Information markets are inefficient. Information products have large upfront development costs, yet their duplication costs are negligibly small; and they are experience goods with high costs of marketing and promotion. As a result, either winner-take-all markets are created through large and expensive promotional campaigns, or artificial monopoly power is conferred by the government through copyright protection, or both, to prevent the collapse of these markets from intense price competition and piracy. Such inefficiency creates opportunities to design more efficient markets by utilizing new technologies. Trust networks provide such an opportunity where the network infrastructure acts not only as a distribution system for information products, but also as an advertising and promotion medium, a payment and pricing mechanism, a guarantee and insurance service, and a copyright enforcement and dispute resolution tool. Such a network-centric market place is proposed to remedy many of the shortcomings of mass markets by relying on peer-to-peer distribution, peer-to-peer payments, and peer-to-peer enforcement of trust and integrity. Analytical models are presented to show that such a market place for information goods can scale up to satisfy large markets without expensive promotions and advertising campaigns, create customized products with dynamic pricing, reduce entry costs by eliminating the distinction between buyers and sellers, and eliminate the need for copyright protection.

Keywords: Information products, Trust networks, Social networks, Market design, Peer-to-peer markets, Network distribution, Copyright protection.
1. Information Markets

Information markets are inefficient. Development of information products, such as books, movies, music, and software, is expensive, but duplication costs are minimal. Consequently, in a competitive market, the prices can be driven to zero by competition, making it impossible to recover the development costs. As a result, government regulation is deemed necessary, in the form of copyright protection, which gives monopoly power to producers for extended periods of time [19, 31]. That monopoly power leads to loss of consumer welfare and reduced access to the product, due to high prices, and it inhibits the production of derivative products [23]. Even with government regulation, the downward pressure on prices is difficult to prevent. Since duplication costs are minimal, there is considerable incentive to bypass the copyright protection, and distribute illegal copies of information products, for a lower price or even free. There is strong evidence that a considerable amount of illegal distribution of information products takes place, especially in countries where the enforcement of copyright laws is lax. Enforcing the copyright laws itself is very expensive, and it is a source of additional market inefficiency [23, 33].

Such inefficiency creates opportunities to design more efficient markets by utilizing new technologies. There are five major assumptions underlying the existing information markets that create these inefficiencies, and all of them can be challenged by using new technologies.

a. Prices are fixed, not dynamic; and the products are standardized, not customized. It is difficult to have dynamic pricing or customized products when prices and products are listed publicly for mass markets. There have been many attempts to implement dynamic pricing especially in online markets. They involve either market saturation strategies or price discrimination on early adopters [9, 13, 21, 31]. But these attempts to dynamically modify prices risk alienating customers, or encourage them to delay their transactions in the hopes of finding a better deal [9, 31]. There have been some attempts to customize information products, but they were very limited in scope because mass markets do not reward
customization, but standardization and brand consistency [23]. Also, the attempts were largely limited to the open source community, because copyright protection is a legal restriction on the ability of third parties to customize products [3, 23]. Most importantly, any attempt to customize products requires identifying the customers and learning about them, but without violating their sense of privacy, and without intrusive and surreptitious tracking systems. Consumers often reject such tracking devices, when they become aware of them, as overly intrusive and technically nontransparent. Even with extensive tracking, collecting sufficient information to do dynamic pricing and product customization is difficult and expensive [13, 22].

b. Potential markets are large, but reaching customers is expensive, requiring elaborate promotions and advertising campaigns on mass media. Information products are experience goods; their quality varies greatly; and their relevance is often subjective. There is considerable research on the difficulty of informing customers about the quality and relevance of information products [25, 38]. It is widely reported that it is difficult to predict who might purchase what information product, without exposing them to the product, often repeatedly, and sometimes also to their social circles, to support a purchase decision [4, 36]. Often, network effects and fashion effects dominate the decision, and the information product that is most widely publicized, promoted, and distributed becomes the de facto dominant product, whether or not it is the best match for the needs of a particular customer. That possibility of a winner take all market creating an arms race of promotional campaigns, and reducing the efficiency of the market, has been studied extensively [4, 9, 11]. There have been some attempts in the literature to use the social media to reduce marketing and customer acquisition costs, but those attempts have been limited to encouraging individuals to participate in word of mouth advertising, and spreading the message of major brands. These attempts do not extend to network based pricing and distribution [12, 13, 24, 25].

c. Buyers and sellers are distinct, with clearly separated roles. Sellers set prices, hold inventory, promote and deliver products, and accept payments; buyers search for products, make purchasing decisions, and make payments. Buyers and sellers rarely exchange roles, except in limited second-hand
goods markets. This is partly because becoming a seller involves a complex and costly process, creating barriers to entry. To become a seller, one needs to develop the capability to acquire and hold inventory, promote products and deliver them to buyers, accept payments from the buyers and process them, and guarantee performance for the products with reputation or insurance, initiate legal action against those who fail to pay, and follow government regulations on copyright and taxation. There have been many attempts to reduce barriers to entry by using new technologies both in research and in entrepreneurship. Cloud based web services have been used to run business software and provide turnkey solutions to automate business processes, so new businesses do not have to reinvent the wheel [6, 14]. They led to significant reduction in management costs. Virtual organizations have been used to outsource some complex parts of businesses to specialized organizations, and then building and modifying new businesses dynamically from standardized components provided by those specialized organizations [16, 29]. They have been relatively successful in reducing operational costs. But these efforts did not impact the marketing and customer acquisition costs, which are significant barriers to entry [21].

d. Government regulation through copyright protection is essential to the viability of markets for information products. There is an extensive literature on the optimum duration and breadth of copyright protection both in economics and law [3, 7, 12]. Various exceptions to the protection have also been debated such as the fair use principle, and the coverage of derivative products [13, 23]. But the basic principle of copyright protection as a necessary tool has endured all challenges [7].

e. Consumers are expected to successfully judge the trustworthiness of information products. In fact, information products can be used to mislead and misinform, especially with political propaganda and advertising. The development of trust in a mass market environment has been studied in great detail. Specifically, there is considerable literature on how trust develops to facilitate transactions [20, 27], how trust is propagated through word of mouth [25, 38], and how specific nodes called influencers might be critical in propagation of trust [24, 25]. Our model differs significantly from this literature by integrating advertising, sales, distribution, and payments all in one unified model of a network-based marketplace,
where every node has a trust neighborhood, the propagation follows the formal network paths, and each node is an influencer of its trust neighborhood. Trust is also influenced by social and cultural experiences and social identity. There is considerable literature on social identity and group identity as a basis of trust [20, 25, 30]. Clearly, it would be normal to expect that people would be more likely to trust others with similar cultural and social experiences. We capture all subjective experiences of consumers in their trust relationships which summarize their social and cultural experiences in their trust links.

Clearly, there is considerable literature and also entrepreneurial activity challenging each one of these assumptions individually, as described above, but challenging all of them simultaneously and eliminating their complex interactions require novel approaches to market design by utilizing new technologies. This article advocates such a novel approach to market design by utilizing a specialized social network, called a trust network. There is already considerable evidence that social networks can be quite effective in locating trustworthy information as evidenced by social-network-based recommendation systems that recommend new products that were purchased or reviewed by one’s network connections [26, 27]. But these systems rely on existing social networks that were not designed for commercial purposes, and the context of connections is often too diverse and too broad to be useful for commercial purposes. For example, one’s Facebook friends or Linked In connections are diverse groups from multiple contexts, and the relevance of those connections for a particular commercial transaction in a particular context is not clear [28]. There is also considerable evidence that social networks can be effective in distributing information, as evidenced by viral videos, political action messages, and online memes and games. However such distribution typically involves free exchange of information, and the potential of social networks to create novel market places has not been realized, or even seriously explored [22].

In this article, we develop a trust network as a novel marketplace where the network acts not only as a search and recommendation tool, but also as a distribution and filtering system, an advertising and promotion medium, a pricing mechanism, a guarantee, insurance, and dispute resolution service, and a copyright enforcement tool. The network-centric marketplace as proposed in this article remedies many
shortcomings of mass markets, by relying on peer-to-peer distribution, peer-to-peer payment systems, and peer-to-peer enforcement of integrity and trust. With information products, the most significant costs involve marketing and transaction processing, since duplication costs are negligibly small. Trust networks are shown to reduce those costs significantly, or even eliminate them, by supporting those activities within the shared infrastructure, potentially creating significantly more efficient markets [19, 22]. In Section 2 we define the trust networks and their relevant characteristics; in Section 3 we build the market mechanism on top of the trust network; in section 4 we develop the analytical models to prove that the network-based markets are as efficient as mass markets, but with significantly lower transaction costs; Section 5 lists some potential applications of the new marketplace; and Section 6 provides a detailed application.

2. Trust Networks

Trust networks are specialized social networks where each node connects to the nodes it trusts in a particular context. The nodes can be individuals, organizations, consumers, producers, buyers, or sellers. Unlike other social networks, the links are not symmetric, but directed, since a node A trusting another node B does not imply the reverse, B also trusting A. For example, a popular music network would connect each node to others whose taste and judgment in popular music is similar and trustworthy, from the perspective of that particular node. As such, trust is personalized, and different from reputation which is global. Such networks have been created in a few domains, such as open source software development and movie recommendations [1, 28, 37]. These early attempts have used trust networks primarily as personalized recommendation systems, to locate trusted sources of information [2, 34]. This article uses trust networks to design novel marketplaces for information products.

The basic assumption underlying trust networks is transitivity. If A trusts B, and B trusts C in a particular context, then A can safely trust C also in that context. Transitivity allows traversing and reaching large subsets of the network, starting from a specific initial node, to identify trustworthy sources of information for that particular node. Conversely, transitivity also allows distributing information
products over trust paths to large segments of the network. That involves pushing information to trusting partners, as opposed to trusting partners pulling information from their trusted partners by explicitly searching for information [38].

Consider a trust network created to promote, sell, and distribute digital products in a particular context. Each node can act as a buyer and a reseller by buying products from the nodes it trusts, and reselling them to the nodes that trust it. Such a multi-step decentralized distribution system can solve a number of problems associated with mass markets.

a. It is relatively easy to reach large markets without expensive promotions and advertising campaigns, because the network acts as a promotion and advertising system. Each node filters the products it receives from its trusted nodes, and offers the relevant products to the nodes that trust it which are called its neighbors. The trust of a node A by another node B in a context C means that the node B trusts the taste and judgment of node A in context C, and it implies that the products offered by A will be relevant and appropriate for B in context C. There is considerable evidence that social networks tend to follow “small world” structure with highly interconnected clusters, and some long distance connections between clusters. As a result, it has been shown both theoretically and empirically that they can find a path between any two arbitrary nodes quite efficiently and the paths tend to be surprisingly short [10, 26]. Similarly, one would expect that they could also distribute information products quite efficiently along those same paths. The distribution is likely to be quite cost efficient since once the network infrastructure is created, the distribution is done at approximately zero cost of merely duplicating information products and transmitting them along established paths, eliminating the major costs of advertising and promotion associated with mass markets. The only critical issues are building the trust network infrastructure, and creating incentives for all to join such trust networks in all contexts that are relevant to them.

b. In such a network based market, every node is free to set its own prices for every product, and every node is a mini monopoly within its neighborhood in the network. There may be some overlap of neighborhoods of nodes that are in the market simultaneously, but by and large each node dominates its
little market during the period it offers a product, and it is free to set its own price. This is especially true when one considers the fact that trust involves taste and judgment and it is very subjective, and each node provides its own subjective filtering and selection to customize information products. The result is a novel market place with highly dynamic pricing and product customization. Although each node posts fixed prices for its small neighborhood, the existence of a multitude of sellers entering and exiting the market at different times with a slightly modified product selection creates a dynamic and customized environment.

c. The distinction between buyers and sellers disappears, since once the network infrastructure is built and the trust connections are established, any buyer is also a reseller with no additional requirements. The process can even be completely automated through a subscription system where each node subscribes to all products delivered by its trusted nodes; then it filters them according to its predetermined preferences, and forwards them to the nodes that trust it and subscribe to it. Entry costs for sellers in such a system are minimal. But to enable such minimal entry costs, the network has to support a variety of commercial processes, such as peer-to-peer payments, peer-to-peer trust and insurance, and peer-to-peer promotion and distribution. Moreover, these minimal entry costs provide very limited access, only to a very small portion of the network for each node, consisting only of its trusting neighbors. Such limited access prevents the collapse of the market, as compared with the mass markets for information products where zero entry costs coupled with zero duplication costs would lead to intense price competition and a precipitous decline in prices.

d. The disappearance of the distinction between buyers and sellers and a flexible pricing system creates an opportunity to eliminate the need for copyright protection. Since every node is a seller, nobody has an incentive to give away the product for free. Moreover, since every node is a monopolist in its small neighborhood, it can extract monopoly prices from its neighborhood with no copyright protection. Most importantly, the original producer of a product can extract monopoly surplus from the whole market, by simply pricing the product correctly. The correct pricing would consider not only the reservation prices of the immediate buyers, but also their potential revenues from reselling. Those buyers would also price the
product similarly, and the potential revenues at each step would be dependent on the potential revenues at the next step, leading to a recursive computation of the correct price by each node. We will show in the next section that the producers of information products can benefit greatly from a network-based market, by charging monopoly prices, and extracting monopoly surplus from the whole network, with no promotion costs, and no copyright enforcement costs.

e. Consumers can also benefit from network-based markets since any consumer is also a reseller. Without any copyright protection, the buyers have the opportunity to modify products, to filter them for specific audiences, and create derivative products, and in effect easily become producers and extract monopoly prices for their partial contributions to the final product. Pure consumers with no contribution would be subject to the same monopolistic prices as in mass markets. But since there is considerable new surplus in a network based market, due to elimination of promotion and copyright enforcement costs, there are opportunities to subsidize pure consumers, so even they could be better off compared to mass markets.

3. Market Mechanism

A trust network is a directed network of nodes where each node is connected to the nodes that trust it in a particular context. Figure 1 shows a trust network with four nodes where A is trusted by B and C, and C is trusted by D in the context of popular music.

![Trust Network Diagram](image)

**Popular Music**

Figure 1: A trust network with four nodes in the context of popular music.
The direction of the links indicates the flow of information products since products flow from trusted nodes to the trusting nodes, in the opposite direction of trust. The trusting nodes of a node are also called its neighborhood. For example, B and C constitute the neighborhood of A, and they receive the products distributed by A. Each node is free to offer any information product it possesses to its neighbors, for any fixed price of its choosing, with no copyright protection. The neighbors are free to buy the product or not, but once they buy a product, they have the complete rights to it, such as modifying it, creating derivative products from it, and reselling it, at any price of their choosing. We assume that the cost of duplicating and distributing an information product is zero.

We will show that such a network-based market mechanism leaves everyone better off compared to mass markets, and accomplishes this with no advertising costs, and no copyright enforcement costs, both of which are significant for information products. The basic concept underlying the network-based market is that each seller has free access to a small segment of the network, his neighbors, and it is a monopolist in that segment, at least temporarily. Moreover, all buyers are also resellers, and that gives a seller access to the larger market indirectly. Each seller sets his own prices by considering not only the reservation prices of his immediate buyers as consumers, but also their potential revenues as resellers. The price at each node then reflects the remaining market potential, and the node’s ability to exploit that market potential through its direct and indirect connections.

Such a marketplace can be created easily over an existing social network such as Facebook, by allowing the users to create labelled trust connections such as the “popular music” connections shown above. These could be done by simply converting some of the existing friend connections to trust connections and labelling them. Each user connects to other users it trusts in each particular domain identified by the label. Labels can be created by the users, or selected from a taxonomy of existing domains. Each user also lists a number of domains as its expertise, and delivers products to its trustees in those domains. The domain labels are similar to hashtags commonly utilized by some social networks like Twitter. The trust connections are expected to reflect real-world relationships people already have, as in
Facebook links, but they are also pruned frequently by the users based on the quality of the products offered. It is also possible for the users to follow the links to friends of friends, and view their product offerings, and establish new trust links with them. This decentralized process of building the trust network is a substitute for the behemoth marketing and advertising industry, by replacing mass marketing with the network propagation of word of mouth. This substitution is the primary source of savings, since the network is built only once for each category of products, as opposed to mass marketing each product individually, and the process of building the network is decentralized and managed by consumers themselves in an incremental fashion.

In this environment, the original creator of the product offers it at a very high price reflecting the total market potential of the product. Clearly, the early buyers will be few in number, and well informed about the industry, since they would be taking a risk on a new product by estimating its market potential. These early buyers are similar to the publishers or studios in a mass market who make upfront payments to the producers of content, and take risks by estimating the potential of the information product. The difference here is the creation of a hierarchical market with many levels where each buyer becomes a reseller. Early buyers are risk takers; they have access to the product early; they pay a high price and sell it at a lower price to later adopters. Latest buyers are similar to ordinary consumers of mass markets; they take little risk; they have late access to the product after the market has been saturated; they pay a low price and sell at an even lower price, or do not sell at all. Each consumer gets into the market at an appropriate level for his risk tolerance, knowledge and interest in the product, and his ability to resell determined by his location in the network.

The network acts as a substitute for the behemoth marketing and advertising industry. Clearly, there is a cost to building and maintaining the trust network, but it is a distributed effort since every node has to build only its own small neighborhood of trusted partners and maintain it. This process is similar to leaving feedback or rankings at recommendation system sites, and many consumers are already familiar with that process. The cost is likely to be similar to the cost of finding trusted merchants and providers in
mass markets, which also has to be maintained. For the sellers, the cost is likely to be significantly lower than mass marketing and advertising costs, since one builds a trust network only once in each domain, and then amortizes it over all products in that domain. This is similar to building a marketplace like Ebay and amortizing the costs over all transactions. In a mass market, every product has to be marketed separately. In our model, we show equivalence in revenues, and claim that any cost savings over mass markets add to the advantage of our market mechanism.

The trust network also obviates the need for copyright protection, leading to potentially huge savings. No copyright protection is necessary, since all users acquiring the product have the full rights to use, modify, and resell the product. Early buyers pay a price reflecting the full market potential of the product, and having paid a high price, they have no incentive to give it away for free. Even if they do give it away, that would have no impact on the early sellers since they likely already saturated their high price market; and it would have little impact on the later sellers since each seller has access to a small share of the market and cannot disrupt the whole market. Moreover, the market is dynamic and adjusts to the sellers’ actions. If there are many who give away the product for free, although they have no incentive to do it, the sellers will continue to price the product on its full market potential, and those who give it away will have to pay a high price for the privilege, with no impact on the revenues of the producers.

The products can be customized easily since the buyers have the complete rights to modify and resell. In this environment, trust is critical to get a reliable and appropriately modified copy of the product, and unreliable sellers will quickly lose their trust connections and the income from future sales. The network is similar to preindustrial social reputation based commerce, and the loss of trust can cascade through the network very quickly and lead to considerable losses, since all users can see their local network and observe who else trusts their trusted partners. Such transparency of the local trust network, and the visibility of products offered and transactions executed, is critical to the success of the market. Such an infrastructure with local visibility is very similar to the existing social networks, and can be easily implemented, where each node can see the connections and activities of its immediate neighbors.
Further savings are possible by extending the trust links, and converting them to subscriptions to all products offered by the trusted nodes in the trusted category. There are several advantages to the subscription model, as opposed to merely offering the products individually, and the additional cost of delivering some unwanted products is minimal with digital products. The main advantage of the subscription model is the elimination of transaction costs incurred in making individual purchase decisions. Moreover, more surplus can be extracted by aggregating multiple products into bundles since that reduces the variance of reservation prices. Finally, subscription reduces the price competition among sellers at all levels because bundles are customized and no two bundles are exactly the same. That further supports the local monopoly assumption that is fundamental to our model. We now develop a detailed analytical model to justify all of these claims.

4. Analytical Models

4.1 Deterministic Model

Consider a market for an information product with n potential buyers each with a reservation price of 1 dollar. A monopolist in this market would charge 1 dollar for the product and make n dollars, extracting the full surplus from the market, assuming full copyright protection and no piracy, and sufficient promotion to inform all potential buyers. We will show that a trust network can generate the same revenues with no copyright protection and no promotion.

Consider a trust network with n+1 nodes: one node producing an information product and n potential buyers. Let the reservation price of each node be 1 dollar, and assume that each node has exactly m neighbors. Also assume that the network is fully connected with a path existing between any pair of nodes. The producer of the information good faces m immediate buyers each with a personal valuation of 1 dollar. But since each buyer is also a reseller, their willingness to pay includes not only their own personal valuation for the product, but also the expected revenues from reselling. This argument applies to every node in the network along the chain of distribution. Assume as a first step a tree structure where
every node has only one incoming link and m outgoing links. The producer in this network faces m immediate buyers, and a total market size of n, since the whole market is reachable through the network. It would charge each one of his buyers n/m dollars, extracting the complete surplus n from the market. Each buyer in turn would face a total market share of (n-m)/m since the market is reduced by m buyers, and it is shared by m buyers. They would price the product at (n-m)/m² and collect revenues of (n-m)/m. Their net payments are their payments minus their revenues n/m - (n-m)/m = 1, which is exactly their reservation prices. At step t, each node faces a total market share of \( \frac{n-\sum_{i=1}^{t}m_i}{m^t} \), charges a price \( \frac{n-\sum_{i=1}^{t}m_i}{m^{t+1}} \) and collects the revenues of \( \frac{n-\sum_{i=1}^{t}m_i}{m^t} \). The net payments of each node at step t are its payment minus its revenues \( \frac{n-\sum_{i=1}^{t}m_i}{m^t} - \frac{n-\sum_{i=1}^{t}m_i}{m^t} = 1 \) which is exactly its reservation price. As a result, the producer extracts the complete surplus n from the market, and each buyer pays exactly its reservation price of 1, duplicating the monopoly mass market.

In general, pricing in a network market is more complex, even in a deterministic case, since the network is not a tree, and each node will have many incoming links. Consequently, because there is more than one path to each node, and the market saturates over time, the resellers will find that not all of their m neighbors are potential buyers, because they may have already bought the item through another path. At each step t then, a proportion of m neighbors already own the product, leading to a gradual decline in sales per node. The sales at each step t then is dependent on the total sales up to that point t. Assuming that each step in the distribution takes one time unit, without any loss of generality, let \( q_t \) denote the total sales up to time t; then \( q_t' \), the time derivative of \( q_t \), is the total sales at time t, and it will depend on the remaining untapped market at time t, \( n-q_t \). The number of immediate neighbors grows exponentially at a rate m, since every node has m neighbors, and at time t, there are \( m^t \) neighbors, but \( \frac{n-q_t}{n} \) of them already have the product, leaving \( \frac{n-q_t}{n} \cdot m^t \) potential buyers at time t. Since all potential buyers will buy the product at their reservation price of 1, the sales \( q_t' \) at time t can be expressed as a linear differential equation \( q_t' = \frac{n-q_t}{n} \cdot m^t \).
To solve the equation we collect all the $q_t$ terms and multiply both sides by $e^{m_t}$ leading to the total derivative of $d\left(e^{\frac{m_t}{n\ln(m)}} q_t\right) = e^{\frac{m_t}{n\ln(m)}} m_t \, dt$

By integrating both sides, we get $q_t = n + c \, e^{\frac{-m_t}{n\ln(m)}}$ where $c$ is a constant.

The total ownership at time 0 is 1, since only the producer has the product at time 0, and $q_0 = 1$ implies $c = (1-n) \, e^{\frac{1}{n\ln(m)}}$ leading to

$q_t \approx n - n \, e^{\frac{1-m_t}{n\ln(m)}}$ and $q_t' = m_t \, e^{\frac{1-m_t}{n\ln(m)}}$

and the price at each time is the untapped market potential per buyer $p_t = (n-q_t)/q_t' = n/m_t$

It is easy to see that total sales is an S shaped curve over time due to the opposing effects of exponentially increasing distribution and exponentially decreasing market potential; and the price is exponentially declining due to the reinforcing effects of exponentially decreasing market potential and exponentially increasing number of sellers.

Figure 3.1: Total cumulative sales and price over time in a trust network.
### 4.2 Stochastic Model

Assume there are $n$ potential buyers for an information product, and their reservation prices are distributed uniformly between 0 and 2, with the expected value of 1. A monopolist would charge 1, and $n/2$ will buy, with expected revenues of $n/2$. The total consumer surplus would be $n/4$. In a trust-network-based market, we will show that both the producer and the consumers can do equally well, and without any advertising and copyright protection costs. We assume that the nodes are not able to trace the complete network, and not knowing the exact number of neighbors at each step of the distribution downstream, they are not able to compute exact distributions for reservation prices. As a result, all nodes make decisions on the basis of their knowledge of their immediate neighborhood, and use global expected values elsewhere.

Consider a trust network with $n+1$ nodes: one node producing an information product and $n$ potential buyers, and their reservation prices are distributed uniformly between 0 and 2, with the expected value of 1. Assume temporarily that each node has exactly $m$ outgoing links and one incoming link, a tree structure, starting at the producer node. Each node at step $t$ faces a uniform distribution of reservation prices between $a_t$ and $a_t+2$ with mean $a_t+1$, where $a_t$ is the expected revenues of buyer nodes at time $t$ by reselling the product. Without an explicit knowledge of the complete network structure, each node is forced to compute the global expected value for $a_t$. Let $q_t$ be the total sales up to time $t$, then $n-q_t$ is the remaining untapped market at time $t$, and let $rn-q_t$ be the expected revenues that will be extracted from that market, with $r$ being the global expected rate of market exploitation. Then $a_t = (rn-q_t)/q_t$ since there are $q_t$ buyers at time $t$ facing a market potential of $rn-q_t$. Let the seller facing the uniform distribution of reservation prices between $a_t$ and $a_t+2$ set the optimum price at $a_t+p_t$, then the sales at time $t$ will be $q_t' = \frac{2-p_t}{2}m^t$ since there are $m^t$ possible buyers at time $t$, and $(2-p_t)/2$ proportion of them will buy the item. The revenues $\pi_t$ of a seller at time $t$ then is:

$$\pi_t = (a_t+p_t)q_t' = (\frac{rn-q_t}{q_t'} + p_t)q_t' = (rn-q_t) + \frac{2-p_t}{2}m^tp_t$$
To maximize revenues at each node with respect to price:
\[
\frac{\partial \pi}{\partial p_t} = m^t(1 - p_t) = 0 \text{ implies that } p_t = 1, \quad q_t' = m^t/2, \quad \text{ and } \quad r = 1/2
\]
indicating that the optimum revenues at each node will be \( \pi_t = (n/2 - q_t) + (m^t/2) \), and the revenues of the producer will be \( \pi_0 \approx n/2 \). The net price paid by each node will be 1, the expected value of the reservation prices; and half of all potential buyers, \( n/2 \) will buy, with the total surplus of \( n/4 \), duplicating the mass market performance.

The analysis above assumed away market saturation, by assuming a tree structure with only one path to every node. In general, pricing in a network market is more complex, since the network is not a tree, and each node will have many incoming links. Assume now a general network, but fully connected with at least one path between any pair of nodes. At each step \( t \), not all \( m^t/2 \) potential buyers will be available as customers now, since some may have acquired the product earlier through a different path. That leads to a similar differential equation as in Section 3.1, since only \( \frac{(n/2 - q_t)}{n/2} \) proportion of potential \( m/2 \) buyers are available as buyers at each time \( t \):

\[
q_t' = \frac{n/2 - q_t}{n/2} \frac{m^t}{2}
\]

Solving for \( q_t \) as in Section 3.1, we get

\[
q_t \approx \frac{n}{2} - \frac{n}{2} e^{\frac{z-m^t}{n \ln(m/2)}} \quad , \quad q_t' = \frac{m^t}{2} e^{\frac{z-m^t}{n \ln(m/2)}} \quad \text{ and the price } a_t + p_t = \frac{(n/2 - q_t)}{q_t'} + 1
\]
Those results lead to revenues $\pi_t = (a_t + p_t) q_t = (n/2 - q_t') + q_t'$ with the producer’s revenues $\pi_0 \approx n/2$, and the total consumer surplus of $n/4$, duplicating the mass market performance, but without advertising and copyright enforcement costs. Those are considerable cost savings; and they create further opportunities to tax and redistribute some of those savings, to create further incentives for all to join the network.

### 4.3 Subscription Model

There are several problems with the model presented in the previous section.

a. Initial purchasing prices are very high, reflecting the large market potential, and the large potential revenues from reselling. But those high prices may create barriers to purchasing, both financial and psychological, even if they are to be recovered later by the revenues from reselling.

b. It is difficult to estimate the market potential of a product even at the aggregate level, so initial purchases may have to take a great deal of risk with respect to reselling opportunities. The system does not provide extra rewards for the higher risk taken by those early buyers.
c. Each product is still offered for sale individually, and the buyers have to decide whether to buy it or not. The buyers’ transaction costs are similar to mass markets then, although the search costs have been reduced due to filtering by trusted partners. As such, there may be an incentive to buy the product directly from the producers, by passing all intermediaries, after receiving recommendations from trusted intermediaries.

d. Social networks tend to be densely connected locally which may violate the local monopoly assumption. Each node may receive offers for the same product from several of its trusted partners simultaneously, despite extensive customization and filtering, and that may force those sellers into price competition. In general, the network architecture may be important to the analytical results, and the assumption of a random network may not be appropriate.

A natural network solution to all of these problems is subscription. Each node can subscribe to all products delivered by its trusted partners, and pay a periodic subscription fee. Each node would receive such bundles from their trusted partners, and create a new customized bundle from those, to be delivered to their subscribers. Such a subscription system elegantly solves all the problems listed above. It reduces the transaction costs for buyers by replacing many individual purchase decisions with few aggregate trust decisions to pick the nodes to subscribe to. Since duplication and transmission costs are near zero, such a strategy has no additional costs. It eliminates the difficulty of financing initial high prices, since any high subscription fees paid are offset by high subscription fees collected by reselling, and collecting subscription fees prior to the delivery of products offsets them against each other. The subscribers only need to pay the difference between the fees owed and the fees earned, and that is the aggregate value of all products delivered to that node during that period. Moreover, there is no need to estimate the market value of each product, but only the market value of all the products flowing through a node during that period, and such aggregate demand is much easier to predict because of the reduction in variance with a large number of products. The aggregate demand is easily computed incrementally and dynamically by constantly aggregating the subscription decisions of one’s neighbors.
Aggregating demand over a large number of products reduces variance in reservation prices. The economic impact of such aggregation is significant since it raises the expected revenue of the producer higher than what was achievable by selling individual products, by reducing market uncertainty. We will show that the stochastic model of Section 4.2 provides a lower bound for producers’ revenues in the subscription model, and the deterministic model of section 4.1 provides an upper bound. Moreover, we will show that all will be better off under a subscription scheme, because of reduction in deadweight loss due to lower market uncertainty. Moreover, the transaction costs are reduced by automating the distribution completely, since now all neighbors of each node receive all products delivered by that node. More importantly, the ability of each node to sell subscriptions ahead of time and to customize the offerings by filtering, refining, and modifying a large collection of information products makes each node unique in its offerings, and justifies the local monopoly assumption. The monopoly power that used to be achieved through copyright protection can now be achieved much more efficiently simply by allowing the nodes to customize the products and offer them only to their trusting partners. This new kind of monopoly power is likely to benefit all, and create much less resistance by the buyers, especially if buyers are also resellers. Finally, these results are independent of the network architecture, as long as the network is fully connected with a path between any two nodes. We continue to assume that each node has m outgoing links for simplicity, but the results do not depend on that assumption, since m could be different for every node and the computations depend only on the local m value for each node.

Consider the same trust network with n potential buyers for each product, where n is much smaller than the number of nodes in the network, because not all products are relevant to every node. Irrelevant products can have a negative value since searching for relevant products within an avalanche of irrelevant products is costly. Moreover, the products with incorrect, misleading, or exploitative content such as propaganda, unwanted advertising, or offensive messages, have an intrinsically negative value. A subscription system relies on trusted partners to filter out irrelevant products. Assume temporarily that each node has m outgoing links and one incoming link as before, but with the new assumption that each
node now receives a bundle of products from its incoming link, and distributes another bundle of k products that it chose as the most relevant to its subscribers. Each node at each step t now faces a normal distribution of reservation prices with mean $k(a_t+1)$ where $a_t$ is the expected revenues of buyer nodes at time t by reselling each product. This normal distribution is obtained by aggregating k uniform distributions of reservation prices for k products, each with a mean of $a_t+1$, for large k. For a particular product within the bundle, the reservation prices also follow a normal distribution with mean $a_t+1$, obtained by dividing the stochastic variable by k. Let $q_t$ be the total sales up to time t for one product, then $n-q_t$ is the remaining untapped market at time t, and let $rn-q_t$ be the expected revenues that will be extracted from that market, with $r$ being the global expected rate of market exploitation. Then $a_t = (rn-q_t)/q_t'$ since there are $q_t'$ buyers at time t facing a market potential of $n-q_t$. Let the seller facing a normal distribution of reservation prices set the optimum price at $a_t+p_t$, $p_t$ will be less than $\frac{1}{2}$ because of the symmetry of normal distribution, $q_t'$ will be greater than $m^t/2$ since there are $m^t/2$ potential buyers at each time t, and the optimum price with a normal distribution always captures more than half those. Clearly, the stochastic model of the previous section is a lower bound for revenues with a subscription model, and the optimum revenues at each node will be greater than $\pi_t = (n/2-q_t) + (m^t/2)$, and the revenues of the producer will be greater than $n/2$.

Relaxing the assumption of a single incoming link, and considering market saturation, as in Section 3.2, we get similar results since only $\frac{(n/2-q_t)}{n/2}$ proportion of potential $m^t/2$ buyers are available as buyers at each time t, leading to $q_t' > \frac{n/2-q_t}{n/2} \frac{m^t}{2}$.

Solving for $q_t$ as in Section 3.1, we get

$q_t > \frac{n}{2} - \frac{n}{2} e^{\frac{2-m^t}{\ln(m/2)}}$, $q_t' > \frac{m^t}{2} e^{\frac{2-m^t}{\ln(m/2)}}$ and the price $a_t+p_t < \frac{(n/2-q_t)}{q_t'} + 1$

And those results lead to revenues $\pi_t > (a_t+p_t) q_t' = ((n/2-q_t) + q_t'$
with the producer’s revenues $\pi_0 > n/2$, and the total consumer surplus $> n/4$, providing lower bounds for revenues of all nodes for the subscription model.

Similarly, when the variance of reservation prices approaches 0 because of very large bundles of $k$ goods, the subscription model reduces to the deterministic model of section 3.1. The deterministic model provides then an upper bound of revenues for the subscription model. As a result, the subscription model has revenues bounded by our two previous models: bounded from below by the stochastic single product model of Section 3.2, and bounded from above by the deterministic single product model of section 3.1. As a result, the subscription model provides higher revenues for all producers, and higher surplus for all consumers, compared to the single product model, while maintaining all the advantages of a network market. It accomplishes this by reducing market uncertainty and deadweight loss. More importantly, these findings are independent of the network architecture, defined by parameters $n$, $m$, and $k$, the number of nodes, the number of links per node, and the number of products bundled.

Figure 3.1: Total cumulative sales and price over time in the subscription model, bounded by two previous models.
5. Applications

A trust-network-based market place for information goods has a number of advantages as discussed in Section 2. Those advantages encourage the development of a variety of novel applications.

a. Information products such as books, movies, music, and software can be marketed and distributed much more efficiently as discussed in section 2.

b. Product recommendations are also information products, and they don’t have to be free, or ad supported, as they now typically are. However, charging for them is difficult as they are usually very small transactions, and their reliability and relevance are difficult to establish. Mass recommendation systems can be replaced with network-based recommendations, where each node subscribes to the recommendations of its trusted partners in each domain of interest, and those recommendations themselves are aggregated from the trusted partners down the chain, through a network of connections. This approach provides an elegant solution to a variety of problems plaguing mass recommendation systems. Reliability is easily established by filtering recommendations through trusted partners; scale problem is solved by aggregating recommendations over long chains of trusted partners; and incentive problems are solved by allowing nodes to subscribe to each other and pay subscription fees. Each node has an incentive to locate and subscribe to the most reliable sources of information, and has an incentive to provide the most reliable and relevant information to its subscribers to keep their business, leading to a decentralized and dynamic solution. Not only the producers of good recommendations, but also those who reliably filter and aggregate recommendations can generate significant revenues in proportion to their incremental contribution, creating a dynamic market with easy entry. Subscription fees can dynamically reflect the contributions made by each node to the recommendations, through incremental and periodic adjustments to the fees throughout the network [1, 2].

c. News business has been in turmoil since the collapse of the newspaper-based classified ad business, and its movement online to specialized businesses. The problems with selling news directly to readers are
the small size of each transaction, and the difficulty of establishing reliability and relevance, as in product recommendations. As a result, customers are forced to subscribe to large collections of news and commentary from many sources, most of which may not be very useful or relevant to them; and they are forced to do a great deal of filtering, aggregating, and interpreting, all of which reduces its usability and its value. Social networks are already providing an alternative to mass distribution of news by virally spreading links to interesting news and opinion articles. But the service is typically free and limited to general purpose social networks, and the links always point to an original source. That limits distribution; discourages the creation of derivative products; encourages copyright violations; and still does not resolve the issue of financing the news business. Trust networks specifically built for the context of news distribution can provide a solution where news providers can sell subscriptions to a small number of resellers with no copyright protection, and at a price that reflects the potential revenues from reselling. Those resellers in turn can distribute the news after aggregating from multiple sources, and filtering to reflect their interests; and the process continues at multiple levels, reaching new consumers who are also resellers at each level. Such decentralized distribution can accomplish customization at multiple levels; improve relevance through filtering by trusted sources; reach scale by aggregating from multiple sources; and collect payments through subscriptions from trusting neighbors. Consequently, not everybody has to subscribe to the primary sources, but the subscriptions can be quite refined, customized, filtered, and aggregated, by personally trusted sources at multiple levels [12].

d. Political action has already benefitted from social networks both in the US and elsewhere. But the distribution of political messages is haphazard and unreliable. A trust network can improve the reliability of information by routing and filtering it through trusted paths, while increasing its coverage through aggregation over many sources. Trust networks can also improve voting and political decision making by delegating decisions to trusted but more qualified agents at multiple levels of delegation. Voters can delegate by assigning their votes to their trusted partners, and as a result votes get aggregated in the hands of a few knowledgeable nodes who can make informed decisions about specific issues, and also represent
the interests of their trusting partners. Representative democracy is based on this ideal, but a trust network can extend that ideal from one level to multiple levels through long chains of trust, where each voter delegates to personally known and trusted partners, but can reach knowledgeable representatives indirectly. It is also possible to incorporate a payment system as described above, to remunerate those who develop expertise on specific issues, and vote on behalf of others who trust their expertise and judgment [18].

e. Collaborative work over social networks is in its infancy. Distributing work and delegating tasks to trusted partners can potentially change the way we work. Delegation has to be done at multiple levels for maximum effectiveness, as the tasks are broken down into components and the finished components are assembled into solutions. This is how corporate hierarchies work, and extending them to all areas of work in such a large scale and with no initial investment of organization design, but by simply relying on the network infrastructure, opens up new possibilities for organizing work. Academic research, book writing, music composing, and many other information product development projects can all be assembled and disassembled over trust networks, extending corporate efficiency to non-corporate work. Contributions can be remunerated or acknowledged with payments or credits flowing over the network either as individual payments or credits, or as long term subscriptions or alliances, with no centralized management [29].

f. Resource sharing on the web is of growing interest. The earliest examples such as car or lodging sharing have been somewhat successful. But there are numerous problems with these business models such as the trustworthiness of the sharing partners, scope and granularity of sharing, and the reliability, payment and insurance mechanisms, all of which can be remedied by trust networks. The paths of trust can be used to locate trustworthy sharing partners, and also to guarantee performance and payment. All participants have an incentive to perform or risk losing the trust of valuable partners, and lose the future benefits, products, and payments that would flow from those partners. Multi-level sharing can solve the granularity and scope problems in a decentralized fashion. Aggregating offerings from multiple nodes and
then filtering and refining them for specific user groups can create a decentralized solution to complex
granularity, search, and scheduling problems. Large numbers of products can be aggregated, and then
divided into shareable components by your trusted partners to match your specific needs or schedules. For
example, trusted partners can collect many transportation, lodging, and food options from their upstream
trusted partners, and filter and refine them to create complete vacation plans for their downstream partners
who trust them for specific occasions such as weddings or conferences. All the payments for such
services are collected from and distributed to contributors over the network with no centralized
management [29].

Payments are also information products and they can flow over the network without any central
control as discussed in section 3. That creates opportunities to manage insurance and investments without
central authorities such as banks and insurance companies. Nodes can provide guarantees and insurance
to those that trust them about the performance of the nodes they trust. Such cascading insurance
protection allows nodes to be protected by their immediate neighbors, even when the actual product is
coming from a distance in the network. Those who break insurance promises will face a loss of trust, and
a loss of future payments that are derived from those trust connections. Investments can also be managed
in the same fashion where each node invests in a portfolio that its trusted partners hold. Those nodes in
turn can invest those funds in other portfolios that are owned by their trusted partners. Each node acts as
an aggregator of securities to build a portfolio from the investments of its trusted partners, and makes the
new portfolio available to those that trust it, leading to a decentralized and multi-level investment banking
system [10, 38].

6. Trust Network as a Payment System

Money can be radically reinvented and decentralized through an effective trust network. Money is an
information system designed to value, record, and track economic transactions. It is an information
system with minimal semantics and centralized control. Consequently, the monetary system fails to
support many transactions directly, but requires intermediaries such as banks, brokers, insurance companies, credit card companies, and investment firms, increasing transaction costs greatly [32]. An effective trust network allows the management of money to be decentralized and its semantics enriched. It can accomplish this by replacing national currencies with private currencies, and creating an automated peer-to-peer network of currency exchange systems to support complex transactions. Each agent can print its own currency which can be viewed as personal IOU’s. They can be used to pay for goods and services to the extent that other agents trust the issuer and will accept its currency as payment. Money is all about trust in the credit of an issuer, and an effective trust system can replace the government as the sole trusted party, with many private trusted parties, whether they are businesses, non-profit organizations, or even individuals. The payments to agents who are not direct trusters of an issuer can be managed by the network, by finding a trust path where every agent accepts the currency of the previous on the path, and a sequence of currency exchanges leads to an effective payment. In effect, the same mechanism that was used in Section 3 to execute transactions, can also be used to pay for transactions [28, 32].

Example 6.1. Give the following snippet of a trust network, where A trusts B and B trusts D for medical services, which is shown in black, and A receives some medical services from D. Similarly D trusts C, and C trusts A for payments, which is shown in red, and A can use this path to pay for the services of D. A uses its own currency to pay C, which C accepts because it trusts A; and C uses its own currency to pay D, which D accepts because it trusts C. In effect A made a payment to D, through a trust path, by using consecutive currency exchanges. Of course, the exchanges are executed automatically by the network, without any manual intervention by the agents involved, so long as the agents are trusted to accept each other’s currency, and the pre-specified limit have not been reached. However, C and D end up holding some foreign currency at the end of this exchange, and those holdings need to be balanced out at some point, as we will discuss later.
Agents are incentivized to accept the currencies of their trusted partners, because payments, just like transactions, are designed to provide a stream of income, to all those involved in enabling them. The system collects a commission from each payment, as is typically done with credit card transactions, and distributes it to all those that are on the trust path that enabled the payment. Each agent sets a limit on how much currency it will accept from each of its trusted partners. When the limit is reached, the two nodes have to balance the payments by exchanging currencies. This is straightforward when two agents trust each other, accept each other’s currency, and periodically as they reach their limits, the system automatically exchanges the currencies and returns them to the original issuer. So, if both A and B trust each other, and at the end of a period, each ends up with 10 dollars’ worth of each other’s currency, the system simply exchanges them, and returns them to the issuer, so each agent ends up with no foreign currency, as expected. However, such reciprocal trust is not always possible, conveniently holding sufficient amounts of the right currency, and longer cycles have to be found to balance the currency holdings.

Example 6.2: Consider the following snippet of a trust network in the payment context.

A trusts B and accepts its currency; B trusts C and accepts its currency; and C trusts A and accepts its currency. When A reaches the limit of the amount of B’s currency it holds, the system will find the smallest cycle, and move some of B’s currency from A to B; move the corresponding amount of C’s currency from B to C; and move the corresponding amount of A’s currency from C to A. In effect it replaces A’s holding of B’s currency with A’s own currency, by taking advantage of the cycle, and moving equivalent amounts around the cycle.
Sometimes a cycle may not be synchronized, and the agents, although they accept each other’s currency, may not have sufficient amounts to complete the cycle at a given point in time. This requires a more complicated strategy involving bisected cycles, and unsynchronized multi-step balancing of the payments.

Example 6.3: Consider the following snippet of a trust network in the payment context.

![Diagram](image)

This is called a bisected cycle, since ABCD forms a cycle, but AC bisects it into two separate cycles, both starting at the same node, yet one including the other. In this case the cycle ACD is included in the cycle ABCD. Such bisected cycles can be used to have unsynchronized multi step balancing of payments. A has an excess of B’s currency reaching its limit of holdings. The system will try to balance the payments by moving B’s currency from A to B, an equivalent amount of C’s currency from B to C, and an equivalent amount of C’s currency from C to A. In effect the system replaced A’s holding of B’s currency with C’s currency, which A both accepts. When A reaches the limit of its C’s currency holdings, the system will use the ACD cycle as before to return all currencies to their original issuers. In effect, the system divided the payment balancing process into two unsynchronized steps, by making A hold C’s currency temporarily.

7. Conclusions

Trust networks have significant potential to create novel market places for information products. They can act as infrastructure to support a variety of economic activities creating new efficiencies. They can provide an efficient distribution and marketing system for information products over trust paths with no copyright protection. They can generate monopoly revenues for the producers of information products,
but without restricting the use, reuse, or the creation of derivative products. They can reward those who
are distributing, modifying, and refining products, appropriately and in proportion to their contribution,
with no central management. They can provide incentives to join the network and find trustworthy
partners, and to maintain the trust of others by providing trustworthy information and reliable and relevant
information products. In this article, we have designed such a marketplace for information products. We
showed that they maintain market efficiency, while significantly reducing transaction costs such as
distribution, copyright enforcement, and advertising costs. Firms can significantly trim their bureaucracies
and reduce their costs in this environment by relying on our network infrastructure to support their
transactions. Future research is suggested in designing or simulating large scale trust networks and
empirically testing the theoretical claims of this article. In practice, building such trust networks as new
business models and testing their competitive advantage would be useful. Trust networks can be initially
built very simply on top of existing social networks by adding domain labels and trust links, with many
other features such as payment systems and insurance mechanisms added as needed.

References