An Internet Core-Based Group-Trading Model

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Abstract. Coalitions, which allow traders to form teams in e-markets, can sometimes accomplish things more efficiently than individuals. Concepts and algorithms for coalition formation have drawn much attention from academics and practitioners. However, most of coalitions are unstable and fall apart easily. The core has become a popular solution, because it provides a way to find stable sets. However its problems hinder researchers from applying it to a real world market. This paper proposes a core-based group-trading model, which involves bundle selling of goods, offering amount discount in group-buying in e-markets. Its outcome is compared with a traditional market under the scenario of a travel agent and is evaluated in terms of five criteria: the use of distributed computing, the degree of computational complexity, incentive compatibility, efficiency and effectiveness.

Keywords: Broker, Core, Coalition, E-Market, Shapley Value.

1 Introduction

"Much of the retail sector's overall growth in both the US and the EU over the next five years will come from the Internet," said the Forrester Research Vice President in March 2010 [1]. There are unceasing large potential profits for traders in Internet e-commerce. E-commerce is "where business transactions take place via telecommunications networks." [2]. E-market, also called e-marketplace, is a new trading model for e-commerce on the Internet in which incentive compatibility, distributed computing, and less computational complexity, are all highly relevant. Many traders gather together with different purposes and they can be grouped in varied formations in an e-market. There are two parties, the sellers and the buyers, who generally are regarded as conflicting parties. When a seller gains more profit in a transaction, this also means the buyer needs to pay more, and vice-versa. Is there any way to benefit both parties at the same time and bring them to work together? There are many practical problems that need resolving, when a model is built for the real e-marketplace.

When customers and suppliers get together and work out deals, they seize every opportunity to maximise their own profits. Forming coalitions on the Internet is an effective way of striving to achieve their goals. Therefore, concepts and algorithms for coalition formation have been investigated in both academics and practitioners [3].

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These research domains have approached the topic very differently. In Computer Science, the coalitions are formed in a precise structure to maximise the overall expected utility of participants. Since finding the coalition structure is NP-complete, researchers try to prescribe formation algorithms of less computational complexity [4]. On the other hand, the economics literature traditionally stresses the incentives of each selfish participant in a coalition [5]. The traders are self-interested to join a coalition only when it is to their own advantage [6]. A coalition with stability is in a condition when every member has the incentive to remain in the coalition.

Certain solution concepts for coalition problems related to stability notions have drawn much attention from researchers. The earliest proposed concept was called the stable set [7], which is a set with stabilities. Its definition is very general and the concept can be used in a wide variety of game formats. For years it was the standard solution for cooperative games [8]. However, subsequent works by others showed that a stable set may or may not exist [9], and is usually quite difficult to find [10]. The core has become a well-known solution concept because of its incentive compatibility and because the way it finds stable sets is more appropriate. It assigns to each cooperative game the set of profits that no coalition can improve upon [11]. The aim of this paper is to introduce a core-based model for e-markets. The concept of the core is described and its problems are discussed. Other solution concepts which are used to deal with these problems are introduced, and a new Core Broking Model (CBM) is proposed. The CBM aims to create a win-win situation for customers and providers in e-markets. The comparison between the results of the new model and a traditional market has been made.

2 The Core

The core plays an important role in the area of computer science and modern economics. The core was first proposed by Francis Y. Edgeworth in 1881, and it was later defined in game theory terms by Gillies in 1953. Individuals in a cooperative game are not only interested in maximising the group’s joint efficiency, they are also concerned with their own profits. If they can gain better profit by working alone without involving others, they will not join a group. If a group can produce a better profit by excluding certain people, it will certainly form a new coalition without those individuals [12]. The core is a one-point solution concept for forming stable and efficient coalitions by calculating the profits of different possible coalitions. Consequently, it is useful to adopt it into the mechanism in an e-market.

In economics, the core indicates the set of imputations under which no coalition has a value greater than the sum of its members' profits [11]. Therefore, every member of the core stays and has no incentive to leave, because he/she receives a larger profit. A core in a cooperative game $\langle N, v \rangle$ with n players, denoted as $C(v)$ of a characteristic function $v: 2^N \rightarrow \mathfrak{R}$, which describes the collective profit a set of players can gain by forming a coalition, is derived from the following function [13],

$$C(v):=\{ x\in\mathfrak{R}^n \mid x(N)=v(N), x(S)\geq v(S) \text{ for all } S\in 2^N\},$$

here N is the finite set of participants with individual gains $\{x_1, x_2, \ldots, x_n\}$. The $x(N) = \sum_{i\in N} x_i$ represents the total profit of each individual element in N by adding xi, which denotes the amount assigned to individual i, whereas the distribution of $v(N)$ can denote the joint profit of the grand coalition N. Suppose S, T are a set of pair wise disjoint non-empty subsets of coalition N. A cooperative game N is said to be convex, if

$$v(S)+v(T) \leq v(S \cup T)+v(S \cap T),$$

whenever S, T⊆N and for N∈2^N.

A convex core is always a stable set [14]. A game with x(N) = v(N) is regarded as efficient [13]. An allocation is inefficient if there is at least one person who can do better, though none is worse off. The definition can be summarised as "The core of a cooperative game consists of all un-dominated allocations in the game" [15].The profit of the allocations in a core should dominate other possible solutions, meaning that no subgroup or individual within the coalition can do better by deserting the coalition.

The core has been tested within some games in the previous work [16], with only one type of consumer and provider dealing with one kind of commodity. It simplifies the computational process of the core and helps us to understand the way the core works, although it seems a bit unrealistic. Undoubtedly, providing a way to find a stable set is one of the advantages of the core. It also gives that set incentive compatibility. In fact, the core is a Pareto efficiency [17], also called Pareto optimality. It is a central concept in Economics, proposed by an Italian economist, Vilfredo Pareto [18]. A Pareto improvement moves the current condition into a better situation that helps at least one person but harms no-one. And then, after some Pareto improvements, a situation will develop, called Pareto equilibrium, in which no Pareto improvement can be made at all. Pareto efficiency is important because it provides a weak but widely accepted standard for comparing economic outcomes. So its framework allows researchers to decide what is efficient.

Although it was proven that the core is always a stable set when the game is convex [14], a number of appealing sufficient conditions have to be identified to confirm whether it is stable or not [19]. The core may exist in different forms: unique-core game, multiple-core game or empty-core game [13]. Three problems of the core have to be solved in order to be applied in the real markets [20]. The first problem occurs when no stable set can be found in an empty-core game. It is a huge problem for everyone -- all the efforts will be in vain if no deal can be agreed with in a market. The second problem is high computational complexity [21]. The core tries to calculate the result of every combination of coalitions and finds the best outcome for a group and for the individuals. The process to find the core is NP-complete [22]. It is too complex to find a core in a large grand coalition. The third problem is that the core seems to deal with complete information only [16]. And these problems make it too difficult to apply in the marketplace.

3 Existing Solutions for the Core

Some solutions are introduced here for the problems of the core when it is applied in e-markets [23]. In cooperative games, the stability of cores is one of the most notorious open problems. It is important to have a stable coalition, for a game with an empty core is to be understood as a situation of strong instability, as any profits proposed to the coalition are vulnerable. Determining the stability of the core is NP-complete [24]. Attempts to solve the above problem seemed to have come to a dead-end, until a balanced game has been proven to have a stable core [25]. An important sufficient condition for a non-emptiness core, is that it is balanced. Let the game <N, v> be balanced. Then C(N, v)≠0 [26]. From the classical Bondareva-Shapley theorem, a cooperative game has a non-empty core if and only if it is balanced [27]. A game is balanced, if for every balanced collection B with weights $\{\lambda S\}_{S \in B}$ and the following holds,

$$v(N) \geq \Sigma_{S \in B} \lambda S \; v(S).$$

A collection B is called a balanced collection if

$$\exists(\lambda S)_{S \in B} \; \forall i \in N \; \Sigma_{S \in B,\, S \ni i} \lambda S = 1, \text{ where } (\lambda S)_{S \in B} \text{ is a vector of positive weights.}$$

It is rather easy to check the stability of coalitions with simple calculations in the above formula.

To locate the core in a coalition is NP-complete [27]. It can be helpful to divide a grand coalition into several small sized sub-coalitions [28] but it is not practical. Some papers show the collaborations of players can effectively reduce the computational complexity [28]. A broker may persuade traders to cooperate together. Suppose n brokers gather m traders. Instead of m traders, the core now only needs to deal with n brokers. Since n is much smaller than m, the size of the coalition is therefore successfully reduced.

When providers collaborate together, it is very important to make sure all of them in the coalition can get what they deserve. Shapley value [14] presents a fair and unique way of solving the problem of distributing surplus among the players in a coalition, by taking into account the worth of each player in the coalition. Assume a coalition N and a worth function v:N→$\mathfrak{R}$, with the following properties,

$$v(\emptyset)=0,\; v(S+T)=v(S)+v(T), \text{ whenever S and T are subsets of N.}$$

If the members of coalition S agree to cooperate, then v(S) describes the total expected gain from this cooperation. The amount that player_i gains is,

$$Sh_i(N)=\Sigma_{S \subseteq (N \setminus \{i\})} (|S|)!(|N|-|S|-1)!/|N|!\,[v(S \cup \{i\})-v(S)].$$

It shows the fact that collaboration can only help and can never be harmful.

4 Core Broking Model (CBM)

This core-based model involves joint-selling of multiple goods, offering volume discount for group-buying coalitions in e-markets. Several providers conduct bundle selling together, while, on the other hand, many buyers form coalitions for the amount discount in the e-markets. The descriptions of its components, which are in the structure represented in Fig. 1, are as follows:

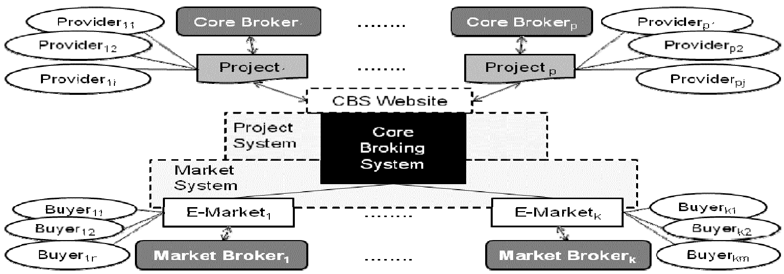

Fig. 1. The Structure of the CBM

- **Core-brokers:** the initiators of the group-trading projects.
- **Projects:** Each project has several sessions of group-trading in e-markets.
- **Providers:** The core-brokers invite them to provide products and services for customers.
- **Market-brokers:** who play the role of team members to help with the group-trading projects.
- **E-markets:** may be any existing online shopping avenues such as eBay or the market-brokers' own sites on which they can post projects and find customers.
- **Buyers:** the market-brokers' clients, who have been attracted to the projects.
- **The Core Broking System** (CBS) consists of three components as follows:
  - **CBS Website:** list of group-trading projects. It is a place where core-brokers and market-brokers meet together. Its resolution centre is designed to deal with any problem with a transaction. Members of the site can report and open a case for a problematic transaction.
  - **Project Subsystem:** a system specially designed to assist the core-broker in managing all the necessary tasks to assure quality outcomes.
  - **Market Subsystem:** by, the market-brokers can use it to perform transactions for a session on a project; purchase electronic coupons from the core brokers and sell them to their clients.

The system flow chart of the model is shown in Fig. 2 and was illustrated in one of my papers [29]. A brief description for the six stages in the process is as follows:

1) **Initiating** – In this stage, a core broker setups a proposal for a group-trading project, settle the project with some providers and lists the project on the CBS website.
2) **Commencing** – After recruiting several market brokers, the core broker officially begins sessions of group trading in the group-trading project.
3) **Gathering –** The market brokers attract buyers to their websites, combine the orders of buyers into market-orders and submit the market-orders to the core broker.
4) **Combining** – The core broker checks the stability of the coalitions, combines the coalitions together, decides the final prices for the items and sends acceptance notices to the market brokers.
5) **Closing –** When the buyers have paid for their purchases, they receive coupons. Finally, the brokers close the deal with their clients and the benefits of the participants are calculated.
6) **Terminating** – The core brokers backup the tables and analyse the transactions in the sessions of the group-trading project for the future use.

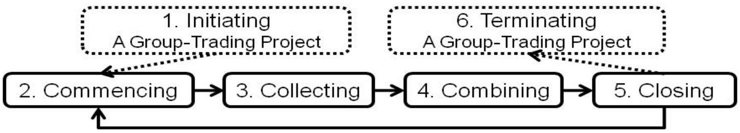

Fig. 2. System Flow Chart of the CBM

To ensure a healthy level of competition, the new model adopts brokers to prevent price makers. The brokers make possible the collaboration between the members of coalitions. Core-brokers are like project managers, while market-brokers act like salesmen in the CBM. The core-brokers initiate projects on the CBS website. The market-brokers promote products of the project on the appropriate shopping sites and form buyers' coalitions there. The core-brokers invite providers to perform joint-selling to increase the 'competitive advantage' [30]. They provide all the necessary information to the market-brokers for them to promote the product and market it. Each session has a starting and an ending date. The suggested duration for a session is usually one week. The iterative process is looping between stage 2 and stage 5. At the end of a session, the core brokers may choose to have a new session of trading or stop the project for good.

There are several assumptions used in the CBM [29]. The model manages the orders on a First Comes First Serves (FCFS) basis. There are many ways to decide how to distribute the items fairly. Other than FCFS, another option is to use the Shapley value, which is decided by the original amount ordered by each customer. An agreement may also be reached amongst the customers on the distribution over the conflicting issues through a multiple stage negotiation process [31].

After surveys to current markets, a fees system for the CBM including the commission for brokers and how the members of the CBS site pay their fees was constructed. Four kinds of fees: final value fee (FVF), handling fee, session fee and online store fee (OSF) are suggested. Session fee of £30.00 is the only fee the core-brokers need to pay for a project, when they list a session in a project on the site. An OSF of £24.50 is a suggested monthly fee for market-brokers, who wish to open an online store on the CBS site including purchase of domain name, server use, maintenance etc. A FVF is 5.5% of final selling price. When a FVF is paid by the providers, it is then divided into 3 portions. The core-broker takes 2%, the market-broker gains 3% and the CBS site keeps 0.5%. A handling fee from the buyers rewards the brokers, because they combine the orders and let the buyers get better discounts. It is 15% of the extra discount, after each of the brokers has processed the orders.

When buyers pay for their orders, they receive electronic coupons from the brokers. Each coupon has a unique ID to ensure that one coupon is redeemed only once. No extra fee for shipping is charged, when they claim the real products and services from the providers printed on the coupons. Alternative payment methods are used including bank transfers, PayPal and utility & debit cards. The results of surveys in Tulsa indicated that most sellers do not feel any risk associated with transactions with a reliable payment mechanism [32]. Bank transfers are regarded as secure and are a common and efficient way of making payments today. PayPal is an alternative safe way but it involves additional cost [33]. The providers and the core-brokers are assumed to receive money by bank transfer, while customers pay for their items via PayPal.

A prototype of the CBS was developed in C# under the development environment of Visual Studio 2008. It consists of one CBS website and two subsystems: the project subsystem and the market subsystem. A database was designed for the CBM so that the core-brokers and market-brokers can manage and store all the data they need to fulfil their tasks in the group-trading.

5 Evaluation

One possible way to evaluate the CBM is to use it in a real-world site and collect data from it. A CBS site has been developed, but the crux of this paper is to make a comparison between the CBM and a traditional market (will be referred to as TM). At this stage, a real-world test would be inappropriate; further it would be unlikely to produce the data set necessary for a rigorous testing, for instance, the costs of the products should be private data of the providers. In order to calculate the net profits of every provider, the costs of the products need to be given here. Therefore, a simulation system was developed to evaluate the CBM using the scenario of a travel agent and was used to produce outputs from the TM and the CBM.

Core-broker Ben created group-trading project S1: 'Summer Time around the Midlands' by integrating the products from the three providers offering inexpensive hotel rooms and low car rentals for economical travel in the Midlands. The purpose of the project is to enable sessions of bundle selling by integrating the resources of the providers. By offering volume wholesale discounts, customers may form groups in order to purchase items. Coupons can be chased and sent to the providers on them and exchanged into hotel rooms or car for the buyers to travel around the Midlands in the UK.

The simulation system was written in C# in the Visual Studio 2008 development environment. The results in this paper were produced in it on a common personal computer with Windows Vista. The system contains a Test Case Generator (TCG), a TM Simulator (TMS) and a CBM Simulator (CBMS). The TMS is based on the core concept and aims to find a core of the coalition in a TM. The CBMS is built to the pattern of the CBM and aims to find a bigger core of coalitions in multi-e-markets. The data generated by the TCG were put into the TMS and the CBMS at the same time. By examining the outputs of the TMS and CBMS, a comparison between the TM and the CBM using the following five criteria:

Table 1. Distributed Computing

Distributed Computing	CBM	TM
Multi Computers	Yes	No
Internet	Yes	Maybe
Multi e-Markets	Yes	No

1. **Distributed Computing:** To fit in a distributed computing environment, by nature, a distributed model requires involving multiple computers to be effective. Another two distributed contexts, namely Internet and multi-markets, are used here to assess the models too. The core is used to find a stable set of a coalition in a TM. This is normally done on one computer. It might cause extra complexity if this problem were to be solved by using multi computers. The TM might transfer into an e-market where it would allow customers to place orders via the Internet, but it is difficult to apply it to multiple e-markets in the Internet environment. Table 1 shows the results of the CBM and the TM in distributed computing.
2. **Computational Complexity:** can be expressed as big O notation, which is also a useful tool to analyse the efficiency of algorithms regarding the time it takes for them to complete their jobs. Assume there are p providers, b orders and g products in the market. There are at most 10 order lines in an order. The number of sub-coalitions is $(p+1)^b$. The fact that CBM has less computational complexity than the TM can easily tell by examining their big O notations. The TM and CBM are $O(n^n)$ and $O(n^2 \times 2^n)$ respectively.

   A task, which uses Shapley value to decide the number of items for each provider, is proven to be a time-consuming job. It have nothing to do with the number of buyers, but mainly come from the number of providers, i.e. p. Assume p is limited within 20, its big O becomes $O(n^2)$ and can be classified as an algorithm with low computational complexity. The computational complexity can be dramatically lessened in the CBM by limiting the number of providers.

   One interesting finding in this paper is that CBM's computational complexity will not become higher, when there are more orders in the e-markets, so market-brokers are free to take as many clients as they could in their e-markets. However, it may take time for

them to negotiate with buyers if the size of a coalition becomes too big or the communications get too busy. In order to make sure brokers to collect the orders in time, one important principle is to limit the size of coalitions in e-markets within one group-trading session, and this needs to be applied in the model. It is usually the brokers who monitor the size of coalitions in their e-markets. All of the brokers have to follow this principle in order to prevent situations where a coalition becomes too large to handle.
The aim is to produce outcomes for a group-trading project on an average computer within a reasonable time. To achieve this, a core-broker should limit the number of suppliers to form a group-trading project. The suggested number of providers is 15.

3. **Incentive Compatibility:** It is crucial to give people incentives to participate in online trading. The effectiveness of both models is assessed by comparing the benefits for participants. In order to compare the incentive compatibilities, the assumption has been made that providers are willing to offer more volume discount to customers if a group of them purchases the same item from the same provider in the core, although it is rather unusual for them to give customers such discounts in the TM. If this is not done, there will be no means of comparing the two systems.
There are three incentives for traders: discounts, an equilibrium price and a fair distribution. The providers offer volume discounts to customers in the CBM. If the core may be empty and unstable, an equilibrium price will not be reached in a coalition. The CBM performs a stability check to make sure that there is a best price for traders. By using the Shapley value, the CBM can make a fair decision as to which items are allocated to which provider, even when customers' requirements are less. The CBM provides fair shares to customers and providers, but the TM does not. Fair distribution is crucial in teamwork. The providers might leave the team if the profits have been distributed unfairly, even though the profit they can get out of it is good. In the CBM, suppliers have a great chance to sell out their products. Even if the customers do not purchase all that is on offer, the suppliers still get their fair share. This will also give them satisfaction. Table 2 shows the CBM has higher incentive compatibility than the TM. The CBM created a win-win situation for all participants in a group-trading session.

Table 2. Incentive Compatibility

Incentive Compatibility	CBM	TM
Volume Discount	Yes	Yes
Equilibrium Price	Yes	Not Sure
Fair Share	Yes	No

4. **Efficiency:** It generally describes the intent to which some valuable resources are well used for an intended outcome. In this paper, the efficiency of the CBM and the TM are judged by the time and cost which they use to complete tasks. The CBM is more efficient than the TM in collecting the necessary data to find a stable set. It is a time-consuming job to collect the information of marginal utility functions, which describe the values that customers are willing to pay for the goods and the price the providers want to sell them for. Collecting such information can be a big problem in the TM. On the other hand, the inputs needed for the CBM, which are price lists and orders, are market information and can easily be collected by a core broker.

Table 3. Efficiency in the CBM and the Core

Efficiency / *Task*	*Less Time*		*Less Cost*	
	CBM	TM	CBM	TM
Information Collecting	√	-	√	-
A Stable Set Finding	√		-	√

Table 3 shows that the CBM has better efficiency than the TM. By jointing providers together and combining orders from multiple e-markets, the CBM becomes more efficient than the TM in locating a stable set in a large coalition. Firstly, it hides the information of providers and customers to ensure that there are less information and quicker data transfer between e-markets. Secondly, the CBM successfully reduces the computational complexity and executing time in group-trading, but there are extra costs in doing so, including some expenses involving multiple e-markets and the commissions for the brokers.

Table 4. Effectiveness in the CBM and in the TM

Effectiveness	*Normal Buyers*		*Demanding Buyers*	
	CBM	*TM*	*CBM*	*TM*
More Net Discount	√	-	√	-
More Profit	√	-	√	-
More Net Profit	√	√	√	-
More Total Benefit	√	-	√	-

5. **Effectiveness:** It includes the discounts to customers, the profits for the providers and the total benefits. The net total benefits excluding the extra expenses to the brokers need to be checked to certain that it is worthy to spend the costs to perform group-trading in the CBM. There are effectiveness of data protection and fairness in the CBM. Market brokers can hide their customers' personal information before they submit orders to the core brokers. In a market, it is usual that if the customers get better discounts, then the providers receive less profit. To ensure the CBM has taken into account the interests of both customers and providers, the average discount that buyers can obtain and the average profit of suppliers are examined here. In this way, the CBM can be evaluated to see whether it gives more benefits than the TM to both customers and providers. Table 4 shows that the customers gain higher discounts in the CBM in both scenarios: the one with normal buyers, and the one with demanding buyers, who ask for extremely high discount for every item. Table 5 summarises the effectiveness in the CBM and the TM.

Table 5. Effectiveness

Effectiveness	*Data Protection*	*Fairness*	*More Discount*	*More Profit*	*More Total Benefit*	*Commission*
CBM	√	√	√	√	√	√
TM	-	-	-	-	-	-

The above comparison between the results of the CBMS and the TMS shows that the CBM is superior to the TM, in terms of five criteria: the use of distributed computing, the degree of computational complexity, incentive compatibility, efficiency and effectiveness. The results from the simulator also demonstrate that the CBM can bring more profits to providers and attract both demanding and normal customers to e-markets.

6 Conclusion

Because the customers can gain higher discounts, the CBM can really attract them to the e-markets and encourage them go through with their purchases, so that the providers can also earn more profits in it, even after part of the profits goes to the brokers as commission. A wise trader, no matter buyer or seller, will definitely choose to join the group-trading in the CBM rather than stay in the core of a TM. The above evaluation has proven that the CBM creates a win-win-win situation for buyers, sellers and brokers.

The new model has overcome a number of group-trading problems on the Internet. The main contribution of this research is the CBM, but during the process of creating this new model for group-trading in e-markets, three additional issues have emerged which also made a contribution to knowledge in this field: (a) the advantages and problems of the core (b) the check of stability for a coalition and (c) the use of brokers in group-trading.

All systems are capable of improvement and some issues with the CBM can be identified. There will be two main targets for future research. One main target will be to create more incentives for participants. Another target will be to expand the CBM by including particular e-markets and selling a great diversity of products and services on them.

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