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Abstract

Many researchers show that "market institutions" are an ideal means to exchange and allocate resources under the assumptions of perfect and symmetric information and perfect competition. However, in the real world, we observe many instances in which these assumptions are not satisfied due to imperfect competition, incomplete information, transaction costs, and externalities.

In this study we found that a posted-price market for digital goods with dynamic-price-update in a digital economy is efficient and the resulting market statistics are close to the competitive market equilibrium under a competitive environment. Another interesting finding from this research is that sellers with customization failed to capture all the consumers' surplus, defying the prevalent myth that sellers may extract the entire surplus from the market by using customization on the Internet and by using information technology tools to identify individual customers. One major explanation for this result is that competition among sellers prohibits them from charging prices according to customers' demand for each product, in cases where switching from one seller to another is not so difficult for the customers.

Keywords: Virtual Field Experiments, Market Mechanisms, Customization, Digital Goods, Digital Economy

1. Introduction

As Henry et al. (1999), Shapiro and Varian (1999), and Tapscott (1996) suggest, we are in the turmoil of an information revolution led by innovations in information technologies such as computers and networks. Although only half-a-decade old, this revolution is having a substantial impact on our economic and social lives. The Internet and related computer networks are enabling and shaping a new economy based on the networking of human knowledge and intelligence. In just three years, electronic commerce over the Internet has become one of the most popular ways of conducting business. In this digital economy, individuals and corporate businesses create wealth by applying knowledge, networked human intelligence, and effort to manufacturing and distributing digital goods and services. Moreover, the players, roles, incentives, market mechanisms, business processes, and requirements for survival and success are all changing rapidly. Traditional business models, business propositions, research, and research methodologies for a physical economy are

undergoing a challenge in this new economy, because of the distinctive features of this new economy, such as zero marginal utility, ease of customization, removal of geographical boundaries for a customer base, low marginal costs of production, and easy transfer of goods. In this research we focus on the efficiency of digital marketplaces, because markets — an ideal means to exchange and allocate resources — play an important role in this new economy.

To analyze and understand this new digital economy, we use virtual field experiments (Kim *et al.* 2001), where a researcher runs experiments in realistic business environments and settings for an extended period of time and analyzes data collected among various control groups in a digital economy. Using this new research methodology, we measure the effectiveness of digital marketplaces in order to find proper business models for a digital economy.

Because a digital economy makes it relatively easy to process information about customer preferences and to customize digital products, many are concerned about the welfare of consumers and about the effectiveness of market mechanisms in this new economy. Our research shows that, despite these concerns, the marketplace in a digital economy is relatively efficient. We found that consumers in this marketplace still retain some of their surplus, even if sellers are trying to charge high prices by customizing products and by using information they have about buyers. This result contradicts a prevalent myth in the digital economy that sellers with more market power may exploit consumers to the extreme, and thus consumers will be worse off in this digital economy. Our research shows, rather, that both buyers and sellers can gain benefits from this new economy when real market mechanisms and settings function as we set up in our virtual field experiments.

2. Research on a Digital Economy

This section briefly discusses the characteristics of a digital economy, reviews a virtual field experiment that proposes a new research approach for the digital economy by modifying traditional experimental approaches in economics, and contrasts this new approach to a few research approaches applicable to the analysis of the digital economy.

2.1 A Digital Economy and Digital Goods

This research focuses on a digital economy, a special economy where all goods and services traded are in digital format. As with physical products, a digital product also needs an outlet or marketing channel through which it can reach the consumer from the producer or manufacturer. The most common marketing medium by which digital products are sold on the Internet today is through a storefront in the form of a web site. Most companies selling software, information, etc., provide an Internet shopping storefront (outlet) as a part of their web pages, allowing consumers to purchase their products directly. Unlike traditional marketing channels, the cost of establishing a storefront on the Internet is relatively minimal, and one can find almost every manufacturer providing its services on the Internet. As a result, consumers are provided with a richer set of choices in terms of price and features. The consumer's choice of an Internet store is determined by factors such as network comfort level, the fit of information, and search cost, as opposed to the cost of traveling to stores in traditional marketing models (Kim *et al.* 1995).

The advantages of a digital economy over a typical physical economy are (1) ease of information access, (2) interaction richness, and (3) low information and interaction costs (Barua *et al.* 1995, 1996-97). These are the major reasons why consumers prefer the digital world to a traditional environment or market mechanisms. In this new environment, users can access relevant information dispersed throughout the Internet without traveling extensively in Webspace. That is, in this digital economy, users can access information more easily than in a traditional economy. This ease of information access is provided by organizing information using intellectual indexing schemes, good search engines, dynamic linking, open connectivity standards, and new market transaction mechanisms. Moreover, meaningful and rich interactions among the users of this environment allow users to overcome the barriers of space, time, and media/document formats in interacting with others. For instance, technological features of the Experimental Digital Economy (EDE), such as multimedia support, interaction management, asynchronous and synchronous communication support (forums, announcement boards, and virtual chat rooms), and dynamic linking capability, provide rich interactions among the users of the system. In addition, by combining features and capabilities in a coordinated fashion within this unique technological infrastructure, we increase the level of information access and interaction richness while reducing the user's costs of information access and interaction. EDE is a technological infrastructure enabling research on electronic commerce and can be accessed at http://ede.bus.utexas.edu.

3. Market Equilibrium Analysis using Virtual Field Experiments

Market equilibrium analysis is a key tool in analyzing the effectiveness of a market institution and settings and predicting the robustness of competitive price theory predictions to institutional and structural alterations (Davis and Holt 1993, Kagel and Roth 1995). We focus on market equilibrium analysis for digital products in a digital economy using virtual field experiments.

3.1 Preparation for a Competitive Market Equilibrium Analysis

In this section, we briefly discuss three research challenges and breakthroughs in the analysis of a digital economy. First, the individual demand curse for a digital product differs from that resulting from most economic analysis on commodities. Digital products generally provide information or services, so that consumers of these goods want to purchase at most one unit, resulting in a kinked or discontinuous individual demand curve. Second, each product in a digital economy is customized and therefore unique. This violates a fundamental assumption in market analysis that products are homogenous. Third, sellers do not price their goods according to the marginal cost of production, which is the primary driving force behind traditional supply curves.

To answer these challenges, we adapt analytical methods in economics and devise new measures. For instance, an approach used in analyzing durable goods is adopted to measure individual and market demand curves. Grouping of comparable or interchangeable products into discrete categories is also used to visualize market demand and supply, since many customized products are still comparable in the eyes of buyers. Finally, we use willingness-to-sell measures rather than sellers' marginal cost measures in our market equilibrium analysis. This series of experiments is the first attempt to use willingness-to-sell in the analysis of market equilibrium.

In this new digital economy, producers and sellers can easily customize digital products for their consumers. Furthermore, many including Gilmore *et al.* (1997) suggest that mass-customization is the key to success in the digital economy. That is, the costs of customization in production or sales are lowered substantially due to technological advances. Customization can enhance the consumer's utility from the consumption of a good and can build customer loyalty to a seller, which can lead to revenue for the sellers in the long run. Each seller can play the role of a monopoly when a product is ultimately customized and priced for each individual consumer. Moreover, if each digital good is unique and ultimately custom-produced, we cannot apply traditional competitive market analysis tools to measure the effectiveness of a marketplace.

Conversely, in the digital marketplace we focus on products from many competitive producers that are often interchangeable. Because a consumer considers buying one information product from among a group of digital products that are comparable or substitutable, we can categorize or group a number of products as one product group based on the characteristics of the product and on consumer needs. For instance, a technology review on cable modems produced by seller A is, technically speaking, different from another review on cable modems summarized by seller B. Nevertheless, consumers may find that either one of these two digital goods can suit their needs, and they may choose to buy the one among the two that delivers a higher surplus. Thus, we can classify these two pieces of information as one product group. In the grouping process we also used measures of "quality" to classify these information goods into five different categories, with experts in the IT industry assessing the products according to quality. Using such categorization of products, we can analyze market equilibrium on each product group at the same quality level without violating intrinsic economic assumptions.

In typical economics research, the demand curve of a market is derived from individual demand curves. That is, when individual consumers' demand curves are given, a researcher can add them up to get a market demand curve. Similarly, if a researcher has a number of independent sellers of a good, he can add up their individual supply curves to get the market supply curve. An individual supply curve measures how much a seller or producer is willing to supply of a good at each possible market price. From this market equilibrium analysis, we have to keep our eyes on a few important assumptions. This analysis is based on generally accepted notions such as the following: an individual prefers to consume more units of the same good, many individuals want to use the same good, and sellers can produce multiple units of the same good at variable costs.

This study, however, found that research methods used for analyzing commodities in traditional economics do not apply at all or must be revised to attain research goals in this new economy. For instance, each buyer's demand for a good is discontinuous when buyers are willing to buy at most one copy of a product. This is seldom observed in research for commodities, but economists interested in durable goods often encounter this problem. Papers in econometrics do discuss this issue by focusing on understanding the demand for durable goods, consumer behavior and characteristics (Roos and Szcliski 1943; Brown and Deaton 1972; Chambers 1992; Masih 1999) and modeling survey bias (Hsiao and Sun 1999). These papers also provide guidelines and methods of answering research questions in analyzing demand for durable goods such as measures, systematic bias in estimation, the roles of various factors in an economy, and price elasticity using data collected from a real economy. In our research we adopt this technique along with methods developed and used by

experimental economists to collect data and analyze market demand and supply in the digital economy.

Consumers in this digital economy search for and purchase an information or service good rather than a physical product. Accordingly, a user consumes only one unit of a product and the utility of consuming additional units of the same product is almost zero. For this type of market environment, we cannot get a typical smooth downward-sloping demand curve for each buyer. Rather we observe a kinked demand curve on one product for each buyer, as in Figure 1. This figure shows individual demand curves for four buyers, A through D. That is, buyer A wants to purchase only one unit of this product at the price of $1,000; buyer B, at $800; buyer C, at $600; and buyer D, at $500, where utilities for each consumer from i = 1 through 4 purchasing at least one unit of a product are as follows: $U_1 = 1000, U_2 = 800, U_3 = 600,$ and $U_4 = 500$, respectively. By adding up these kinked demand curves (Davis and Holt 1993), we can get the market demand curve for each product in the digital economy in the following:

$$D = \sum_{i=1}^{n} d_i(p_i, h_i, m_i), \text{ where}$$

d_i: consumer i's demand function with $1 \le i \le n$ and $d_i \le d_{i-1}$;
p_i: reservation price for a good;
h_i: consumer's preference for a good;
m_i: consumer's wealth or budget for a good;
n: the population of buyers participating in a virtual field experiment.

Each individual's demand for each good depends on price, his or her own characteristics or preference for goods, and monetary income. A consumer's demand is completely described by his *reservation price*, the price at which he is willing to purchase just one unit of a good. This equation of market demand can also be represented graphically, as in Figure 2. The market demand curve in this case might slope downward, since a decrease in the market price increases the number of consumers who are willing to pay at least that price.

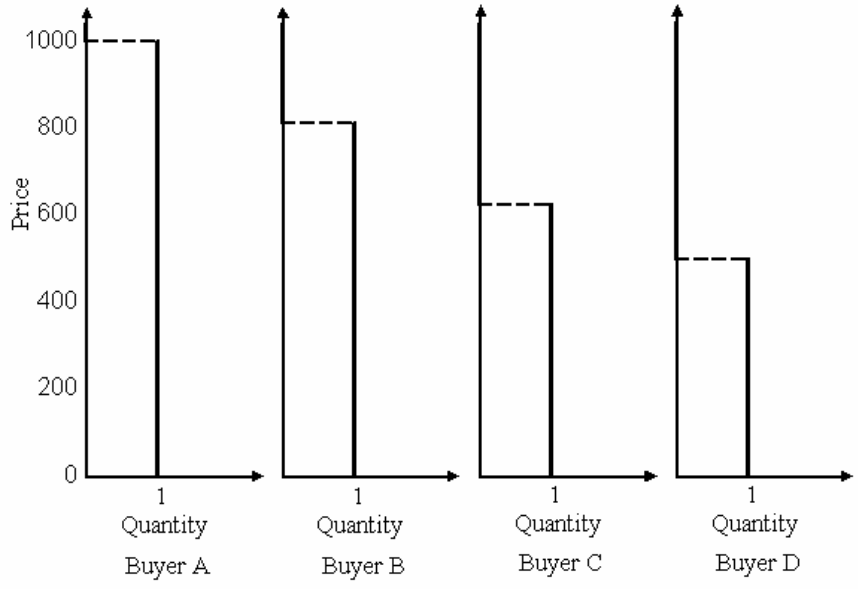

Figure 1. Individual Demand Curves for a Digital Product

Understanding this process of capturing market demand or a willingness-to-pay curve for a marketplace is critical in analyzing market equilibrium. This whole process makes it feasible for an experiment to explore market equilibria for this new type of market environment. This is the first step in the data collection and analysis of a digital economy.

3.2 Proxy Measure for Supply and Demand

The cost of digital products is worth mentioning, because this element of the digital economy — the cost structure — distinguishes digital goods from physical goods. Experiments in economics (Davis and Holt 1993, Kagel and Roth 1995, Plott 1989) use a marginal cost, not equal to zero, as a crucial assumption in driving and understanding the supply of products. On the other hand, as Choi *et al.* (1997), and Shapiro and Varian (1999) argue, the cost of creating a digital product is substantial, but the cost of reproducing or customizing it for a customer is minimal. That is, the fixed cost of producing a digital good is high, but the variable costs that cover reproduction or duplication of the good are substantially low, so that the good cannot be priced based on its variable or marginal costs. Because of this nature of digital goods, sellers often find themselves giving up the traditional pricing approach, one based on an analysis of cost structure.

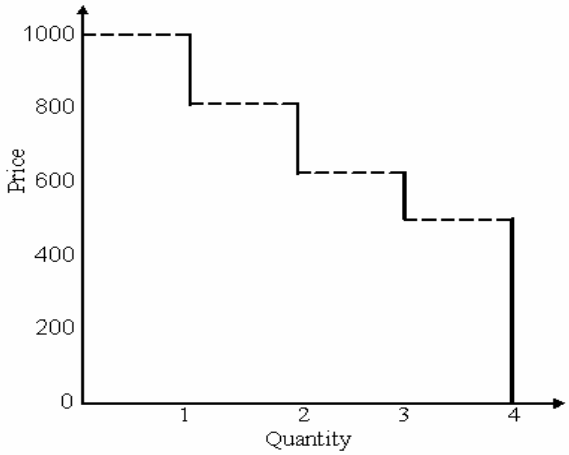

Figure 2 Aggregated Demand Curve

We also found from virtual field experiments that most sellers in this market price their products based on the expected price that a consumer is *willing to pay* for their products rather than on the marginal costs of production. This led us to collect data on a *willingness-to-sell*, the price at which a seller is willing to sell a product to a consumer, rather than focusing on how many hours and other physical or mental resources the seller has put into producing this product. That is, for each seller *i*, there is a unique reserve price, p_i^s, at which this seller will supply one or more units of the good at a price higher than p_i^s, but will not supply anything at a price less than p_i^s. For clarity, we use the term *reserve price* for a seller, in contrast to the *reservation price* for a buyer. People are often reminded of the sellers' reservation price when we discuss the *reserve price*, because many auctions on the Internet use the term *reserve price* rather than *reservation price* for the reservation price of a seller, whereas economists often use the term *reservation price* in auctions and in many microeconomic analyses which focus more on consumers than on sellers.

Collecting information such as willingness-to-pay and willingness-to-sell through administering survey questions and using such data as a proxy of real value is controversial in economics. However, the use of willingness-to-pay in order to elicit the economic values of goods in economics has been gaining credibility. Ryan and Miguel (2000), Johannesson *et al.* (1997), Neill *et al.* (1994), and Sinden (1988) explored whether hypothetical willingness-to-pay from a questionnaire survey does equal actual willingness-to-pay. Through traditional experiments where subjects are randomly assigned, Johannesson *et al.* (1997) and Sinden (1988) find no statistically significant difference between hypothetical willingness-to-pay and actual willingness-to-pay. Neill (1999) also confirms this result and attributes the bias of a higher hypothetical willingness-to-pay than actual willingness-to-pay in earlier controversial studies to experimental setting and methods. Ryan and Miguel (2000) looks at the consistency of responses and suggests that any information not relevant to the commodity being valued should not be provided in the process of gathering hypothetical willingness-to-pay. Thus we use these proxy measures in this research with great caution.

There is a natural incentive for buyers to report lower their willingness-to-pay and for sellers to inflate their willingness-to-sell if such information were to be disclosed publicly. In order to make this revelation of willingness-to-pay and willingness-to-sell values as truthful as possible, we did not disclose this information in the marketplace. Participants were aware of this confidentiality.

3.3 Experimental Set-up for a Virtual Field Experiment

This virtual field experiment enabled by the technological infrastructure of EDE has many advantages over traditional experimental settings in economics. This technological infrastructure permits large-scale participation by both experimenters and subjects without regard to geographical limitations. In our experiments conducted during the fall of 1998 and the spring of 1999, participants were upper-division undergraduates and MBA-level students taking information-systems-related classes at the University of Texas at Austin, George Mason University, The Monterrey Institute of Technology (ITESM) in Mexico, and the University of Illinois at Chicago. Participants were students who were both sellers and buyers: in our experiment we had around forty companies selling their digital products to around eight hundred buyers, all on EDE. Participation in this experiment was voluntary and participants were expected to abide by policies on academic honesty in the course of the experiment.

Traditional experimental settings with strict controls and strong internal validity as a result may not bear much resemblance to the real world, whereas realistic (natural) situations have numerous competing explanations for their results. Our experiment drew on students at different institutions and at different levels of expertise in order to simulate a market for information goods. Students who were sellers created “digital products” which provided students who were buyers with information helpful to them in their classroom assignments. In this case, the digital products were teaching aids on the subject of information technology itself, helping “buyers” better understand technologies on data communications, databases, and programming languages. Among the most popular items in this marketplace were brief descriptions of a technology, summaries of interviews with managers in information-technology-related businesses, and sometimes also software. “Buyers” – often students in introductory level classes – then used such goods to help them on their assigned projects and to gain knowledge on certain technology issues.

Within our experimental digital marketplace, transaction methods also simulated those in a digital economy. For instance, participants used digital money (electronic cash, or E-cash, provided by a digital bank) in buying and selling products. E-cash lowered the transaction costs of trading digital goods and the inconvenience of the payment process. Student participants' incentives, for both buyers and sellers, were both pedagogical and market-driven: on the one hand students gained knowledge about information-system-related technologies and first-hand experience in electronic commerce, with different participants producing or consuming digital goods or by running an organization in a digital economy. On the other hand, students received grades, cash prizes, and award certificates on the basis of their performance in various market settings.

In order to achieve high external validity, economists (Davis and Holt 1993; Plott 1989) are concerned about the valuation of products and the reality of exchange medium (E-cash). Participants in our experiment had used E-cash for at least a few months before beginning this experiment, guaranteeing their familiarity with such electronic money. This permits our participants to assess the economic value of a commodity or product in this virtual field experiment as naturally as they would in the real world.

4. Analysis and Results

Many researchers in economics hold that "market institutions" in theory are the ideal means to exchange and allocate resources, under conditions that assume perfect and symmetric information and perfect competition (Coase 1960, Tirole 1993). However, in the real world, we observe many instances under which these assumptions are not satisfied. In reality, imperfect competition, incomplete information, transaction costs, and externalities contradict the theory of efficient markets. Therefore, many economists and experimentalists investigating this market efficiency issue look for instruments and policies that can narrow this gap between theory and reality. As discussed earlier, a digital economy has many features that distinguish it from a typical economy for physical goods. This led us to investigate these fundamental questions of market efficiency and market effectiveness in a digital economy.

4.1 Supply and Demand for Digital Goods

Among the students who participated in this research, eighteen student groups (sellers) who produced and sold digital products on database management systems (DBMS) posted 134 digital products for sale on the EDE site. The contents of these digital goods ran from a simple syntax for SQL, which is five to ten lines of information in text-format, to an extensive review, several pages long, on database language.

We described earlier that willingness-to-buy and willingness-to-sell measures were used to develop market supply and demand curves. For this purpose, buyers were asked to answer a short questionnaire on their experience before and after they purchased a product. Based on these answers, we determine buyers' *willingness-to-pay* for each product and other information on buyers' shopping behavior, which we then use to draw a demand curve for each trial of experiments. Sellers similarly fill out a set of questions whenever they register products on EDE, and these questionnaires allowed us to track sellers' *willingness-to-sell*. This shows that the supply curve is still sloping upward, even if the cost structures for digital goods are substantially different from those of other goods.

From this market demand curve, we can see that a monopolist can maximize its profit by selling 25 units of this product at a price of $800.00. At this point, the consumer surplus is $17,199.40. That is, consumers' net surplus – the consumers' utility after deducting the prices they paid for these products – runs almost up to $17,200.00, while this monopolist extracts the consumer surplus, $18,900.00, from consumers.

4.2 Market Equilibrium for a Digital Economy

The market as a whole is a combination of the demand and supply schedules (Hey 1991). This analysis of demand and supply curves allows us to find the competitive market equilibrium (CE) for each trial of an experiment. The competitive equilibrium is the intersection of demand and supply curves. Using experiments, we can find whether marketplaces in a digital economy yield outcomes that converge to the CE, as Coase (1960) expected.

In this market, the competitive equilibrium price is $200.00 and fifty-two units are being sold at this price, as in Figure 3. The total expected revenue at this equilibrium is $10,400.00, while the consumer surplus is $36,099.40. On the other hand, collusion among the sellers could result in an increase in prices and a deficit of consumer surplus.

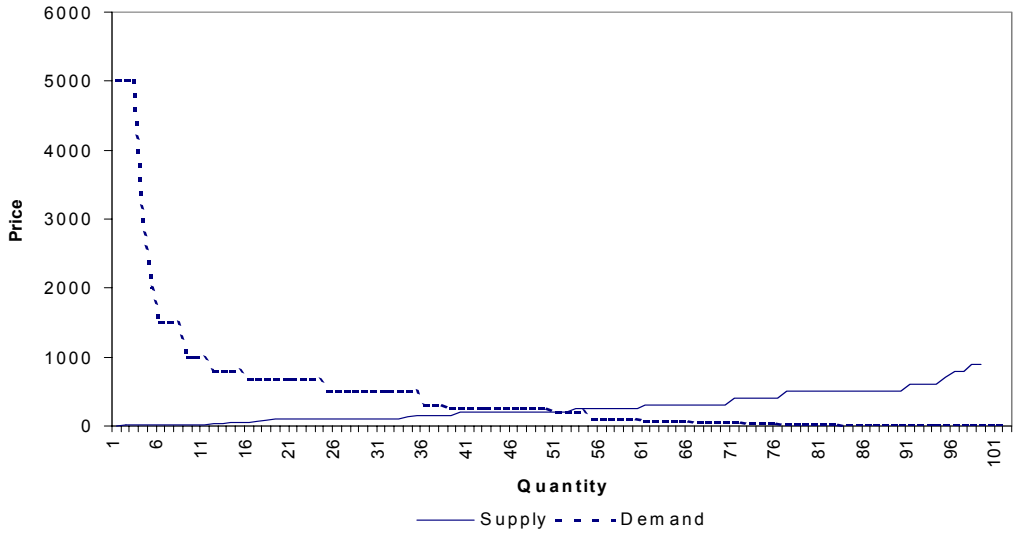

Figure 3 Market Equilibrium

In our experiments, fifty-one units of database products were sold at an average price of $348.35. From these market transactions, sellers gained a total revenue of $17,766.00. This price is almost twice the competitive equilibrium price, but it is still far closer to the competitive price than to the monopoly price. Moreover, the quantity sold in this marketplace is fairly close to the equilibrium quantity. Unlike many experiments done for a double auction, which is known to be very efficient at attaining a competitive equilibrium (Smith 1990, Hey 1991), the market prices we observed from virtual field experiments with a dynamic price update option are higher than the equilibrium price in this competitive market for digital products.

Unlike traditional economists' claim that products are all traded at the equilibrium price where the market is perfectly competitive, the market prices in this experiment show a difference in prices, from the highest price, $1005.00, to the lowest price, $25.00. This gap between high and low prices implies that differences in product quality, customization, and product differentiation have a great deal of impact on the market environment.

This implies that the market mechanism tested in this experiment is still quite efficient but has some room for improvement. One possible way of improving the efficiency of this market would be to introduce third-party certificates or related measures that can provide more product quality-related information, as suggested by Kim *et al.* (2001).

4.3 Seller's Market Power: Does Customization hurt Consumers?

A major concern about the new digital economy is that sellers can access and collect information on consumers easily due to new web technologies and network environments. The convenience and economics of mass- and micro-customization of digital products heighten the level of consumer satisfaction. Some are concerned, however, that sellers might be able to distinguish a consumer from others based on his/her shopping behavior and characteristics at an electronic store and might be able to estimate precisely consumers' willingness-to-pay. The fear is that this may lead sellers to extract the entire consumer surplus by using monopolistic pricing on their customized products. That is, sellers may end up getting the entire surplus generated in this digital economy, because the sellers have more tools and measures to understand consumer surplus and can exercise perfect price discrimination. In this study, we tested this possibility of sellers' excessive power and the consumers' worse fate and found these fears to be overstated.

In our digital economy, sellers or suppliers of digital goods failed to capture all the net-surplus that the market generated unlike what Diane (2000) and Montgomery (1997) conjectured. The vertical gap between the two lines in Figure 4 shows that the consumers' surplus in this digital economy has not been extracted by the sellers or producers who might have more information about their customers, and also possess the tools and technology to charge higher prices. One of the reasons that these sellers fail to capture surplus from the consumers is competition among the sellers. That is, pressure from market mechanisms and competing businesses keeps sellers' prices lower than the prices that they can charge or that consumers are willing to pay.

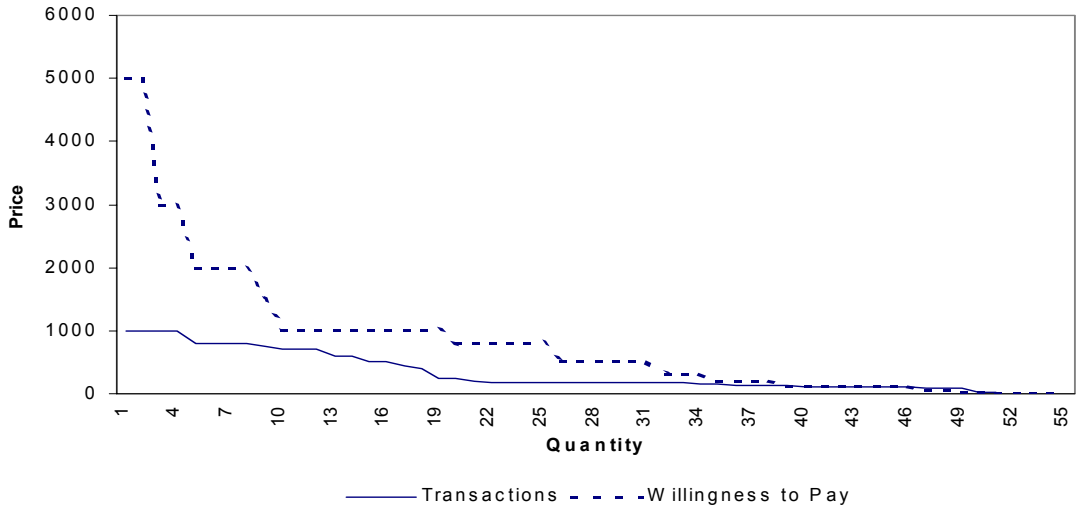

Figure 4 Consumers' Net Surplus

This result shows that this new market mechanism is efficient enough so that actually realized prices and transactions in the experiment are very close to the competitive equilibrium quantity and near to the equilibrium price. Even if sellers have better tools for understanding consumer characteristics and acquiring market-transaction-related information, consumers are not being sold over-priced goods.

As many other experimentalists in economics did for the physical economy, we can study, in the future, the speed of markets converging to a competitive equilibrium, if it ever does. Moreover, we can study whether the nature of the trading process used in the market affects either the attainment of competitive equilibrium itself or the speed of such attainment.

5. Conclusion

Distinctive characteristics of digital goods, such as nominal marginal costs, uncertainty of quality, and ease of transaction, require investigating the issues like the efficiency of various market mechanisms and the effectiveness of corrective measures.

The contribution of this article is twofold: First, it provides guidelines for a market equilibrium analysis of virtual field experiments. This paper addresses how to overcome challenges for research on a digital economy, such as understanding the characteristics of digital goods and mechanisms, handling the product customization issue, and formulating demand and supply. This research shows how to run a virtual field experiment for digital goods that can overcome many of these difficulties. Second, this research assesses the effectiveness of market mechanisms and the benefits for and welfare of sellers and buyers in a digital economy. Our market equilibrium analysis contradicts the myth that sellers can exercise monopoly power using customization in a digital economy. Rather, the actual transactions in this market setting are close to a competitive market outcome. While consumers enjoy the benefit of customization and low transaction costs, prices are kept relatively low due to low buyers' switching costs and competition among sellers. In short, this experiment demonstrates that a competitive market with dynamic price updates is efficient enough to attain market prices and quantities close to the competitive equilibrium.

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