Cinéma, théâtre, concerts	(SOR)	200.00
Cassette, musique, vidéo, télé	(MUS)	100.00
Jeux vidéo, multimédia, PC	(JEU)	200.00
Radio, culture, musées, lecture	(RAD)	50.00
Voyages, shopping, week end	(VOY)	1200.00
Mode, vêtements, lunettes	(MOD)	500.00
Luxe, hte couture, parfum, bijoux	(LUX)	2500.00
Sport individuel ou en association	(SPO)	100.00

Fig.#7 - Hobby's good file

6.3 - An Example of Simulation with the "SINGUL" software

```

MARCHE DE 20 OPERATEURS
      10 VENDEURS ET      10 ACHETEURS

ETAT DES PATRIMOINES
  1 ACH -2 57.6000 16.3000 0.350 19200.0000 5 -
  2 ACH -3 39.5000 19.5000 0.390 17500.0000 5 -
  3 VEN  2 54.5000 20.0000 0.310 17800.0000 5 -
  4 ACH -4 40.0000 21.7000 0.360 19200.0000 5 -
  5 VEN  2 41.3000 37.0000 0.320 16900.0000 5 -
  6 VEN  1 50.0000 34.7000 0.310 18500.0000 5 -
  7 VEN  1 49.3000 20.4000 0.350 17200.0000 5 -
  8 ACH -2 41.3000 16.3000 0.380 19400.0000 5 -
  9 VEN  1 53.0000 23.4000 0.350 19900.0000 5 -
 10 VEN  4 48.9000 36.2000 0.390 16600.0000 5 -
 11 VEN  2 54.7000 38.5000 0.340 16500.0000 5 -
 12 ACH -1 38.4000 35.5000 0.350 18500.0000 5 -
 13 VEN  3 45.9000 26.8000 0.320 18800.0000 5 -
 14 ACH -4 54.7000 27.0000 0.370 17300.0000 5 -
 15 ACH -2 48.9000 15.2000 0.370 18900.0000 5 -
 16 VEN  3 51.8000 36.5000 0.340 17900.0000 5 -
 17 ACH -2 36.0000 21.9000 0.310 19000.0000 5 -
 18 ACH -2 59.2000 20.9000 0.310 17200.0000 5 -
 19 VEN  2 46.3000 39.7000 0.350 18000.0000 5 -
 20 ACH -1 47.4000 22.1000 0.400 17000.0000 5 -

DELTA STOCKS      21      -23

PERIODE 1

PRIX D'EQUILIBRE      38.3740 QUOTE D'EQUILIBRE      0

RESOLUTION DU MARCHE ETAPE 1 ----- ( 5/ 14)
36.5333 ( 13/ 12) 38.1000

FIN DES TRANSACTIONS -----

NOMBRE DE TRANSACTIONS      2
POURCENTAGE DE TRANSACTION 20.0000%
PRIX MOYEN DE TRANSACTION 37.3167 PRIX MODAL DE TRANSACTION
36.5000 DELTA STOCKS      2      -5

ETAT DES PATRIMOINES
  1 ACH -2      16.3000 0.350 19200.0000 5 -
  2 ACH -3      19.5000 0.390 17500.0000 5 -
  3 VEN  2 54.5000      0.310 17800.0000 5 -
  4 ACH -4      21.7000 0.360 19200.0000 5 -
  5 VEN  1 41.3000      0.320 16936.5333 5 0.639
  6 VEN  1 50.0000      0.310 18500.0000 5 -
  7 VEN  1 49.3000      0.350 17200.0000 5 -
  8 ACH -2      16.3000 0.380 19400.0000 5 -
  9 VEN  1 53.0000      0.350 19900.0000 5 -
 10 VEN  4 48.9000      0.390 16600.0000 5 -
 11 VEN  2 54.7000      0.340 16500.0000 5 -
 12
 13 VEN  2 45.9000      0.320 18838.1000 5 0.469
 14 ACH -3      27.0000 0.370 17263.4667 5 0.954
 15 ACH -2      15.2000 0.370 18900.0000 5 -
 16 VEN  3 51.8000      0.340 17900.0000 5 -
 17 ACH -2      21.9000 0.310 19000.0000 5 -
 18 ACH -2      20.9000 0.310 17200.0000 5 -
 19 VEN  2 46.3000      0.350 18000.0000 5 -
 20 ACH -1      22.1000 0.400 17000.0000 5 -

7 VEN  1 49.3000      0.350 17200.0000 5 -
8 ACH -2      16.3000 0.380 19400.0000 5 -
9 VEN  1 53.0000      0.350 19900.0000 5 -
10 VEN  4 48.9000      0.390 16600.0000 5 -
11 VEN  2 54.7000      0.340 16500.0000 5 -
12
13 VEN  2 45.9000      0.320 18838.1000 5 0.469
14 ACH -3      27.0000 0.370 17263.4667 5 0.954
15 ACH -2      15.2000 0.370 18900.0000 5 -
16 VEN  3 51.8000      0.340 17900.0000 5 -
17 ACH -2      21.9000 0.310 19000.0000 5 -

DELTA STOCKS      19      -21

PERIODE 2

PRIX D'EQUILIBRE      34.1240 QUOTE D'EQUILIBRE      0

RESOLUTION DU MARCHE ETAPE 1 ----- ( 19/ 20)
30.1667

FIN DES TRANSACTIONS -----

NOMBRE DE TRANSACTIONS      1
POURCENTAGE DE TRANSACTION 10.0000%
PRIX MOYEN DE TRANSACTION 30.1667 PRIX MODAL DE TRANSACTION
30.2500 DELTA STOCKS      2      -5

ETAT DES PATRIMOINES
  1 ACH -2      16.3000 0.350 19200.0000 5 -
  2 ACH -3      19.5000 0.390 17500.0000 5 -
  3 VEN  2 54.5000      0.310 17800.0000 5 -
  4 ACH -4      21.7000 0.360 19200.0000 5 -
  5 VEN  1 41.3000      0.320 16936.5333 5 0.639
  6 VEN  1 50.0000      0.310 18500.0000 5 -
  7 VEN  1 49.3000      0.350 17200.0000 5 -
  8 ACH -2      16.3000 0.380 19400.0000 5 -
  9 VEN  1 53.0000      0.350 19900.0000 5 -
 10 VEN  4 48.9000      0.390 16600.0000 5 -
 11 VEN  2 54.7000      0.340 16500.0000 5 -
 12
 13 VEN  2 45.9000      0.320 18838.1000 5 0.469
 14 ACH -3      27.0000 0.370 17263.4667 5 0.954
 15 ACH -2      15.2000 0.370 18900.0000 5 -
 16 VEN  3 51.8000      0.340 17900.0000 5 -
 17 ACH -2      21.9000 0.310 19000.0000 5 -

```

18 ACH -2 20.9000 0.310 17200.0000 5 -
 19 VEN 1 46.3000 0.350 18030.1667 5 0.004
 20
 DELTA STOCKS 18 -20
 PERIODE 3
 PRIX D'EQUILIBRE 34.1240 QUOTE D'EQUILIBRE 0
 RESOLUTION DU MARCHE ETAPE 1 ----- (10/ 14)
 36.3857
 FIN DES TRANSACTIONS -----
 NOMBRE DE TRANSACTIONS 1
 POURCENTAGE DE TRANSACTION 10.0000%
 PRIX MOYEN DE TRANSACTION 36.3857 PRIX MODAL DE TRANSACTION
 36.5000 DELTA STOCKS 2 -5
 ETAT DES PATRIMOINES
 1 ACH -2 16.3000 0.350 19200.0000 5 -
 2 ACH -3 19.5000 0.390 17500.0000 5 -
 3 VEN 2 54.5000 0.310 17800.0000 5 -
 4 ACH -4 21.7000 0.360 19200.0000 5 -
 5 VEN 1 41.3000 0.320 16936.5333 5 0.639
 6 VEN 1 50.0000 0.310 18500.0000 5 -
 7 VEN 1 49.3000 0.350 17200.0000 5 -
 8 ACH -2 16.3000 0.380 19400.0000 5 -
 9 VEN 1 53.0000 0.350 19900.0000 5 -
 10 VEN 3 48.9000 0.390 16636.3857 5 0.344
 11 VEN 2 54.7000 0.340 16500.0000 5 -
 12
 13 VEN 2 45.9000 0.320 18838.1000 5 0.469
 14 ACH -2 27.0000 0.370 17227.0810 5 0.940
 15 ACH -2 15.2000 0.370 18900.0000 5 -
 16 VEN 3 51.8000 0.340 17900.0000 5 -
 17 ACH -2 21.9000 0.310 19000.0000 5 -
 18 ACH -2 20.9000 0.310 17200.0000 5 -
 19 VEN 1 46.3000 0.350 18030.1667 5 0.004
 20
 DELTA STOCKS 17 -19
 PERIODE 4
 PRIX D'EQUILIBRE 34.1240 QUOTE D'EQUILIBRE 0
 RESOLUTION DU MARCHE ETAPE 1 ----- (5/ 14)
 36.5333
 FIN DES TRANSACTIONS -----
 NOMBRE DE TRANSACTIONS 1

POURCENTAGE DE TRANSACTION 10.0000%
 PRIX MOYEN DE TRANSACTION 36.5333 PRIX MODAL DE TRANSACTION
 36.5000 DELTA STOCKS 2 -5
 ETAT DES PATRIMOINES
 1 ACH -2 16.3000 0.350 19200.0000 5 -
 2 ACH -3 19.5000 0.390 17500.0000 5 -
 3 VEN 2 54.5000 0.310 17800.0000 5 -
 4 ACH -4 21.7000 0.360 19200.0000 5 -
 5
 6 VEN 1 50.0000 0.310 18500.0000 5 -
 7 VEN 1 49.3000 0.350 17200.0000 5 -
 8 ACH -2 16.3000 0.380 19400.0000 5 -
 9 VEN 1 53.0000 0.350 19900.0000 5 -
 10 VEN 3 48.9000 0.390 16636.3857 5 0.344
 11 VEN 2 54.7000 0.340 16500.0000 5 -
 12
 13 VEN 2 45.9000 0.320 18838.1000 5 0.469
 14 ACH -1 27.0000 0.370 17190.5476 5 0.954
 15 ACH -2 15.2000 0.370 18900.0000 5 -
 16 VEN 3 51.8000 0.340 17900.0000 5 -
 17 ACH -2 21.9000 0.310 19000.0000 5 -
 18 ACH -2 20.9000 0.310 17200.0000 5 -
 19 VEN 1 46.3000 0.350 18030.1667 5 0.004
 20
 DELTA STOCKS 16 -18
 PERIODE 5
 PRIX D'EQUILIBRE 36.4240 QUOTE D'EQUILIBRE 0
 RESOLUTION DU MARCHE ETAPE 1 ----- (10/ 14)
 32.4750
 FIN DES TRANSACTIONS -----
 NOMBRE DE TRANSACTIONS 1
 POURCENTAGE DE TRANSACTION 10.0000%
 PRIX MOYEN DE TRANSACTION 32.4750 PRIX MODAL DE TRANSACTION
 32.2500 DELTA STOCKS 2 -5
 ETAT DES PATRIMOINES
 1 ACH -2 16.3000 0.350 19200.0000 5 -
 2 ACH -3 19.5000 0.390 17500.0000 5 -
 3 VEN 2 54.5000 0.310 17800.0000 5 -
 4 ACH -4 21.7000 0.360 19200.0000 5 -
 5
 6 VEN 1 50.0000 0.310 18500.0000 5 -
 7 VEN 1 49.3000 0.350 17200.0000 5 -
 8 ACH -2 16.3000 0.380 19400.0000 5 -
 9 VEN 1 53.0000 0.350 19900.0000 5 -
 10 VEN 2 48.9000 0.390 16668.8607 5 0.139

