# Trust in Peer-to-Peer Digital Society: An Economics Perspective

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*Abstract*—**Peer-to-Peer (P2P) technique manifests file sharing, distributed computing, and communication and collaboration between peers in contrast to client/ server architectures. P2P digital society is emerging in our life. It changes our way of living, work, and play. Meanwhile, the trust is still a core issue in P2P digital society. The objective of this paper is to survey trust in P2P digital society from the point of economics view. Through employing the framework previously proposed, some implications on trust in P2P applications are given from the economics perspective. In this paper, we analyze trust emerging in P2P digital society through the economics perspective from the following levels: technology, product, business process, market, and the macroeconomic.**

*Keywords - trust; peer-to-peer (P2P); economics.*

## 1. INTRODUCTION

As a result of the quick transformation of the information society, human relationships and activities exhibit different styles than before. However, the concept of trust has remained fundamental for all social activities throughout human society. Trust is essential, especially in distributive information technology (IT) architectures as Peer-to-Peer (P2P) architectures. Research, both theoretical and empirical addresses the nature and role of trust, the moderators of trust, the antecedents of trust, as well as empirical methods in examining trust [5]. Whereas the economic analysis offers the researcher the opportunity to sort out explanations for changing market structure, to identify critical factors that result in firm success and failure, to interpret the speed and breadth of adoption of the new Internet technologies, and much more [9].

Kauffman and Walden [9] noted that many of the developments on the Internet seem new to most managers. But economic analysis provides a longstanding and well-developed theoretical vantage point from which to observe and interpret these developments in the context of continuing technological innovation in the business economy. Wang, Hori, and Sakurai [22] also noted the economic and social characteristics of trust system in P2P applications. Through the way, they may have an accurate characterization of the structural properties of the network. This can be of fundamental importance to understand the dynamics of the system. Only we have a clear picture of the economics of trust that the significant improvements can be expected. The objective of this paper is to survey trust in P2P digital society through this systematic economics framework.

Kauffman and Walden [9] proposed a comprehensive framework for electronic commerce (EC) research from the economics perspective. Though they aimed to survey EC researches, we employ their multiple levels of analysis from an economics perspective which is different from the usual technology-first perspective. Their level of analysis and relevant economic theories are noted in Table 1. In this paper, we will address the perspective of economics of P2P digital society.

The remainder of this paper is organized as follows. Section 2 introduces the trust and P2P applications. Section 3 describes the economics of the trust in P2P applications. Finally, future issues and applications are given in Section 4.

## 2. PRELIMINARIES FOR TRUST AND P2P APPLICATIONS

We firstly state the concept of trust and then describe the issues of trust in P2P Applications.

### 2.1. Trust

The concept of trust has been studied in diverse contexts; therefore there are manifold definitions of trust. Trust has been defined in various terms, ranging from "the willingness to be vulnerable to the actions of another party" to "the probability one attaches to cooperative behavior by other parties" [18]. Trust has also been defined as the belief by one party that another party will behave in a predictable manner [13]. From the viewpoint of processes, trust may be also classified into two cases: one is general trust (developed between customers and

companies over time and after experiences), the other is initial trust (developed after a customer's first experience with the company's web site).

Actually, trust is a psychological status of involved parties willing to pursue further interactions to achieve a planned goal. However, the key concepts are twofold. Firstly, for the trusting party, there must exist uncertainty about a potential or existing relationship—business, social, or otherwise—that leads to a certain perception of risk or vulnerability. Secondly, this perception of risk is generally based upon the beliefs regarding the ability, integrity, and benevolence of the trustee [11].

TABLE 1 LEVEL OF ANALYSIS AND RELEVANT ECONOMIC THEORIES COMPOSED BY KAUFFMAN AND WALDEN [8]

| Level of Analysis | Relevant Economic Theories |
|---|---|
| Technology | Public goods theory, efficient pricing, game theory, negotiation, network externalities and standards |
| Product | Pricing theory, versioning, information goods, switching costs, network externalities and standards, economies of scale and scope |
| Business Process | Adoption theory, economics of design, cost-benefit analysis, allocation of benefits, IT value, negotiation, economies of scale and scope, game theory |
| Market | Auction theory, industrial organization, transaction costs, market microstructure, intermediation, adoption and diffusion, perfect competition, returns to scale, optimal market structure |
| Macroeconomy | Monetary economics, taxation theory, labor economics, regulatory economics, public goods |

## 2.2. Trust in P2P Applications

Casadesus-Masanell, Hervás, and Mitchell [1] gave a vivid description of trust in P2P environments. They mentioned that as of 2006, the term 'pirate' was used more frequently to describe a person downloading music, movies and software than a buccaneer robbing ships on the high seas. Eye patches, swords and talking parrots had been replaced with software such as Napster [23], Kazaa [24], Limewire [25], eDonkey [26] and BitTorrent [27]. The battle between proprietary systems and P2P file sharing seems to be forever prolonged.

Trust also mediates the social relationships between websites and consumer characteristics and behavioral intent related to websites [10, 18, 21]. Reputation determines trust in an electronic store, which affects the attitude, risk perception, and in turn, the willingness to buy in an electronic store. The P2P reputation systems are closely related to the efforts of online communities, such as eBay, to develop incentive-compatible systems for rating the performance of a distributed set of users. Trust (and reputation) has related much with the incentives mentioned above. Kollock [10] proposed that the key design issues in evaluation are: evaluators, evaluations, history of evaluations, summary measures, and modifying evaluations. However, the design of reputation systems for P2P networks is complicated by two factors: one is that the distributed and intermediated nature of P2P network interactions makes it easy for users to conceal or change their identity, and the other is that in some fully distributed applications, the administration of the rating system must also be distributed throughout the network, making it vulnerable to coordinated gaming strategies.

Tan and Thoen [20] proposed a generic trust model for the successful performance of the transactions. They argued that the agent's trust in transaction is a combination of both external and internal factors. The external factors are the agent's trust in the other party (both objective / subjective trust reason) and its trust in the control mechanisms (both objective / subjective trust reason). The internal factors are potential gain and risk, along with its attitude. In [16] argued that trust in the vendor is defined as a multi-dimensional construct with two inter-related components—trust beliefs (perceptions of the competence, benevolence, and integrity of the vendor), and trusting intentions—willingness to depend (i.e., a decision to make oneself vulnerable to the vendor). Three factors are proposed for building consumer trust in the vendor: structural assurance (i.e., consumer perceptions of the safety of the web environment), perceived web vendor reputation, and perceived website quality.

The factors that determine trust are usually objective. Trust is built from experience (e.g., calculus), personal knowledge or bias (e.g., perception), and contextual elements (e.g., social characteristics) [13]. The evaluation of trust in a public key certification authority is already mentioned by [2]. They identified two major categories of trust factors, the first category being requirements for quality, quality of services offered, commitment, personnel responsibility and authority, and the second category being the conformance to qualified policy [13]. Krishnan, Smith, and Telang [12] noted the following approaches that provide quality of service differentiation to users based on a distributed mechanism that tracks user reputations: the evolutionary prisoner's dilemma (EPD), "stamp trading" mechanisms, "tit for tat" treatment, admission control system.

Significant questions addressed in this section include the various costs of services or topologies, the role of incentives in improving network performance, the motivations of users who consume and provide resources in P2P networks, the application of trust and recommendation mechanisms to the unique environments present in P2P networks, and the balance among copyright holders, entrepreneurs, and consumers. All these above advantages and trends are highly related to a great level of trust in the peers. Without trust, there can be hardly any success in P2P environments. This leaves a necessity of understanding trust, in particular, from the perspective of economics. When we stand on the foundation of economics, we can find the equilibrium of technology and the ecology.

## 3. ECONOMICS ON TRUST IN P2P DIGITAL SOCIETY

In this paper, we employ the framework proposed by [9] to survey trust in P2P environments from the

perspective of economics. Moreover, we will identify important areas of research integrating an economic perspective into the analysis of P2P environment. In their framework, Kauffman and Walden [9] noted that there are two prerequisite parties. They are firms and consumers. Firms use related technology to create new kinds of products (especially information goods (e.g., MP3 music recordings and digital newspapers) and to recreate services (especially information-intensive operational services). Consumers use technology in a variety of ways as individuals, in homogeneous groups and overall in society at large so as to take advantage of the leveraging benefits that are offered (e.g., for improved product search, to acquire more information, to enable infomediation and for enhanced personalization, etc.)

Both Firms and consumers use technology to form the whole economic hierarchy. Besides the two players they mentioned, we think there is still one party which plays an important role. That is the third party, such as governments, and stand-alone organizations. They promote and maintain the stability of the whole economic hierarchy. Following these parties, we proceed to each analysis level from technology, to product, business process, and market, and moreover, to the macroeconomic. Through Lu's work [13], the existing P2P systems may be classified into three categories, these being file sharing, distributed computing, and communication and collaboration. Our framework is depicted in Table 2. The issues in each cell are illustrated in the following paragraphs.

### 3.1. The analysis level of technology

The technological innovations have impacts at a number of levels of analysis [8]. With regard to the economic characteristics, the services provided on P2P networks are different, hence there is a need for new theoretical models as well as empirical and experimental analyses in order to understand the behaviors of P2P users.

The design of reputation systems for P2P reputation systems, such as eBay, is complicated by two factors. First, the distributed and intermediated nature of P2P network interactions makes it easy for users to conceal or change their identity. Secondly, in many some fully distributed applications, the administration of the rating system must also be distributed throughout the network, making it vulnerable to coordinated gaming strategies [12].

Based on an economic model, [22] proposed a VCG (Vickrey-Clarke-Grove)-like reputation remuneration mechanism in order to stimulate rational peers not only to provide reputation feedback, but also to offer feedback truthfully. Considering that trust and reputation is subjective, they divided the trust into functional trust and referral trust, and extended the referral trust to include two factors: similarity and truthfulness, both which can efficiently reduce the trust inference error.

P2P is merely a network architecture that could be deployed to a number of other applications such as distributed computing, instant messaging, voice telephony, spam filtering, and other commercial activities. In the category of file sharing, there are several cost/ benefits we

have to consider. They are free rider, latency (benefit) cost, service cost, routing cost, topology maintenance cost, etc. Among these, the free rider matters trust most. For the category of distributed computing, we have to take quality of service into consideration in order to ensure the trustworthiness of computing. According to the category of communication and collaboration, both security and reputation mechanism are employed to guarantee the trust among peers.

TABLE 2   THE ISSUES ON TRUST IN PEER-TO-PEER  APPLICATIONS FROM THE ECONOMICS PERSPECTIVE

| Level of Analysis | file sharing | distributed computing | communication & collaboration |
|---|---|---|---|
| Technology | ● free rider | ● quality of service | ● reputation mechanism <br> ● Security |
| Product | ● intellectual property rights <br> ● extent <br> ● balance <br> ● free-riding <br> ● privacy | ● specialization <br> ● collaborative filtering <br> ● semantic web <br> ● privacy <br> ● intellectual property rights <br> ● storage capacity | ● contents <br> ● recognition schemes <br> ● payment methods <br> ● privacy <br> ● quality of service |
| Business Process | ● effect <br> ● presence management <br> ● network management <br> ● free-riding <br> ● simplicity <br> ● robustness <br> ● liability <br> ● motivation free-riding | ● efficiency <br> ● collaborative filtering <br> ● mobile agents <br> ● frequency of requests <br> ● semantic web assistance <br> ● collaborative filtering <br> ● mobile agents | ● type of services <br> ● contents <br> ● quality of service <br> ● interaction <br> ● altruistic behaviour <br> ● regulation <br> ● rewards <br> ● recommen- dation agent |
| Market | ● user behaviour, | ● a third party <br> ● trust provider <br> ● social interaction | ● valuable information <br> ● the trustworthiness of the participants |
| Macro- economy | ● culture <br> ● intellectual property debate | ● social welfare | ● labour market |

### 3.2. The analysis level of product

In a traditional economy, we have a classification of goods as depicted in Table 3. However, information goods share the properties of both public goods and quasi-public goods (club goods). Due to P2P characteristics, the rivalry is hard to maintain. This causes a dilemma in trust. In P2P environments, the nonexcludability is accomplished on account of network resources and are typically provided to all members of the network equally. Given that a downloading user will share the content they download, the non-rivalry is accomplished because the net number of opportunities to download does not decrease for other users on the network.

However, this non-rivalry property will not hold if some network users consume network resources but do not share their content in return. This phenomenon is known as free-riding, which is a common characteristic of P2P

networks. It is also a fundamental tension between individual rationality and collective welfare. This causes both over-consumption and under-provision of community resources. It seems to extrapolate to P2P networks is the inability of individually rational behavior to bring about socially optimal outcomes.

TABLE 3  KINDS OF GOODS IN DIFFERENT CHARACTERISTICS
OF SUPPLY AND DEMAND

| Demand / Supply | Rivalry | Non-Rivalry |
|---|---|---|
| Excludability | Private goods | Quasi-public goods |
| Non-Excludability | Quasi-Private goods | Public goods |

In typical economic models, individual economic actors will only consider their private utility when making decisions about consumption and provision. They will not consider the impact (a.k.a. the externality) this decision will impose on other community members. Because of this, in the absence of external incentives, the self-interested consumption of public goods may deplete the overall public utility. This is known as the "tragedy of the commons". Common examples of such "tragedies" include over-grazing by farmers using public lands and over-fishing of public waters [12]. Krishnan et al. [12] detailed the differences between resources provided over P2P networks and other typical public and club goods. Consequently, in P2P environments, the network externality has deftly solved the above problem.

Information goods have characteristics that are different from traditional goods, and they prompt us to ask new questions related to their design, their pricing and their support in the marketplace [9]. In a network economy, the supply is unlimited on account the network externalities. Besides this, the consumption of the good by one user does not reduce the utility of other users. The Internet is exposing the impossibility of sustaining a transaction-based economy. As the net drives the cost of certain goods and services toward zero, it strips profit from transactions. We have to find out some advanced P2P business models, e.g., pricing strategy, the combination of brand loyalty and network effects [1,6,17].

The significant open questions addressed here is the balance between the rights of copyright holders, entrepreneurs, and consumers. It is increasingly important for coming researches. In the category of file sharing, the P2P technique impacts the intellectual property. The appropriate context the intellectual property should protect is always needed to be carefully defined. For the category of distributed computing, we still have to deal the following issues: specialization, collaborative filtering, semantic web, privacy, and storage capacity. As the category of communication and collaboration, contents recognition schemes, payment methods, privacy and quality of service will be core issues.

### 3.3.    *The analysis level of business process*

The firms are also able to take advantage of P2P capabilities, and make them available in the marketplace in the form of assistance for consumers' purchase of goods, and in the form of information services, as well [9]. This high-end computing power allows for real-time pricing of a variety of products (e.g., news and information access, excess inventory -- and not just stock prices), the technologies of electronic auctions (e.g., FirstAuction [28], MobShop [29] and Priceline.com [30]), comparison engines (e.g., MySimon [31], one-to-one marketing based on collaborative filtering (e.g., Net Perceptions [32]), and entirely new business models such as Yahoo [33] and eBay [34].

When used appropriately, the new technologies allow firms to streamline their business processes to achieve lower operating costs and increase sales revenue, as well as to improve channel coordination. The technologies also can beneficially impact the overall costs associated with doing business, e.g., creating a presence in the marketplace, replacing the physical infrastructure of a selling organization with a virtual infrastructure, and improving the immediacy and responsiveness of the firm while broadening its coverage in the marketplace.

More and more firms take advantage of the P2P technique to transform their business process. However, there are some emerging trust issues. In the category of file sharing, there are effect presence management, network management, free-riding, simplicity, robustness, and liability. For the category of distributed computing, it still includes collaborative filtering, mobile agents, frequency of requests, semantic web assistance, collaborative filtering, and mobile agents. As the category of communication and collaboration, in order to have a closer relationship with provider, customers, and peers, they have to deal contents, quality of service, behavior interaction, altruistic behavior, regulation, rewards, and recommendation agents.

### 3.4.    *The analysis level of market*

The new business models for the firm and the transformed business processes associated with them influence, and, in turn, are influenced by the market context in which they exist [9]. The rapid technological changes create opportunities for disintermediation, as we have seen with the new electronic intermediaries in the travel industry, such as Microsoft's Expedia.com [35], Internet Travel Network / GetThere.com [36] and Preview Travel [37]. Meanwhile, the airlines are increasingly interested in providing producer direct electronic booking solutions, even to the point of cooperating with one another to attract booking.

Tan, Yang and Veliyath [19] mentioned guanxi, a type of particularistic trust observed in Confucian societies has mostly been viewed as a static phenomenon. Based on neo-institutionalist trust perspectives, they argued that the role of guanxi also arose from the paucity of market system trust created by the absence of well-established market institutions during China's transition from a centrally planned to a market economy. Johanson [8] noted that a fundamental element of planned economies is the idea that exchange between units and firms should be

planned by authorities remote from the performance of the exchange. The institutions, where plan governance is the main mechanism, are therefore assumed to affect how trust is developed and maintained in an economy. However, when the planned economy undergoes institutional changes and plan governance erodes, trust is likely to play a different role. He suggests that both inter-unit exchanges and inter-firm exchanges contain three dimensions, which are influenced by the degree of plan governance: knowledge use, interaction, and dynamics. His study shows that plan governance in various degrees influenced the exchanges, which, in turn, gave a different level of importance to the role of trust in the economy.

The future of marketing is trust-based [6, 15]. The rapid technological changes create de-intermediation and re-intermediation in the market. The significant questions addressed here are as follows: the motivations of various actors, culture, and planned economy. User behavior is important for future researches in the category of file sharing. A third party trust provider for social interaction is urgent for the category of distributed computing. Valuable information about the trustworthiness of the participants is demanding in the category of communication and collaboration.

### 3.5. The analysis level of macroeconomic

Kauffman and Walden [9] stated most observers recognize that the impacts are occurring at the microeconomic and macroeconomic levels. With the rapid adoption and diffusion of technologies and the Internet, along with the high levels of new business capital that are being made available for firms, the macro-level effects are likely to be substantial, even if they are difficult to track and accurately measure with today's tools and approaches.

Business is not constrained by physical borders on account of information technology (IT). Globalization brought about by IT is a problem not traditionally faced by firms. Never before has a firm's first digital storefront been accessible by customers on a global basis on its first day of operation. Much research remains to be done to understand how this pressure will shape firms in the future [8]. This creates issues that must be solved involving how to tax and regulate business across state lines and across national boarders. Meanwhile, the use of P2P technology is transforming the search characteristics of the labor market. Glaessner, Kellermann, and McNevin [7] noted developing public policy to improve or establish electronic security needs to be built. Macroeconomy level shifts occur in the demographics of employment and firm growth and value, as well as changes in the issues that government regulators must track to ensure that social welfare is maintained [9]. Digital money is made possible through encryption technologies. Current obstacles to electronic money involve adoption inertia and the characteristics it must have to be a substitute for traditional money.

In [3] demonstrate the impact of Napster phenomenon on the ethic of digital delivery. It noted the connections of P2P techniques and culture, legacy, and industry. On the moving from print economy to digital economy of information, the economies of publishing have to find the balance points. The system quality and culture significantly affect trust in the IT artifact and point to rich possibilities for future research in these areas. As we can see, there are still many questions remain to be explored. In the category of file sharing, the culture and intellectual property debate will continued. For the category of distributed computing, the social welfare is ultimately concerned. As the category of communication and collaboration, the following issues are addressed: labor market, public policy, social welfare, digital money and monetary policy, tax and regulation across national boarders.

### 4. CONCLUSION AND FUTURE WORK

The environment under the peer-to-peer (P2P) architecture is increasingly important. In this paper, through the survey of P2P, trust and their economics, we may see that environment employed P2P computing model is undergoing. In particular, we focused on the economics of the trust in P2P environment. We also identified the related variables as shown on Table 2 for the future studies. This paper is an opening effort to explore the economic issues on trust in P2P environment.

As Table 2 shown, we analysis the economic issues on trust in P2P digital society through a comprehensive level. For the technology and product level, the issues are being researched relatively more than other levels. However, for the business process, market, and macroeconomic level, there are still many left to be studied both empirically and theoretically. In Table 2, the terms underlined mean already noticed now, while those not underlined means more changeable. This implies we have distinguished the factors which may influence the trust in P2P environments. So we may have a clear scheme for the future P2P environment. In the changeable variables, we may adjust the levels of trust. While in those not easily changed variables, showing inherent properties for P2P environment, it is most likely that we may hold the levels of trust constantly.

Current trust mechanisms mostly are based on social control philosophy, that is, two peers collaborate each other in sharing information on services. However, this kind of mechanism lacks of service semantics. A Security-By-Contract (SxC) mechanism based on security behavior and quality of service may be complementary [4]. Through SxC approach, the peers choose and trust according to service characteristics, as well as discover services according to interface and semantic description. The combination of the above two kinds of mechanism mean that trust between peers is based on both semantic and social approach [4]. In this way, we may model the evolution experiences in different collaboration stages.

From the economics perspective, we also provide some implications on the future of P2P environment such as the influence factors, killer-applications, evaluations, etc. These are stated as follows: (1) The existence of extensive free-riding on these networks has social and economic implication. New theoretical models as well as

experimental and empirical data to understand user behavior are necessary. Thus we may build new models to understand the relationships between the characteristics of information goods and trust. Besides, the trust alteration between peers will be more dynamic than ever. A new approach based on a stronger (semantics-based) notion of trust is needed [4]. (2)  When specifying the important costs, their influence (or even collapsing) factors and the workable incentive mechanisms, both pricing and non-pricing models should be taken into considerations. Thus we may draw a picture of what the killer applications for P2P systems. Besides, we may testify the relationships between the cost and trust. Owing to different essences than usual contracts, we depict that there should be some modifications for transaction cost theory and agent theory. (3)  Developing a formal representation of trust evolution between two peers in order to validate that whether the trust will regress in function on the peers' experience as well as the third party between two trust established peers. Other user contexts such as behavior, motivation, characteristics, culture, and public key infrastructure (PKI) are undergoing areas of research. All the stakeholders have to design new distribution mechanisms for information goods. The implementation with novel approaches on the effects of trust for the above contexts is worth further understanding.

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