A Study on Partnering Mechanism in B to B EC Server for Global Supply Chain Management*

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B to B Electronic Commerce (EC) technology is now in progress and regarded as an information infrastructure for global business. As the number and diversity of EC participants grows at the agile environment, the complexity of purchasing from a vast and dynamic array of goods and services needs to be hidden from the end user. Putting the complexity into the EC system instead means providing flexible auction server for enabling commerce within different business units. Market mechanism could solve the product distribution problem in the auction server by allocating the scheduled resources according to market prices. In this paper, we propose a partnering mechanism for B to B EC with market-oriented programming that mediates amongst unspecified various companies in the trade, and demonstrate the applicability of the economic analysis to this framework after constructing a primitive EC server. The proposed mechanism facilitates sophisticated B to B EC, which conducts a Pareto optimal solution for all the participating business units in the coming agile era.

Key Words : Supply Chain Management, Virtual Market, Multi-Agent, E-Commerce

1. Introduction

B to B Electronic Commerce (EC) technology is now in progress and regarded as an information infrastructure for global business management in global supply network environment^{(1),(2)}. As the number and diversity of EC participants grows at the agile conditions in SCM, the complexity of purchasing from a vast and dynamic array of goods and services needs to be hidden from the end user. Putting the complexity into the EC system instead means providing flexible auction server for enabling commerce within different business units⁽³⁾. Market mechanism could solve the product distribution problem in the auction server by allocating the scheduled resources according to market prices.

Solving product distribution problem in B to B EC presents particular challenges attributable to the distributed nature of the computation. Each business

unit in EC represents independent entities with conflicting and competing product requirements and may possess localised information relevant to their interests. To recognise this independence, we treat the business units as agents, ascribing each of them to autonomy to decide how to deploy resources under their control in service of their interests⁽⁴⁾.

Assuming that a product distribution problem in EC transactions must be decentralised, markets can provide several advantages as follows :

- i) Markets are naturally distributed and agents make their own decisions about how to bid based on the prices and their own utilities of the goods.
- ii) Communication is limited to the exchange of bids and process between agents and the market mechanism.

In market-oriented programming we take the metaphor of an economy computing multi agent behaviour literally, and directly implement the distributed computation as a market price system⁽⁵⁾. In this paper, we propose a partnering mechanism for B to B EC with the market-oriented programming that mediate amongst unspecified various companies in the SCM trade, such as in e-Market Place system, and

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demonstrate the applicability of the economic analysis to this framework after constructing a primitive EC server with server side script environment. The proposed mechanism facilitates sophisticated B to B EC trading, which conducts a Pareto optimal solution for all the participating business units in supply network.

2. Market-Oriented Programming

2.1 Basic concept

Agent activities in terms of products required and supplied are defined so as to reduce an agent's decision problem to evaluate the tradeoffs of acquiring different products in market-oriented programming⁽⁵⁾. These tradeoffs are represented in terms of market prices, which define common scale of value across the various products⁽⁴⁾.

In this paper the framework of general equilibrium theory⁽⁶⁾, which is proposed in microeconomics research field, has been adopted. In economics, the concept of a set of interrelated goods in balance is called general equilibrium. The general equilibrium theory guarantees a Pareto optimal solution at competitive equilibrium in perfect competitive market⁽⁷⁾. The connection between computation and general equilibrium is not all foreign to economists, who often appeal to the metaphor of market systems computing the activities of the agents involved. Some apply the concept more directly, employing computable general-equilibrium models to analyse the effects of policy options on a given economic system⁽⁸⁾. Since EC constructs a virtual market in cyber space, market-oriented programming is obviously well-structured for EC partnering model.

2.2 Market-oriented programming in B to B EC

In market-oriented programming we take the metaphor of an economy computing multi-agent behaviour literally, and directly implement the distributed computation as a market price system⁽⁸⁾. Figure 1 illustrates the structure of computational market based on market-oriented programming with M supply agents, N demand agents and S products. It is shown that each product naturally constructs general market in this figure.

Suppose $P_t(s)$ is the price of product s in time t , f_{ms} is the supply function in supply agent m for product s , and g_{ns} is the demand function in demand agent n for product s . The algorithm of the proposed market-oriented programming for the partnering mechanism in B to B EC server is shown as follows:

Step 1: A demand agent n sends bids to markets to indicate its willingness to buy the product s according to its current price $P_t(s)$ at time t . The demand agent willingness is defined as a

Fig. 1 Market-oriented program

demand function in the bid message. The agent can send bids to the market within the limits of its domestic budget. Each product has its own market, and they construct a competitive market mechanism as a whole.

Step 2: A supply agent m sends bids to the market to indicate its willingness to sell the product s according to its current price $P_t(s)$ at time t . The supply agent willingness is defined as a supply function in the bid message. The agent can send bids to the market within the limits of its current inventory level.

Step 3: The market in product s sums up demand functions ($\sum f_{ms}$) and supply functions ($\sum g_{ns}$), then revises balanced price $P'_t(s)$ of product s at time t . All the market must revise their balanced price via the same process.

Step 4: Check the balanced prices of all the products and if all the prices are converged, the acquired set of the prices is regarded as equilibrium price, then go to Step 5. If not, go to Step 1.

Step 5: If dealing time is up, then stop. And if not, $t = t + 1$ and go to Step 1.

There exist the following research subjects to build up an appropriate B to B EC model with the market-oriented programming concept.

i) Definitions of supply and demand functions in the agents.

ii) Budget constraint in the agents

We try to clarify these subjects in the next section.

3. Agent Definitions

3.1 Supply agent

Suppose supply agent i has production function H_i , which defines manufacturing efficiency from input resources X_i to products Y_i .

$$Y_i = H_i(X_i) \quad (1)$$

where

$$X_i = \{x_{i1}, x_{i2}, \dots, x_{is}\} \quad (2)$$

$$Y_i = \{y_{i1}, y_{i2}, \dots, y_{is}\} \quad (3)$$

In this paper we adopt a basic Cobb-Douglas function as the production function described in the following equation:

$$y = ax^b \quad (\text{where } 0 < a, 0 < b < 1) \quad (4)$$

It is well known that Cobb-Douglas function handles economical scale in market by index constant b , and in case of $0 < b < 1$ the production function is defined as a convex function, in other words, a diminishing returns function. In case production function is defined as convex type, market prices are established at a predictable level in the general equilibrium theory.

Finally production function h_{is} of agent i for product s is given by

$$y_{is} = h_{is}(x_{is}) = a_{is}x_{is}^{b_{is}} \quad (5)$$

Suppose the single unit cost of x_{is} is p_{0is} and the single unit sale of y_{is} is p_{is} , then the profits E_{is} of agent i for product s is defined as Eq. (6)

$$\begin{aligned} E_{is} &= p_{is}y_{is} - p_{0is}x_{is} \\ &= p_{is}y_{is} - p_{0is}(y_{is}/a_{is})^{1/b_{is}} \end{aligned} \quad (6)$$

Supply agent utility in the dealing is motivated to earn maximum profit and supply function is conducted from iso-profit curve with maximum return. Finally supply function f_{is} with maximum profit is given as follows:

$$\begin{aligned} \max E_{is} &= \partial E_{is} / \partial y_{is} \\ &= p_{is} - (p_{0is}/b_{is})(y_{is}/a_{is})^{(1-b_{is})/b_{is}} = 0 \end{aligned}$$

then

$$y_{is} = f_{is}(p_{is}) = a_{is}(b_{is}p_{is}/p_{0is})^{b_{is}/(1-b_{is})} \quad (7)$$

where $0 < a_{is}, 0 < b_{is} < 1$

3.2 Demand agent

Suppose demand agent i has demand function G_i , which defines its demanding amounts Z_i of the target products, then we have

$$Z_i = G_i(P_i) \quad (8)$$

where

$$P_i = \{p_{i1}, p_{i2}, \dots, p_{is}\} \quad (9)$$

$$Z_i = \{z_{i1}, z_{i2}, \dots, z_{is}\} \quad (10)$$

In this paper we adopt a power function as the demand function described in the following equation:

$$z = cp^{-d} \quad (\text{where } 0 < c, 0 < d) \quad (11)$$

In this function, index constant d indicates "price elasticity", which represents the price effects into demand utility.

$$\begin{aligned} (\text{Price elasticity})_{is} &= (dz_{is}/dp_{is}) * (p_{is}/z_{is}) \\ &= -(dcp_{is}^{-d-1})(1/cp_{is}^{-d-1}) = -d \end{aligned} \quad (12)$$

Power function is applied into demand function in this paper in order to handle price elasticity factors in practical trading, because price elasticity of each product is kept in constant shown in Eq. (12). Finally

demand function g_{is} of agent i for product s is given by

$$z_{is} = g_{is}(p_{is}) = c_{is}p_{is}^{-d_{is}} \quad (13)$$

where $0 < c_{is}, 0 < d_{is}$

3.3 Budget constraint

In this paper we introduce the idea of budget constraint for demand agents as well as the inventory limitation for supply agents so as to establish more practical B to B EC model.

Suppose demand agent i has budget constraint B_i , and the relationship between demands and budget constraint are shown in the following equation:

$$B_i \geq \sum_{s=1}^S z_{is}p_{is} \quad (14)$$

3.4 Utility proportional strategy in budget constraint

In market-oriented program each agent is regarded as a price taker. They assume product costs never be affected by their bidding activities during a dealing. Therefore once they detect product prices were altered after their bid, it is necessary for them to modify their bidding functions according to their strategy in order to find a Pareto optimal solution shown in the previous section.

We propose a utility proportional strategy in demand agents as the modification mechanism. In the utility proportional strategy demand agents are assumed to have rigid intention and hold a fixed proportional utilities about all the demanding products during a dealing time period t under their budget constraint. Because index constraint d_{is} in demand functions (13) represents price elasticity, which is unique to product s and should be fixed, a coefficient c_{is} is revised by applying the rule given by Eq. (15) in the proposed strategy.

$$g_{is}(p_{is}) = \begin{cases} c_{is}p_{is}^{-d_{is}} & (B_i \geq \sum_{s=1}^S z_{0is}p_{0is}) \\ c'_{is}p_{is}^{-d_{is}} & (B_i < \sum_{s=1}^S z_{0is}p_{0is}) \end{cases} \quad (15)$$

Since demand and budget relationship is given by Eq. (16), the newly revised coefficient c'_{is} is given by Eq. (17).

$$B_i \left(z_{0is}p_{0is} / \sum_{s=1}^S z_{0is}p_{0is} \right) = c'_{is}p_{0is}^{-d_{is}}p_{0is} \quad (16)$$

$$c'_{is} = B_i \left(z_{0is} / \left(\sum_{s=1}^S z_{0is}p_{0is} \right) p_{0is}^{-d_{is}} \right) \quad (17)$$

It is obvious that the proportional rate of demand utilities for each product is maintained as constant by Eq. (17) shown in Fig. 2.

4. Market Dynamism

4.1 Experimental B to B EC model

Experimental EC model based on computational market is constructed shown in Fig. 3 so as to analyse qualitative characteristics of the proposed partnering

Fig. 2 Demand function modification

Fig. 3 Experimental virtual market

mechanism by simulation.

The followings are the default experimental parameters in the basic EC model.

- supply and demand agents : 3
- product types : 3 (A, B, C)
- interval time of product supply : 1 (day)
- lot size of supplied products from supply agents*
: A : 100, B : 150, C : 200
- required product size in demand agents*
: A : 100, B : 150, C : 200
- price elasticity of products : 1.0
- value of constants in production function
: $a=1, b=1/2$
- initial value of constants in demand function
: $c_0=1, d=1$
- the number of simulation trails : 100

* followed by uniform distribution in the interval $\pm 20\%$

Fig. 4 Products allocation

Fig. 5 Supply and demand convergence

Three types of products {A, B, C} are defined. Product A and C symbolise small lot size product and large lot size product respectively.

4.2 Basic trading dynamism

Experimental results on the number of demand/supply products at a demand agent are shown in Fig. 4. Small figures indicate the acquired equilibrium price of each product at daily dealing processes in this figure. The daily difference of equilibrium prices, which were acquired as a Pareto optimal solution led by general equilibrium theory, are within 3% and it is obvious that dealing process in computational market is settled under budget-constraint free environment.

It is obvious that the amounts of supply and demand are converged into equilibrium shown in Fig. 5. Since our methodology is perfectly endorsed by 'general equilibrium theory' in microeconomics, we can get a Pareto optimal solution in the equilibrium. That means the goods distribution policy followed by the acquired solutions, i.e. the amounts and the prices, are Pareto optimal in the entire market. The influence of price elasticity with the constant parameters c, d into the price convergence has been already

clarified in Ref.(9). Efficient partnering strategy for B to B EC with market mechanism are attainable by the proposed approach.

4.3 Supply and demand balance

Figure 6 demonstrates the relationship between supply/demand ratio and equilibrium price in product A. In this figure the horizontal axis is supply/demand ratio, and ratio: 1.0 means the number of supplied products is completely equivalent to the number of demanded ones. The vertical axis represents non-dimensional equilibrium price, which is divided by the price acquired at (supply/demand ratio)=1.0.

As the supply/demand ratio increases, equilibrium price decreases. They are in negative correlation, and the experimental values agree well with the theoretical trends of general equilibrium in micro-economics. This result indicates the proposed market-oriented approach successfully constructs a perfect competitive market in product distribution problem for B to B EC server.

4.4 Basic constraints

The relationship between budget constraint and acquired equilibrium price is shown in Fig. 7. In this figure the horizontal axis represents non-dimensional budget ratio, which is divided by the perfect balanced budget. The vertical axis represents non-dimensional

Fig. 6 Supply and demand balance

Fig. 7 Budget constraint

equilibrium price, which is divided by the price acquired at budget ratio=1.0.

They are in positive correlation, and the experimental values agree well with the qualitative trends of general equilibrium theory as well. In general price of goods increases under the condition of plenty of budget in demand agents, because the economy in the competitive market is getting inflated. On the other hand, equilibrium price decreases under deflated economy caused by the shortage of budget in demand agents.

In this paper we focused on the budget constrain as the first step. However further considerations on the other attributes, such as due date or trust in trade, are necessarily in the next step.

5. EC Server

5.1 Structure

We developed a prototype B to B EC server with the proposed partnering mechanism shown in Fig. 8. The server consists of i) Web server, ii) Relational database, iii) Virtual market model.

Web server: Microsoft Peer Web server (PWS)

Server side script: Microsoft Active Server Pages (ASP)

Relational Database: Microsoft ACCESS

Virtual market model: Microsoft Visual C++

5.2 Transaction flow

Product suppliers and demanders will access the EC server via Internet Browser. Transaction flow is as follows:

- Step 1: All the suppliers and demanders create user accounts and register their personal information on the EC server.
- Step 2: Suppliers input their products with their preferable price and quantity.
- Step 3: Demanders input their preferable price and quantity on the products to buy.
- Step 4: Virtual market collects all the bids over a specified interval of time, then clear the market with a Pareto optimal solution at

Fig. 8 B to B EC server

Fig. 9 Trading proposal window

the expiration on the bidding interval.

Step 5: All the suppliers and demanders input their final decision on the proposed trade by the virtual market.

Step 6: Final trade is announced to all the participants.

A snap shot of the trading proposal window is shown in Fig. 9, as an example. We validated the efficiency of the proposed partnering mechanism in B to B EC server with the prototype system. The virtual market implemented in the server successfully produced reasonable clearing on multiple bids with several business units.

6. Conclusions

In this paper, we proposed a partnering mechanism for B to B EC with the market-oriented programming that mediates amongst unspecified various companies in the trade, and demonstrated the applicability of the economic analysis to this framework.

It has been proved that all the natures of our market-oriented programming based approach perfectly agree with the theoretical trends of general equilibrium in microeconomics by simulation experiments. Our approach is completely distributed and a Pareto optimal solution is attainable only by defining

the supply/demand functions into each business units, because market mechanism equips dealing protocol by nature. The proposed server facilitates sophisticated partnering mechanism for B to B EC, which conducts a Pareto optimal distribution of products for all the participating business units, in the coming agile VE era.

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References

- (1) Iwata, K. and Fujii, S., New Manufacturing Era—Adaptation to Environment, Culture, Intelligence and Complexity, CIRP, (1997).
- (2) Goldratt, E.M., The GOAL, (1983), North River Press.
- (3) Laudon, K., Management Information Systems—New Approach to Organization and Technology, (1998), Prentice Hall.
- (4) Kaihara, T. and Namikawa, J., A Study on Distributed Resource Allocation by Using Market-Oriented Programming in Distribution System, The Transactions on The Institute of System, Control and Information Engineers, Vo. 12, No. 6 (1999), pp. 349-356.
- (5) Wellman, M.P., A Market-Oriented Programming Environment and Its Application to Distributed Multi-commodity Flow Problems, ICMAS-96, (1996), pp. 385-392.
- (6) Layard, P.R.G. and Walters, A.A., Microeconomics Theory, (1978), McGraw-Hill, London.
- (7) Okuno, H., Suzumura, K., Microeconomics I, (1985), Iwanami.
- (8) Shoven, J.B. and Whalley, J., Applying General Equilibrium, (1992), Cambridge University Press.
- (9) Kaihara, T., Supply Chain Management based on Market Mechanism in Virtual Enterprise, Infrastructures for Virtual Enterprises, (1999), pp. 399-408, Kluwer Academic Publishers, Boston.