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A Multidimensional Dynamic Regulation Model for E-Marketplaces: DYNEX

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Abstract: The lack of dynamic double-side regulation models for E-Marketplaces is a main reason for their lack of success as advanced open trading places.In this paper, a new model – DYNEX – is developed to generate homogeneous markets of goods or services and to optimize for each homogeneous market the trading price and the negotiation process between buyers and sellers.

Keywords: eMarketplace, trading, negotiation model

1. INTRODUCTION

Internet is supporting the development of new trading spaces allowing the interaction between large numbers of sellers and buyers with small access costs and negligeable differentiation in terms of geographical distance. E-Marketplaces serving a wide range of industries with vertical horizontal or mixed vocations are good examples of this new type of trading sites (Timmers, 1999).

However, the practical success of several E-Marketplaces has been small with disappointing commercial results, perhaps in contrast with other business models also supported by electronic technology (Elliot, 2002). This is confirmed by (EITO, 2002) despite the optimistic views generally supported by this

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Observatory (see "E-Marketplaces when they first appeared on the B2B scene were considered to be the next big thing for E-commerce, a phenomenon that would bring huge benefits to both buyers and sellers. However they have not quite lived up-their expectations" in EITO, 2002, Page 34.).

Several reasons can de identified such as the lack of information systems in SMEs (Tavares and Pereira, a 2000) or the fear from too wide competition but the analysis of how E-Marketplaces operate shows clearly a deficit of conception and modelling of market mechanisms and regulation models appropriate to this new kind of trading spaces. Successful exceptions are private E-Marketplaces owned by one company and its network of suppliers where open market models are no longer required.

The purpose of this paper is presenting a new model – DYNEX – designed to cope with these new challenges.

2. FROM STATIC TRADING TO DYNAMIC PRICING

The general problem of trading can be formulated in terms of a set of suppliers who offer products, goods or services, with specific qualities and, available amounts **(asks)** and a set of consumers who are willing to buy such products at given amounts **(bids)**.

Transaction prices are a key feature of each market and they can be determined by internal and or external mechanisms. It is clear since the famous work by Edgeworth (Edgeworth, 1881) that most often there is a continuous range of prices allowing the transactions with positive advantage both for buyers and sellers.

Such prices are confined by the marginal utility of buying (a) or of selling the studied product (b), by buyers and sellers, respectively. That range exists if $a \geq b$ and it is defined by $[b, a]$.

Actually, prices are undetermined magnitudes and each business culture along history can be described by how society organizes and rules the interaction between supply and demand forces and how transaction prices are generated (Newman, 1965).

Old cultures based on the arabian tradition have emphasized the one-to-one system where each buyer negotiates directly with each supplier, starting with initial prices quite far from the final agreement. The concept of market is then, basically, a physical space (*Medina*) where supply is located to make easier the comparison by consumers between alternative sellers.

The perfect competition model is quite different as it assumes that there is just one price for each product in each market and that it is open and well known by all buyers and sellers. Supply and demand is aggregated and convergence for equilibrium can be achieved by the interaction between supply and demand in the long run, under specific conditions. The theory developed by L. Walras (Walras, 1874) shows that competitive equilibrium prices correspond to a Pareto optimal solution of consumption and production decisions under specific conditions.

The equilibrium price has the property of maximising the surplus of suppliers and consumers, as it is shown in Fig. 1

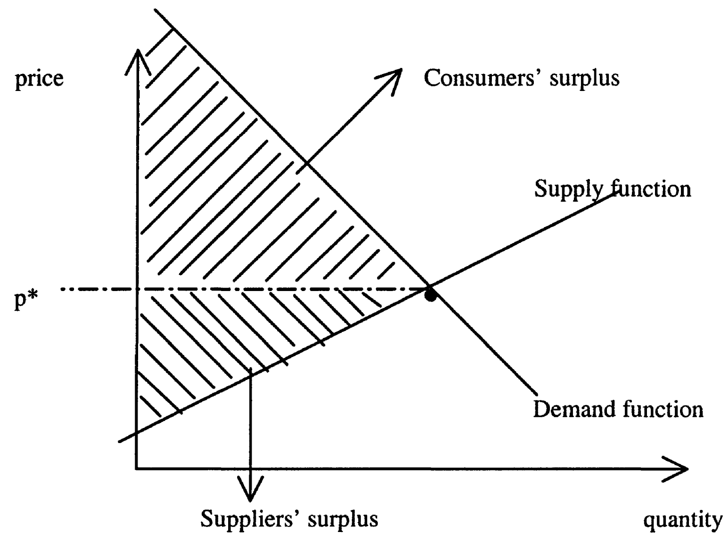

Fig. 1. Surplus of consumers and of suppliers for continuos supply and demand functions

but convergence for p* by the interaction between sellers and buyers tends to be a long and risky process.

The concept of the same and open price for each product has become popular after industrial revolution to help mass consumption of standard products avoiding personal negotiation and to allow long run convergence for equilibrium prices. Competition may lead suppliers to search for more "protected" markets (quasi-monopolies) or to adopt product differentiation policies.

During last decades, the level of income has increased significantly in most western societies and the preferences of consumers tend to be more diversified due to such increase. The need to adopt policies of product differentiation has overamplified such segmentation explaining why the number of different goods and services being traded has increased dramatically during last two decades.

Progressive liberalisation of world markets has increased competition and reduced marginal profits in many industries, from construction to electronics, from computers to automobiles, explaining why many firms have collapsed and merging dynamics has been a general trend.

The need to achieve equilibrium pricing in short range processes for modern economies is a major goal to implement the perfect competition model and to achieve the optimality property of maximisation of suppliers' and consumers' surplus. Internet allows the implementation of fast interactive processes with a central server and hence it can be a precious tool to develop such model in modern E-Marketplaces. Then, important added values can be generated through the information systems of participating firms (Tavares and Pereira, 2000 b) and new incentives will help to promote their development.

Unfortunately, most existing E-Marketplaces have just implemented the standard trading procedures, namely the following models (Bichler et al, 2001):

- Static Model

Each supplier offers a catalogue with fixed priced products and each consumer has to make his selection from existing catalogues.

This approach is not using the potentiality of Internet interactions and it is a clear example of using a new technology according to old paradigms.

Also, the procurement value assigned to products bought by catalogue tend to be a small percentage of the purchase budget of important firms as most of them belong to the so-called MRO type (Maintenance, Repair and Operations) and therefore the commercial failure of E-Marketplaces based on this model can be easily expected.

- Auction Model

This model uses interactivity to stimulate competition between buyers increasing the selling price. However, auctions are effective to sell unique goods but otherwise they will be rapidly substituted by alternative models.

- Reverse Auction

This model is applicable for important buyers but not for fragmented demand. Furthermore, it requires the comparison of just the price between goods or services. The application of this model without a symmetrical counterpart helping suppliers has been responsible for opposition from many firms to participate in E-Marketplaces.

It should be noted that auctions or reverse auctions do not comply with the assumption of the perfect competition model.

This analysis confirms the need to propose a new model exploring the interactivity of Internet to implement perfect competition through the clustering of similar products and the dynamic optimization of price.

3. MULTIDIMENSIONAL CLUSTURING OF PRODUCTS

Most products have different attributes as a result of demand segmentation and of policies of product differentiation already discussed.

Therefore, the regulation of a market implies a previous effort oriented to identify clusters of products with quality similarly perceived by potential clients.

The issue of quality definition has been intensively discussed and a multidimensional concept is required:

$$V(k) = [\, V_1(k) \ldots V_m(k)]$$

where V (k) is the perceived quality of product k and $V_m(k)$ is a cardinal measure of the perceived quality for attribute m. Any $V_m(k)$ has to be defined on the same metric scale (value scale) and usually a higher value of $V_m(k)$ corresponds to a higher preference. This value scale can be bounded (e.g., between 0 and 10) or unbounded. The transformation of the indicator describing each attribute (for instance, size, shape, resistance, delivery time, reliability, warranty, brand, etc.) on this value scale can be performed by several methods.

Besides quality, two other dimensions have to be included:

- Amount → Q(k)
- Price → P (k)

Therefore, each product *k* will be defined on a metric space with dimension equal to (M+2).

The identification of any homogeneous cluster of products with similar perceived quality implies a taxonomic model applied on the M-multidimensional metric space and several developments have been proposed in different areas like Multivariate Analysis (Dillon and Goldstein, 1984), Clustering Techniques (Aldenderfer e Blashfield, 1985) or Multicriteria Decision Theory (MCDT, Roy, 1985).

Here, a new relation is proposed based on MCDT contributions to define **similarity:**

Two products, *k* and *k'* are considered with a similar perceived quality if and only if:

(1) $$| V(k)-\overline{V}(k') | = | \Sigma\lambda_m[V_m(k)-V_m(k')] | \leq \alpha$$

and

(2) $$\text{Max} |V_m(k)-V_m(k')| \leq \beta$$

where λ_m is the coefficient of importance associated to attribute m.

The first condition expresses the closeness between the quality of k and k' in terms of an weighted average of their attribute values. The second condition guarantees that the discrepancy between the values of k and k' according to each attribute never exceeds threshold β. Obviously, these two parameters, α and β, control how strict or how relaxed is the concept of similarity applied to the population of goods.

Any set of products, S_r, where each pair [(k, k'), ε S_r] satisfies conditions (1) and (2) is called a **cluster.**

Hence, representing the set of products by a graph where each product corresponds to a vertice and where an edge exists connecting two nodes if conditions (1) an (2) apply, the problem of determining a cluster is the problem of determining a **clique** for this graph (Berge, 1991).

Obviously, the number of edges is controlled by α and β and a sensitivity analysis of the number of clusters in terms of α and β can be carried out.

For each selected pair (α,β), the identification of clusters is undetermined because the definition of any cluster can affect the identification of the other clusters.

An algorithm was developed to build up a set of clusters covering the whole set of supplied products, $\{s_1,\ldots, s_I\}$ and of demanded products, $\{d_1,\ldots, d_J\}$, using as main objective the minimization of the number of clusters, R and as a second objective the

$$\text{minimization of} \quad \bar{Z} = \frac{\sum_{r=1}^{R} Z_r}{R} \quad \text{where}$$

$$Z_r = \left| \sum_{k \varepsilon S_r} Q(k) - \sum_{k \varepsilon D_r} Q(k) \right|$$

for any cluster r, with r = 1,..., R and where S_r or D_r is the sub-set of supplied or demanded goods belonging to *r*.

The first objective (Min R) expresses the aim of having large homogeneous markets and the second one represents the wish of having balanced markets. An alternative formulation can be adopted using the second objective as a restriction:

$$\text{Min } R$$

$$\text{with} \quad \bar{Z} \leq L$$

where L is the accepted upper bound.

Obviously, this model is equivalent to the unconstrained optimization of $[R+(\bar{Z}+W-L)]$ being W the non-negative slack variable given by:

$$\bar{Z}+W-L=0$$

4. OPTIMAL REGULATION OF THE MARKET

Each cluster corresponds to a market that will be treated as an homogeneous market and therefore the traditional analysis of supply and demand functions can be applied (Fig. 2).

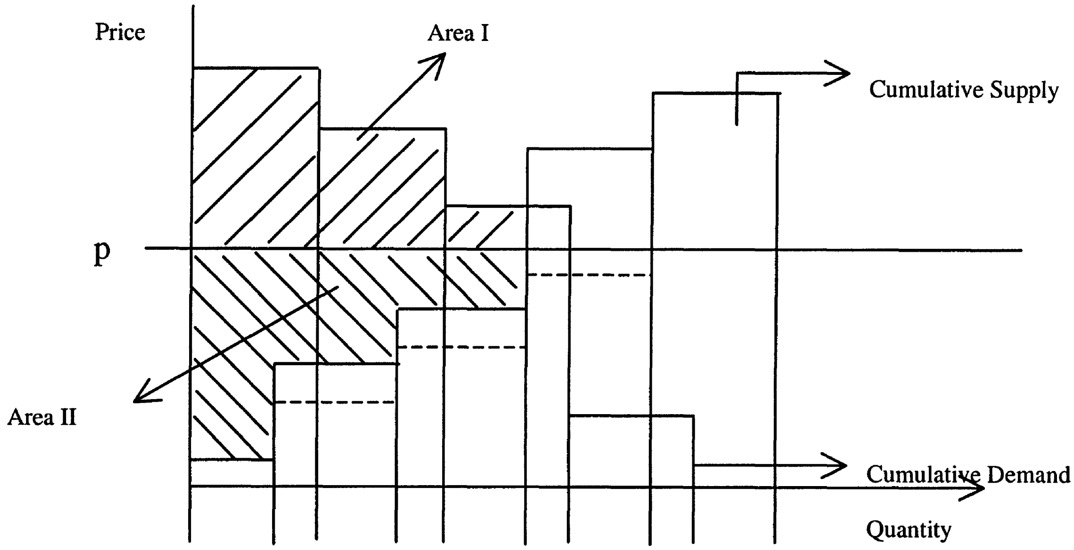

Fig. 2. Surplus of consumers and suppliers for discrete supply and demand functions

The price of each ask and of each bid should be considered as a lower or an upper bound, respectively (reservation prices). The regulation of the market implies setting up a price, p, to clear the market, and this is the main decision variable to be selected, in terms of the regulation objectives. As it was discussed before, such objectives can defend just one side of the market (Supply or Demand) or can balance the interest of both sides. The authors believe that the stagnation of E-Marketplaces is partially due to their implementation of static models as it is the case of catalogue sales or to the support given to the demand side through the reverse auction model creating too tough conditions for suppliers. Therefore, their frequent reluctance to join E-Marketplaces can be hardly surprising. Alternatively, the proposed model is sufficiently flexible to allow the adoption of double-side objectives and to balance the interest of both sides.

A main difference of this model if compared to an auction or to a reverse auction model is that in this model a set of suppliers and consumers is considered as a whole and thus optimal control can be discussed for the studied homogeneous market.

The objective function representing the interest of consumers can be expressed in terms of the consumers' surplus:

(3)

$$D(p) = \sum_{i=1}^{i(p)} Q_d(i).[P_d(i) - p] \qquad \text{being} \quad i : P_d(i) \geq p$$

and with

$$\sum_{i=1}^{i(p)} Q_d(i) \leq LQ$$

and

$$\sum_{j=1}^{j(p)} Q_s(j) = LQ \qquad \text{being} \quad j : P_s(j) \leq p$$

where

$i(P)$ is the number of buyers with $P_d(i) \geq p$

and $j(p)$ the number of sellers wth $P_s(j) \leq p$.

The function D(p) corresponds to area I in Fig. 2.

Similarly, the suppliers' surplus will be defined by:

$$S(p) = \sum_{j=1}^{j(p)} Q_S(j)[p - P_S(j)] \qquad \text{being} \qquad j : P_S(j) \le p$$

and with

$$(4) \quad \sum_{j=1}^{j(p)} Q_S(j) \le LD$$

and

$$\sum_{i=1}^{i(p)} Q_d(i) = LD \qquad \text{being} \qquad i : P_D(i) \le p$$

corresponding to area II in Fig. 2.

The optimal price, p*, will maximize

$$(5) \quad F = f.D(p) + (1 - f).S(p)$$

where $0 \le f \le 1$ is an weighting coefficient expressing the relative importance of D(p) compared to S(p).

The optimal amount of the product sold from sellers is given by:

$$Q^* = \min (LQ, LD).$$

The proposed model solves problem (5) with conditions (3) and (4) and informs buyers and sellers about p*.

Then, another round is carried out asking for new prices, $\{P_d(i)\}'$, $\{P_s(j)\}'$, under conditions

$$\{P_d(i)\}' \geq \{P_d(i)\}$$
$$\{P_s(j)\}' \leq \{P_s(j)\}$$

and therefore, $F'^* \geq F^*$.

This process can be repeated along a small and quite number of iterations to reach a final solution.

Thus, during a given period (for instance, one hour, one day or one week) buyers and sellers present their bids and asks, respectively, and DYNEX produces a specific number of homogeneous markets using the algorithm presented in previous section. Then, the optimal price is computed by DYNEX and buyers and sellers are informed about p*. A few iterations are allowed (e.g, 2 or 3) to converge to a final price. Once this price is set, buyers and sellers can interact directly and carry out any transaction following the recommended prices.

5. OPTIMIZATION ALGORITHM

5.1 The optimization of (5) given (3) and (4) can be carried out through an algorithm defining

a) $X_i = 0$ or 1 if

$P_d(i) < p$ or $P_d(i) \geq p$, respectively.

b) $Y_j = 0$ or 1 if

$P_s(j) < p$ or $P_s(j) \geq p$, respectively.

An iterative procedure can start with p equal to the maximal $P_d(i)$ or minimal $P_s(j)$ and then increasing or decreasing its value until p* is reached.

However, an alternative interesting formulation can be also proposed using Linear Programming providing that the definition of buyers and sellers is discretized to have $Q_d(i)=Q_p(j)=Q$.

Then, one has condition (3) expressed by

$$\begin{cases} X_i \geq 0 \\ X_i \geq P_d(i) - p \\ \text{Min} \sum_{i=1}^{I} X_i \end{cases}$$

and condition (4)expressed by:

$$\begin{cases} Y_j \geq 0 \\ Y_j \geq p \ - P_s(j) \\ \text{Min} \sum_{j=1}^{J} y_j \end{cases}$$

being $F = \left(\sum_{i=1}^{I} X_i + \sum_{j=1}^{J} Y_j \right) Q$ the objective function to be maximized in terms of p.

This means that, for each p, the following problem should be solved:

$$\begin{cases} X_i \geq P_d(i) - p \\ X_i \geq 0 \\ Y_j \geq p - P_s(j) \\ Y_j \geq 0 \end{cases}$$

with

$$\text{Min}\left[\sum_{i=1}^{I} X_i + \sum_{j=1}^{J} Y_j\right] \geq G$$

and having as objective function the maximization of G.

6. CONCLUSIONS

Internet offers new possibilities of access, interactivity and of no distance cost which can support the development of new E-Business transaction models.

In this paper, a new dynamic transaction model (DYNEX) is developed avoiding the shortcomings of static models (like catalogue sales) or of one-sided approaches (like auctions or reserve auctions).

DYNEX includes:

- a databasis about asks from sellers and about bids from buyers;
- a clustering method to identify homogeneous markets in terms of multi-dimensional quality assessment;
- a price regulation method to determine the optimal price for each homogeneous market;
- a negotiation process allowing iterative convergence between sellers and buyers.

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The identification of homogeneous markets is an essential step to stimulate competition between supply and demand.

The price regulation is a key feature of this model allowing the optimization of the sellers' and buyers' surplus and avoiding the one sided approaches.

The negotiation procedure is also quite useful to support the equilibrium convergence between the supply and the demand.

Therefore, DYNEX can enrich the role to be played by the operation of E-Marketplaces using the new potentialities offered by internet and avoiding the limitations of common systems. Such operation can balance the interest of buyers and sellers and can offer them important advantages over traditional marketing systems:

- Identification of markets of homogeneous products for price setting;
- Optimal regulation of price, balancing supply and demand;
- Dynamic negotiation helping convergence between buyers and sellers.

This model increases the added value generated by E-Marketplaces to sellers and buyers helping to promote E-Business.

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