ABSTRACT
We are exploring the design and creation of information markets with a goal of bringing an electronic, distributed market to a community or an organization to enhance knowledge sharing, innovation creation, and productivity. We apply innovative market mechanisms to construct incentives while still encouraging pro-social behaviors. A key advantage of this study will be a direct appeal to information economic theories and market principles on information markets design. A web-based software platform called Barter is developed and deployed at several university sites. User data have been collected and analyzed to test the effectiveness of an information market and its various forces. In this paper, we focus on presenting the framework design of an information market, and demonstrating why such market architecture provides a long-term sustainable incentive structure to an organization and its members. We also present in this paper key findings we have learned through system deployment.

Categories and Subject Descriptors
H.4 [Information Systems Applications]: Miscellaneous;
H.5.2 [Information Interfaces and Presentation]: Miscellaneous

General Terms
Design, Economics, Management

Keywords
Knowledge markets, Information markets, Mechanism design, Organizational design, Incentive design, Information economics

1. INTRODUCTION
1.1 Background
Knowledge and innovation represent significant organizational resources and directly impact organizations' success and competitiveness. A class of information systems, referred to as knowledge management systems (KMS), have been promoted both by researchers in academia and by industry leaders in practice [2]. Firm managers often appreciate the critical role of knowledge management systems in retaining employees' knowledge, encouraging information sharing and innovation creation, and enhancing work productivity, usually through the usage of 'Enterprise Web 2.0' platforms. However, a discouraging fact is that more than 70% of KMS initiatives among U.S. organizations are underperforming mainly because of the adoption problem [12]. An important reason for the failure is that the incentive structure has not been designed and constructed properly. Members of an organization, e.g. firm employees, lack the incentive to participate and share information, especially in the presence of their existing work commitment and reporting hierarchy. In several other cases, the competitive culture of the organization actually dis-incentivizes its members from sharing knowledge, either because a question or a request might be interpreted as a signal of weakness, or because people believe sharing critical knowledge or information implies giving up their competitive advantages. These practical challenges faced by many firms, especially the ones with competitive environments and relatively scarce resources, in part motivated the research work presented in this paper.

The concepts of KMS and internal social media are closely linked to recent research development on crowding sourcing and collective intelligence. “Incentive” is considered as one of the “genes” that constitute collective intelligence [11]. However, organizations' management usually carries out incentive design in a central-planning manner, neglecting the power of the crowd itself in determining appropriate rewards. As a result, though many organizations invest significantly in incentive design when deploying an internal KMS, the measures taken often fail to achieve long-term effectiveness, fairness, and stability.

In our research, instead of building a knowledge management platform, we aim at establishing a “knowledge economy” inside an organization. We apply market principles to the underlying mechanism in order to address the challenge of incentive design, and use the price tool to balance the supply and demand of knowledge, innovation and even user activities. In the knowledge economy, users can share information, contribute innovative ideas, serve requests, etc., and get rewards that truly reflect the value of their efforts, as determined by the markets. [3] lays some of the theoretical foundation for designing an internal knowledge market. Quoted from this article:
“Managing the information economy within the firm can improve forecasting, innovation, and productivity.” ... “Markets cause resources to speak up and self-identify. Markets provide the framework to arbitrage the gap between problem and opportunity. To get these benefits, executives must bring market forces to bear within the firm. The rules, the rewards, and the running of internal markets differ from those of a hierarchy.”

The importance of incentive mechanism design goes beyond the scope of an organization or knowledge management. Nowadays, web and mobile platforms are pervasively used to collect resources and wisdom from the crowd to complete tasks and spread information collaboratively. Incentivizing users to participate and contribute in such networked systems has become a critical issue. For instance, the winning strategy in the DARPA Red Balloon Contest incentivized users to forward information by rewarding users along a social path connected to the user who found the balloon [14]. The complexity of the incentive structure depends on the time horizon of the system’s intended use.

When we develop the framework of “Open Transaction Networks (OTN)”[10][9]. In OTN, users share their personal transaction histories and associated opinions in order to explore the full social value of transaction information. A crucial assumption and challenge here is that users have the incentive to share private information within their social networks, and receive benefits and rewards appropriately.

In this research, we focus on an organizational setting, where management of the organization tries to design the optimal incentive structure to maximize internal information sharing, innovation creation and productivity under certain constraints. An information market is deployed at the core of the platform, joined by “social substitution”, which provides the general incentive structure. Our research provides specific design details, and insights into problems pertinent to information markets through software deployment and data analysis.

Several subareas of economic theories constitute the theoretical foundation of this research, and guide the design of an information market in practice, which include:

**Economics of Information** while a classical problem in this domain is about information asymmetry, we focus on another important aspect, which is when information is traded as a product or “commodity”. When information is generally considered non-excludable with zero repetition costs, how shall we design a market platform that takes these characteristics into consideration and prevents market failure[11].

**Two-Sided Market Theory** describes how to promote adoption of a technology standard and stimulate third-party development by subsidizing user/developer network effects. For knowledge management, this tells us how to get users to adopt a new system and how to subsidize content creation and content consumption so employees themselves add continuous value.

**Price Theory** describes how markets efficiently allocate resources across an entire economy using only private information. It also tells how markets supply missing goods. For knowledge management, this is critical in getting people to produce valuable knowledge for others but only when this is more valuable than what they are already doing. It can also tell us how to value intangibles.[8]

**Quantity Theory of Money** or more broadly macroeconomic theories on monetary policies, describes how to manage a supply of value – money, credit, and points – to achieve economic vitality and growth by choosing expansionary or contractionary policies. For knowledge management, this shows how to stimulate and regulate trade volume in the firm’s internal knowledge economy[7][6].

**Financial markets theory** provides the rules and guidelines when information products are securitized and exchanged on a secondary market [13]. The theory also covers computerized market-making algorithms[9].

In addition to the economic theories listed above, several other research fields also play crucial roles in the design process of an information market and determine its overall success. For example, Natural Language Processing (NLP) is applied when we need to compare, sort or index textual information contents users create. Social network modeling and analysis techniques are instrumental in understanding the dynamics of social interactions and how information propagates through the network. Information presentation and visualization is particularly important when we design dashboards and gadgets to monitor or control global/personal economic activities. Another closely related area is user interface design, or more broadly, human-computer interaction (HCI) design, which determines the usability and user experiences of the software system.

### 1.2 Research Problems & Goals

The problem is originally motivated by the actual failure of KMS inside organizations. However, the significance of information markets design, or more broadly, incentive mechanism design, goes well beyond the scope of organizational knowledge management.

The prevalence of web2.0 systems, mobile devices and pervasive internet access creates unprecedented information ecology among human beings. The abundance of information and the convenience of accessing information also create a strong demand for organizing information and quickly identifying the most critical bits of knowledge. This is often accomplished in a decentralized process, dubbed as “crowd-sourcing” or the “wisdom of crowds”. Users collectively share their knowledge, evaluate and validate knowledge or information they receive from peers. A flurry of platforms have been invented and established on the web or on the mobile network to realize this crowd-sourcing model. Goals and functions of these platforms are widely diverse, including social bookmarking (reddit.com), review/rating exchange (yelp.com, Amazon.com), Q&A (quora.com, vark.com), to name a few examples. Moreover, there are new models and systems being continuously developed and released to customers.
The premise of these systems is that users have the incentive to spend some time of their already hyperactive-packed daily lives, and share their knowledge with others or perform certain activities. Whether a solid and sustainable incentive structure is designed and systemically placed crucially determines the success of these systems that rely heavily on user participation and contribution.

There are many starting points to design incentives. People contribute their personal resources (time, knowledge, skills) for a variety of reasons: altruism, gaining reputation, expertise promotion, fun, self-learning, etc., which can be broadly categorized into “social incentives” and “economic incentives”. The primary goal of this research is to design an information market in a pro-social manner, providing a rigorous incentive mechanism based on market principles while preserving the significance of pro-social behaviors in the system. Many existing systems, including KMS platforms or internal social media platforms that organizations deploy, rely more heavily on social incentives, and barely explore the creation of a proper market incentive. In some other cases, the platform recognizes the importance of providing economic rewards for users’ contribution; however, users are not rewarded fairly based on the true value of their contribution. In addition, such reward plans are not sustainable, lacking long-term effects needed to maintain users’ interests and participation.

These challenges inspire us to reconsider and compare how we human beings organize our production and wealth distribution in the real world: we have created a product-service economy with market forces that guide the allocation of resources and direct human power. Pivotal factors of such a decentralized economy include currency, centralized control and regulation, and other non-market determinants such as social forces. Though stumbling occasionally, a well-established economy sustains its growth, fairness, and efficiency. The next question is: can we extend and apply the power of a market-based economy to the domain of information and innovation management? If so, how to design such a market where information and innovation products exhibit peculiar characteristics?

At a high level, the goals of this research include:

- Identify circumstances and conditions where a market-based mechanism is applicable and effective;
- Understand the relationship and trade-off between social incentives and market incentives, and how to design a market in a pro-social way;
- Identify building blocks and crucial elements when constructing information markets, and dependencies and linkages among them;
- Study and measure the strength and effects of various market forces;
- Explore the impacts of user interface design in the adoption and efficacy of the platform.

The scope of this research is very broad, and there are a wide spectrum of related research questions and issues from diverse fields we can address. This paper aims at defining and establishing the framework of designing an organizational information market, and stimulating discussions on this new research area.

The remainder of this paper is organized as follows. The focus of this paper is on the framework design of an information market, which is covered in detail in the next section. Section 3 introduces the software deployment and discusses on lessons learned from collecting and analyzing user data. We conclude and point to future directions in the last section.

2. SYSTEM ARCHITECTURE

In this section, we focus on the framework design of an information market, and introduce its software implementation. We present in detail the market framework we have designed, and illustrate key concepts and design choices by using diagrams and screenshots from the software. The best way to fully understand the system as well as the research is to join Barter (http://iknow.mit.edu/) as a user and navigate its features.

2.1 Overview of Barter

What is Barter? Broadly speaking, Barter creates an information economy inside an organization.

- Barter is a market-incented wisdom exchange, or simply speaking, an information market, designed for organizations and communities to maximize the creation and usage of knowledge and innovation from their members;
- Barter applies a multiplicity of sub-type markets to address different organizational challenges;
- Barter provides a mechanism to monitor and govern the economy, and apply macroeconomic policies to influence its running;
- Barter is capable of measuring the value of information, and provides a long-term sustainable incentive structure to reward information contributors fairly and encourage user participation;
- Barter provides solutions to several problems that commonly happen to new IT platforms using innovative market-based approaches. Examples of these problems include early elicitation of participation, system abuse and fraud, system growth and self-improvement.

While the interface and the experience of using Barter is clean and straightforward, the internal mechanism of Barter is sophisticated. We find it helpful to compare side-by-side Barter with the U.S. economy and understand how different components of the platform operate, as shown in Table [1].

Table [1] displays the list of crucial elements of the U.S. economy, and their counterparts on Barter. It is worth emphasizing that by applying a more advanced infrastructure and system design, we are able to enable certain functions and features that are not feasible in our real-world economy, as explained in detail in subsequent subsections.
Table 1: Comparison between U.S. economy and the Barter information economy

<table>
<thead>
<tr>
<th>U.S. Economy</th>
<th>Barter Information Economy</th>
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<tbody>
<tr>
<td><strong>Currency (U.S. dollar)</strong></td>
<td>Barter implements its own virtual currency system. A unit of currency is named a “Yuanbao”. It is a single-typed currency universally accepted and circulated inside Barter. Users can exchange “Yuanbao” for either knowledge or physical rewards. Advanced features of Barter’s currency system include serialization and expiration.</td>
</tr>
<tr>
<td><strong>Markets for products &amp; services</strong></td>
<td>Barter implements multiple types of markets to meet various organizational needs, such as 1) Q&amp;A market, 2) document exchange, 3) idea market, 4) prediction market, 5) service market, 6) news market, 7) reward auction market, 8) self-design market, 9) fraud market, etc. These markets are referred to as “primary information markets”.</td>
</tr>
<tr>
<td><strong>Federal Reserve Bank &amp; monetary policies</strong></td>
<td>Barter establishes an entity, dubbed as the “world bank” to track the issuance and retrieve of currency into and out of the economy. A set of dashboards is designed for the “chief economist” of Barter to monitor and understand the status of the economy. Another set of economic tools is implemented and can be used by the administrator to adjust certain parameters of the economy and impact its operation and running.</td>
</tr>
<tr>
<td><strong>Organizations versus Individu al s</strong></td>
<td>Users on Barter can form groups, and perform intra-group or inter-group market activities. A more advanced grouping structure is called a “guild”, of which users have to “earn membership” by accumulating enough expertise points on a certain field.</td>
</tr>
<tr>
<td><strong>Regulatory bodies</strong></td>
<td>Barter employs self-governing and regulation by resorting to the crowd and creating similar market incentives.</td>
</tr>
<tr>
<td><strong>Securitization and secondary markets (Equity, Commodity, Bond markets, and Derivative markets)</strong></td>
<td>On Barter, information products can also be securitized and the information securities can be traded on a secondary market. Securitization can be applied to multiple markets, such as the Q&amp;A market, the document exchange and the idea market. Such derivation increases market thickness, helps sort and organize information by its value, and improves the timeliness and quality of information by establishing ownership.</td>
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</table>
2.2 Design Principles of Barter

Barter is a market of a special type - an information market, where information products are exchanged among users. However, Barter first needs to adhere to the general principles of markets design, as summarized in the diagram in Fig.1. The four principles listed in Fig.1 need to be satisfied in order to have almost any type of market running stably and efficiently.

Next, when the exchanged goods in a market are information products, the following characteristics of information need to be carefully taken into consideration when designing Barter, as illustrated in Table 2. Otherwise, the market is prone to failure.

2.3 System Architecture

Before introducing how each individual market on Barter works, we first present the system architecture of the entire Barter platform, as depicted in Fig.2.

The infrastructure that underlies and supports Barter involves two critical modules: a social network backend and a transaction backend.

In the middle layer lies the core of the system - a suite of various types of information markets designed to satisfy different organizational needs. Users on Barter perform most of their market activities through these different types of markets. Three important modules, 1) Economy Monitor/Control module, 2) Knowledge indexing/storage module, and 3) Expertise matching module, are designed and built as peripheral modules around the suite of markets, and are instrumental in managing information and maintaining the health of the economy.

On top of the system hierarchy is an interesting but powerful layer called secondary markets of information, also introduced in Table 1. It is built on top of two mechanisms - 1) information securitization and 2) fair distribution. Secondary information markets address some very significant challenges such as the lack of incentives to spend or insufficient market liquidity.

In the following subsections, we first introduce the functions and mechanisms of different types of markets, and then discuss about each individual module in the system diagram.

2.4 Multiple Types of Information Markets

These different types of information markets are the primary interfaces to end-users. An organization deploys these markets (or a subset of them) to address different challenges. A list of various types of markets with their names and short descriptions are illustrated in Fig.3. These markets are referred to as primary information markets, as opposed to “secondary markets” when we discuss about securitization and fair distribution later.

Currently, in the software implementation of Barter, all markets except the service market and the prediction market have been implemented and operational, to various degrees. Prediction markets have already been extensively studied in the research community and in industry practice. Instead, we propose a prediction market built on top of an idea market, and plan to test its effectiveness through experiment.

Fig.4 displays a screen shot of the Barter platform. The tab bar on the top-right shows a list of information markets the user can access and participate in. Two dashboards selected from the “Global Economy” monitoring panel are shown in Fig.5, which illustrate the transaction volume categorized by market types, and transaction types.

Elaborate descriptions of how each type of market operates require considerable page space. Therefore, we only select the most significant features and explain the design choices. Fig.6 highlights three independent and special markets, whose roles and mechanisms are distinctly different from other markets.

2.4.1 Design Market
Table 2: Challenges of Information Products and Barter’s Solutions

<table>
<thead>
<tr>
<th>Characteristics of Information Products</th>
<th>Barter’s Design and Solutions</th>
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<tr>
<td>Information and innovation has spillover effects, and is non-excludable</td>
<td>1. The spillover effects should not be treated negatively in the context of organizational knowledge sharing and innovation creation. A more important issue is to reward information creators fairly; 2. We have devised algorithms to track information reuse, trace back contributors, and reward them fairly. 3. We encourage pro-social behaviors to reward information providers, such as tipping.</td>
</tr>
<tr>
<td>Information is costly to create and costless to replicate</td>
<td>1. The fair distribution mechanism guarantees that original information creators get continuously rewarded for providing valuable information; 2. A market-based approach for the detection of fraud and copyright infringement; 3. Several mechanisms are in place to protect information providers. For example, answerers in the Q&amp;A market can choose to hide their answers until the question expires.</td>
</tr>
<tr>
<td>Evaluation of information requires accessing non-excludable information first</td>
<td>1. Rewards are offered by information seekers upfront, and are frozen by the World Bank to enforce payment and allocation. 2. Information seekers get penalized for ignoring to judge information quality and distribute rewards, and charged for extending the expiration time.</td>
</tr>
</tbody>
</table>

Figure 3: Various types of information markets on Barter: names and functions

Figure 4: A screen shot of Barter - A user is viewing all ideas submitted in the iDea market; the tab bar at the top displays the list of information markets she can access.

Figure 5: Two “global economy” dashboards displaying pie charts of total transaction volume by a) market types, and b) transaction types.

The purpose of the design market is to empower Barter to keep improving itself by having new features, bug fixes, and detecting market defects through the market mechanism itself. We also call it “design for self-design market”.

Instead of having the IT department take the full responsibility of maintaining the system, discovering market loopholes, and prioritizing new features or bug fixes to implement, an organization can utilize the market platform itself to achieve these goals much more wisely efficiently.

The crowd of users collectively helps design the market and prioritizes tasks. When a user discovers a bug, a market loophole, or needs an extra feature, she can submit it to the iDesign market and offer a certain number of points as rewards to developers if her idea gets implemented. Other users can vote on the idea to change its priority. If they deeply like the idea and want the idea to be realized sooner, they can supplement more points to the pool of rewards. Fig. displays the interface for an idea and related controls.

2.4.2 Product Auction Market

iBid is an auction market where users can exchange their virtual currency for physical products or services they enjoy...
in real lives. Any user can post an item for sale and other users bid on the item using their “Yuanbao”, as they do on eBay with real money. iBid provides a mechanism for users to acquire points when they run out of points, or cash out points for physical rewards. We need to emphasize two important roles the product auction market plays which are critical to the entire information market framework:

1. It provides the organization’s management with an important tool to offer long-term sustainable monetary incentives to the platform. The auction market isolates the monetary incentives from unnecessary details of information creation;

2. It provides an important mechanism to take virtual currency out of circulation when the “chief economist” exerting contractionary monetary policies.

We will revisit this issue when we discuss about incentives and organizations’ strategies later.

Fig. 7 displays a screenshot of the product auction market. As seen from the list of products on sale, users are creative in choosing what products/services to sell.

2.4.3 Market Fraud and Fraud Market

A companion of any type of market is market fraud, which jeopardizes the market safety as highlighted above. Possible types of market fraud include

Money laundering For example, a user transfers points to another user by asking a simple question and allocating all points to the other user who just provides a naive answer. The goal is to 1) boost the user’s expertise status for related tags, or 2) turn unearned points into earned points.

Market abuse Users leave garbage comments or information to earn system subsidy.

Copyright infringement There are two possible cases - 1) upload copyrighted materials in the document exchange, or 2) directly plagiarize other users’ content and paste without acknowledgement.

All these types of market fraud were evident in our research deployment, where we did not deploy a governing and regulatory mechanism. To clean and prevent future market fraud, we have designed a market-based mechanism, i.e., the fraud market. Detection of market fraud is sourced to the crowd. For example, when a user detects a potential fraud or inappropriate content, she can red flag it. When flagged enough times, a case will be moved to the fraud market, where users can vote on whether the case actually involves a fraud. When the case is closed and a verdict is made, users who vote on the right side will be rewarded. The offender gets penalized so that she experiences both economic losses and social damages on reputation.

2.4.4 Other information markets

In this section, we briefly explain the roles and functions of the other major types of information markets.

Q&A Market (iKnow) is an information market that allows users to ask questions to the Barter community and reap a profit if their questions become popular. Each time a user asks a question, she needs to create an associated reward and an expiration date by which all answers must be received. When the question expires, the asker can receive answers and divide up reward funds based on the quality of the responses. The asker can also rate each answer so that users know the quality of provided answers. Other users can vote on answers, and if they find an answer really helpful, they can tip the answerer with extra funds. Fig. 8 shows the page of a Q&A interaction.

Document exchange(iDoc) is an exchange that allows users to share documents with the Barter community. Other members of Barter can rate the documents, and pay a one-time fee in order to download or view what others have posted. When a user tries to post and share an important and original document, she can set the price of the download that each user must pay when accessing the document. If a document contains an idea which gives rise to other related contents on Barter, the original contributor receives a kickback for posting the original document.
Figure 8: The page of a Q&A interaction in the iKnow market.

News Market (iNews) is an information market that allows users to post articles, news, or announcements to the Barter community and reap a profit if their postings become popular. Members of the Barter community can vote on all submissions, and the popularity of a posting snowballs over time as top trending posts work their way to the iNews front page. When a user posts an article, news item, or personal anecdote, she needs to allocate for the posting an initial value (Budget) and a set number of points that are given to users who read her story (Points Per View, or PPV). It is helpful to think of PPV as an advertising cost paid for each user: when people read her story for the first time, the amount of points set as PPV is deducted from the user’s Budget. When the Budget runs out, the post expires.

Views are not the only factor that affect a posting’s Budget – votes from viewers play a crucial role as well. Whenever a posting receives an up-vote, PPV points are credited back to its Budget, which means that users who read and up-vote a posting help its Budget – and since users can vote multiple times, a posting’s Budget will increase if it would attract many users. By contrast, a user may down-vote a posting, which harms the Budget by subtracting PPV points for each downvote. Since voting affects the Budget significantly, we put safety measures in place to mitigate the market risk - for each additional vote, the cost of voting increases exponentially to the same user.

Idea Market (iDea) is a marketplace for innovation, and for matching solutions to problems. A user can either submit a standalone idea or submit one in response to another user’s request. A member of an organization might have innovative ideas on the organization’s operations, products or activities. She can submit her ideas on the idea market, get them examined, validated and improved by other members, and receive rewards when an idea gets promoted by senior management or even adopted. Another use case is like an “online brainstorming” session. A user might need inspirations on a particular problem, such as “how should the next-generation ATM machines look like?”. She can “request” ideas from the community on this issue by offering rewards, and distribute them to users who submit the best ideas. Users who are not the original submitter of an idea can participate by rating and voting on the idea.

The iDea market is used by two MIT courses “Development Ventures” and “Media Ventures” as class tools for students to exchange venture ideas and cross-evaluation.

All Q&A interactions, documents, news items, and ideas are tagged by both original information providers and the entire community as well, for knowledge indexing, searching and storage.

2.5 Backend & Peripheral Modules

2.5.1 Social Network Backend

Social features are instrumental in getting users attracted and engaged. On Barter, a user manages her profile and controls what information is accessible to other users. Users can establish friendships and form communities among themselves if they share similar interests or job functions. The formed social graph constantly updates itself with new market activities. For instance, a user can make her question or document private by sharing it only with her friends network or within a particular group. Conversely, the system has the capability to tell a user who she interacts with most in the market so that a friendship link can be potentially established, users who share similar interests and interact more can form a group.

Fig. 9 displays an interactive tool on Barter for social navigation with a user-centric view. Attributes of the visualization are interpreted as follows: (a) Radius: frequency of interactions in the market; (b) Thickness of links: amount of points exchanged; (c) Color of links: inflow vs. outflow of points; (d) Popup list: past interactions in the market; (e) Buttons shown when a user’s icon is clicked: ask the user a question or go to the target user’s self-centric view.

When Barter is deployed as an internal market tool for an organization, organization hierarchy is implied in the social network in addition to user-formed connections. No user on such a socially bounded platform can act as an absolute stranger. Thus, we can expect that users exhibit socially responsible behaviors, which in turn reduces the risk of users gaming the system and sabotaging the market fairness.

2.5.2 Transaction Backend
Barter’s transaction backend has two prominent features: 1) currency serialization, and 2) global bank accounts.

Each unit of currency has its own unique serial number, and has its assigned owner. Its creation and issuance is handled by a special entity in Barter called the “World Bank”. The “World Bank” is treated as a special user, who also maintains a bank account. Transactions can occur either between two users, or between a user and the “World Bank”. Any currency transferred from a user to the “World Bank” effectively jumps out of circulation, and reduces the global money supply. New currency is created when the “World Bank” needs to transfer currency to other users but without enough balance in the bank account.

The serialization of currency allows us to conveniently track the flow of currency in the economy such as currency’s turnover rate and total supply. It also allows us to realize advanced currency controls such as the expiration of currency. Expiration of currency, when managed properly, is a mechanism to encourage user spending in the economy. It is also a revenue stream for the “World Bank” so that it has the budget to fund system subsidies. When transactions occur, the owner of corresponding currency units gets changed, and the expiration date gets reset according to predetermined rules.

Each individual market also has a global bank account to facilitate and safeguard transactions. For instance, in the Q&A (iKnow) market, we require the asker to allocate “all” offered points to answerers unless no answers are submitted. We achieve this by “freezing” the offered points from the asker’s bank account, and transferring them to the “iKnow account”. These points will be unfrozen and transferred from the “iKnow account” to answerers’ accounts when the question expires and the asker selects the best answers.

2.5.3 Expertise matching

A user claims “expertise tags” in her profile. However, the provided information is only partially considered when the system calculates the true expertise tags of a user.

The system keeps accumulating and mining historic data about a user’s activities in the market, including questions she asks or answers, documents she shares and downloads, ideas she contributes or solicits, etc. A new list of expertise tags are then synthesized and displayed on the user’s profile.

When a user posts a new question or requests a new idea on the market, the system identifies top experts by matching their expertise tags with the textual description of the posting. The user has the option to pay extra points to let the system acquire the attention of these experts.

Fig.10 shows an interactive tool on Barter named “Expertise Cloud”. On the left panel is a tag cloud that consists of the most popular tags in the system. Tags are positioned following a modified force-directed algorithm. Links between tags represent concurrence. Linked tags get highlighted when a tag is clicked. The top-right panel displays a list of experts for the clicked tag, sorted by scores, and the bottom-right panel displays a list of past items in the market tagged by the clicked tag. This is a visualization tool on Barter for exploring popular topics inside the organization and matching top experts to tags.

2.6 Discussion on Incentives

According to David Ritter, CTO of Innocentive[1], internal knowledge markets are most effective when three forms of incentives are combined: spendable currency, recognition for expertise, and the opportunity to have a positive impact[3]. Barter has achieved all three forms of incentives nicely, and provides a long-term sustainable incentive structure for the organization and its members. In this section, we focus on the capacity of Barter in offering material incentives.

Users on Barter can spend their virtual currency either on information they need, or on physical rewards through the
auction market. Let’s use two examples as comparison to show why the framework of Barter is more robust and sustainable. HP once established an incentive program based on frequent flier miles to stimulate its employees to seek and contribute knowledge. For example, posting a useful document to the platform earned 2,000 miles, posting a question earned 1,000 miles, and posting an answer earned 500 miles. However, only 20% of the target audience performed one of these activities 90 days after the launch of the program. Siemens had a similar program that relied on “shares” participants could redeem for prizes. Participating employees earned 20 shares for contributing solutions and success stories, while they earned only 10 shares for other easier tasks. This program greatly boosted participation and contribution; however, information quality was poor.

These examples clearly show that organizations are aware of the significance of providing material incentives to promote their knowledge platforms, and are willing to invest in creating monetary incentives. However, the approaches they took exhibited some fundamental flaws:

1. Both programs were one-time shots that lacked long-term planning. After the expiration of the incentive program, users stopped contributing. Existing knowledge collected during this period became outdated without further maintenance or update.

2. Price theory suggests that efficiency is maximized when prices float. Both programs used fixed-price rewards. As a result, only information that’s less valuable than the given price was created.

3. In both cases, organizations attempted to directly associate monetary rewards with created raw information. This is equivalent to labeling information with dollar prices, while in practice it’s extremely difficult to predetermine the value of information and map it in dollar terms.

In contrast, Barter adopts a floating-price mechanism. Information seekers raise offered rewards for critical issues that require more efforts to provide. Information owners choose whether to supply it given the current price, or directly negotiate with information seekers. The auction market provides the management of an organization a layer to isolate delivering material incentives from classifying and evaluating knowledge created inside the platform. Exchanges of all types of information products are denominated in virtual currency, the value of which is determined separately by the crowd of users through their activities in the auction market.

Instead of offering a one-time lump-sum reward, an organization can distribute material rewards through the auction market in a continuous and strategic way. Depending on several key economic indicators, such as user activities, price indexes and currency supplies, the “chief economist” of Barter can determine the density and value of the products posted in the auction market. While used to provide material incentives, the auction market is also an important mechanism to stimulate or stabilize the entire knowledge economy.

3. SYSTEM DEPLOYMENT & DATA ANALYSIS

Barter is a web-based software platform that realizes the information market designed in our research. A functional site is currently hosted at [http://iknow.mit.edu/](http://iknow.mit.edu/) Barter has been deployed, or is being deployed, in a few different environments, primarily in classroom settings at a few universities. New features are continuously developed and added to the Barter platform. Through the wide deployment of Barter, we are able to collect a rich dataset on market operations and user behaviors.

There are around 350 users from five universities with diverse backgrounds and expertise areas who are using Barter. They started with certain number of “Yuan Bao” allocated to their bank accounts. We do not ask users to engage in any particular activity attentively. Simply, Barter serves as a day-to-day tool for students to exchange knowledge, share documents, contribute ideas, post news, etc., following the underlying market rules.

Incentive design, especially the translation of virtual points to meaningful rewards, is important to the deployment and experiment. The goal is to get users motivated and incentivized to participate. The auction market, “iBid”, provides a mechanism for users to exchange earned points for rewards they care about. Meanwhile, we can use the auction market to measure the value of information in dollar terms for our research purpose. We designed and decided upon an incentive structure, advertised it to users at the beginning of the deployment period. For example, we keep posting iTunes gift cards, small consumer products, and lunch opportunities with faculty members on the “iBid” market. For a few classes, participation grades were associated with earned points. All user activities, transactions and market statistics have been captured by the system and stored in the database. There are over 90 database tables supporting Barter at the backend. For addressing different research questions, we will utilize and analyze different subsets of the datasets.

In this paper, since the primary focus is on the framework design and system architecture, we only present some preliminary results from the user study and data analysis.

Fig.11 shows several dashboards for monitoring the global economy for the past year (04/2010-04/2011). The “chief economist” of Barter can use it to monitor several key economic indicators of the economy. For instance, Fig.11 contains three dashboards that show the number of questions and answers each day, the “price index” of the iKnow market, and the transaction volume as time series. It is evident from these curves that users do respond to material incentives. In mid-June 2010, we posted an iPad on the auction market, which greatly stimulated market activities (and market fraud too!). In March 2011, we released the inews market to users and posted several valuable rewards on the auction market, which also stimulated the economy.

A question frequently asked in the context of an information market is if market forces are effective. The Q&A market (iKnow) was first implemented and used in the deployment. Thus, we analyze data collected from iKnow to see if offered
points affect the quantity and quality of answers provided.

Fig. 12 shows the number of questions asked for each level of offered points, anonymous, non-anonymous, and total numbers are all displayed. The dataset is collected from the main demo site (iknow.mit.edu). Most questions were asked with around 20 points offered, while only a limited number of question rewarded >100 points. Fig. 13 shows the average number of answers a question can receive for different levels of offered points. As we see, when the number of offered points is less than 100, there is a general trend of increased number of submitted answers as the offered points arise. As the offered points exceed 100, we can expect that the difficulty of the question would increase significantly, thus the number of submitted answers decreases sharply. Interestingly, there is strong linearity for anonymous questions. In Fig. 14, we use the average length of answers as a proxy for the quality of answers. It is evident from the graph that the average length of answers keeps increasing as the offered points arises for a question, and when the offered points exceed 100, the increased difficulty thwarts good quality answers.

Both curves exhibit a reverse-U shape, and the local maximum in terms of both quantity and quality of answers is achieved when the number of offered points are in the 90-110 range. Interestingly, this is also where the curve in Fig. 12 reaches a local peak value.

4. CONCLUSION

In this paper we present the design of an information market framework which is able to provide a long-term sustainable incentive structure to organization members to collaboratively share knowledge and create innovation. We have also introduced the software deployment and lessons learned from user activities. By applying innovative market mecha-
nism design, we are able to address organizational challenges using a market mechanism efficiently. Our preliminary data analysis demonstrates that market forces are effective in incentivizing users to contribute information and engage in a new platform.

The next stage of the research is to utilize the existing Barter platform to design experiments, test several research hypotheses by conducting rigorous data analysis and gain further insights into information markets design. Examples include:

• What is the correlation between the quality and quantity of supplied information and the attributes of an information request?

• Which is more effective in getting users to contribute, social incentives or economic (market) incentives?

• Can an information market regulate and correct itself by using the same crow-sourcing mechanism and market incentives, given the evidence of market abuse, points laundering, IP infringement and fraud?

• Can securitization and a secondary market encourage user participation, increase market liquidity, and enhance the quality and validity of provided information?

We believe this is an interesting and promising research area that’s worth more exploration. The learnings from the research will offer great insights into organizational design.

5. REFERENCES