THREE APPLICATIONS OF ECONOMIC THEORY AND METHODOLOGY IN INFORMATION SYSTEMS RESEARCH

MENG, ZHAOLI

(*M. A. Wu Han University, China*

B.Sc. Xi'an Jiao Tong University, China)

A THESIS SUBMITTED

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF INFORMATION SYSTEMS

NATIONAL UNIVERSITY OF SINGAPORE

2005

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. First of all, I am deeply indebted to my two supervisors: Dr. Sang-Yong Tom Lee and Dr. Ivan Png, for their insightful guidance, sustained support and generous help.

Four years ago, my oral English was so poor that I almost could not finish a complete sentence. Dr. Lee accepted me as his student and helped me with all the patience. He has spent much time and effort on teaching me how to be an independent researcher. And, he has given me a lot of encouragement along the road. I still clearly remember that I made a very bad presentation and almost lost all my confidence in my third year study. Dr. Lee talked to me after the presentation and I heard one of the most beautiful words in my life: “Trust me. You have the ability to get your Ph.D degree. I never doubt you can do that.” His trust gave me the strength to move on. Without his support and encouragement, I could not persist to today.

Dr Png is my idol (☺). He is the smartest and most capable man I had ever known. He has taught me not only how to do research but also how to do things perfectly. I admire his ability to make things simple and elegant. He is also a perfect manager, who knows exactly how to help the subordinates to find and use their strong points. The only bad thing to be his student is that it is almost impossible to find a better boss than him, which makes the graduation a pity. He has so many merits worth me learning from. One year's study under his guidance is too short and will be cherished in my heart.

I owe thanks to my two best friends in Singapore: Yin Yin Latt and Hu Yu. Yin Yin Latt comes from Myanmar. It is precious that two girls from different countries with different culture could be true sisters. All the shining days hanging around with them, all the laughter and tears, are my best memory. I know they will guard me and hold my hands whenever I need.

I am grateful to my friends here. They are Sun Jing, Wang Qiu Hong, Li Lin, Zhang Cheng, Zhou You You, Guo Rui, Shi Shao Mei, Xia Chen Yi, Gao Jiong, and Guo Xin Yu. Their friendship brings me a lot of joy.

I would like to express my heartfelt appreciation to Dr. Julian Wright for his effort to maintain the IO workshop, which provides a platform for the researchers in economic and IS fields to exchange ideas and discuss research questions together. I have met a lot of excellent researchers there, such as Dr Lu, Jing Feng and Dr Candy Qian Tang. They have given me a lot of encouragement and help for my research.

I thank Dr Laina Ho for her excellent lecture on English writing, where I learnt a lot of skills about how to organize and write the Ph.D thesis. Also, I thank the Department of Information Systems of NUS for giving me an opportunity to study in Singapore, as well as the financial support.

I give my deepest thanks to my families, especially to my parents, for their unconditional love to me. My parents know how important education is because their generation did not have the chance to attend University. They make all their efforts to support my brothers and me to get high-level education. It is a very difficult thing in my lovely and undeveloped hometown. In my four years of oversea study, I never encountered any other student from the same province, which reminds me what a precious opportunity my parents have given me. I know that they will feel happier than me to see this thesis.

Finally, this thesis is a gift to me. It represents my four-year effort, happiness, loneliness, and success.

Meng, Zhaoli

December 2005

TABLE OF CONTENTS

SUMMARY

Many problems in the field of IS can be solved using the theory and methodology of economics. In this thesis, three IS research problems: competition and compatibility between open source and proprietary software, IT investment value, advertising and signaling in eBay, are investigated from an economic perspective.

The first study focuses on the compatibility choices of a proprietary software producer when it competes with an open source software provider. By applying the Hotelling linear city model, I find that the best compatibility strategy for the proprietary software producer depends on the market coverage conditions. When the market is fully covered, inward compatibility is the best strategy. On the other hand, when the market is not fully covered, two-way compatibility is the best strategy. Such results are not affected by software quality. Furthermore, the proprietary software producer does not favor a proprietary rival changing to providing open source software, and such a change may lower social welfare.

The second study uses the event study methodology of economics to examine whether IT investments can pay off. A comparative study of IT investment value in China and the U.S. investigates the differences in IT value between developing and developed countries. The results clearly demonstrate that IT investments significantly increase the market

value of firms in China while insignificantly in the U.S. This suggests that IT investments have a more significant effect in developing rather than developed countries.

The third study aims to examine whether the optional features in eBay, such as Gallery, are advertising tools or quality signals. Using field data, I find that auctions with Gallery feature exhibited more intense competition, and thus had higher final auction price. Therefore, the Gallery feature served as an advertising function. Moreover, for high-priced products, high quality sellers were more likely to use the Gallery feature compared with low quality sellers. Thus, the Gallery feature served as a quality signal, which mitigated the information asymmetry between buyers and sellers.

These three studies demonstrate that economic theory and methodology can be used effectively in IS research to address problems related to IT and its application in e-commerce.

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INRODUCTION

1.1. General Background

This thesis applies economic theory and methodology in Information Systems (IS) research to study issues associated with information technology (IT) and its application in the electronic market. A basic definition of IS and its relationship with economics is given in the following sections to explain why economic theory and methodology can be usefully applied in the IS field.

The IS discipline has been defined in different ways. It has been depicted as "the study of the interaction of development and use of IS with organizations" (Cushing 1990), and "understanding what is or might be done with computer and software technical systems, and the effects they have in the human, organizational and social world" (Avgerou and Cornford 1995). Meanwhile, Davis et al. (1997) presented two areas which IS investigates: "(1) acquisition, deployment, and management of information technology resources and services (the information systems function), and (2) development and evolution of infrastructure and systems for use in organization processes (system development)". In conclusion, IS discipline investigates: (i) the development and application of IT, (ii) the relationship between the IT and social organization.

Economics has been widely accepted as not only one of the reference disciplines of IS but also one of the main IS research themes. Ever since the first International Conference of Information Systems (ICIS), economics has been deemed as one of the four reference disciplines of IS together with computer science, management science and organization science (Benbasat and Weber 1996). These four reference disciplines form the major foundations of IS (Keen 1980). Moreover, many researchers classify economic application in IS research as one of the main subjects of IS research (Culnan and Swanson 1986, Culnan 1987, Swanson and Ramiller 1993, Gosain et al. 1997). Various economic theories, such as game theory and economic models of organizational performance, have been applied to explain, predict and solve IS problems.

The reasons for the wide application of economics in IS field are: (i) IS and economics have an affinitive relationship, (ii) the economics discipline has solid theory foundation and mature methodology, which could be used as effective tools by IS researchers, (iii) economics addresses new problems arising with the growth of Internet Commerce.

The three essays in this thesis apply economic theory and methodology to solve three research problems in the field of IS, which are competition and compatibility between open source software and proprietary software, IT investment value, advertising and signaling in eBay.

1.2. Three Studies

1.2.1. Competition and Compatibility with Open Source Software

The first essay applies the Hotelling model of horizontal product differentiation to investigate competition between open source software and proprietary software. Open source software allows software developers to use shared source codes, identify and correct errors, and redistribute the source codes (OSI 2001, O'Reilly 1999). Open source software has won striking success in recent years and become a threat to proprietary software. Typical examples include Linux vs. Windows and Apache vs. Microsoft IIS.

Facing open source competitors, the developers of the proprietary software intentionally chose different compatibility strategies in different cases.[1] For instance, Microsoft intentionally made its website incompatible with Firefox, the new open source web browser. However, concerning web server software, Microsoft chose to be inward compatible with the open source software.[2] For example, in the web server market, Microsoft IIS (the proprietary web server) can support both PHP and ASP, the server side programming language. Thus, the programs designed for Apache (the open source web server) using PHP language can be run in IIS. However, since ASP belongs to Microsoft and cannot run on Apache, the programs designed for IIS using ASP are not fully usable in Apache.

In competition between two products with separate networks, if the network effects are strong enough, the respective producers face a dilemma regarding the choice of the compatibility. By choosing to be compatible, its users benefit from the network of the rival, but this increases competition. On the other hand, by choosing to be incompatible,

[1] Katz and Shapiro (1998) defined compatible as "when two programs can communicate with one another and/or be used with same complementary system components, they are said to be compatible".

[2] For the proprietary software, inward compatibility means that the files or programs designed for the open source software product can be used by the proprietary software, but the files or programs designed for the proprietary software may not be fully usable in the open source software product.

the producer may reduce the intensity of the competition, but then prevents sharing of the network from the competitor.

Which compatibility strategy should be chosen? What is the profit for the proprietary software producer under each compatibility strategy? Will the profit of a proprietary software producer increase or fall when its rival changes from providing proprietary to open source software? What are the welfare implications? Such research questions are interesting to both researchers and industry practitioners.

Although the competition and compatibility of two products with different networks have been well explored in the economic and IS fields (Katz and Shapiro 1985, 1986, 1994; Conner 1995), their results may not be applicable in the case of open source software vs. proprietary software. The reason is that the open source software is free and its profit is zero. Therefore, its competition with proprietary software is obviously different from the traditional duopoly competition where two parties pursue maximum profit.

Concerning such differences, I have built a Hotelling linear city model to study competition between open source and proprietary software, where only the proprietary software producer aims at maximizing the profit and the open source software reacts passively. The best compatibility strategy of the proprietary software producer is investigated in two cases - where the market is fully covered and where the market is not fully covered. It is found that the best compatibility strategy under these two cases is different. Furthermore, it is proved that the proprietary software producer does not favor its proprietary rival changes to open source software. Such change may reduce social welfare.

1.2.2. IT Investment Value

Past decades have witnessed substantial increases in IT investments. However, despite the heavy investments in IT, there has been little evidence of the value produced by IT in aggregate output statistics. Nobel laureate Robert Solow (1987) concluded that "you can see the computer age everywhere but in the productivity statistics". This widely known "productivity paradox" has engendered many amounts of studies including research at the country-level (Baily 1986, Jorgenson and Stiroh 2000), industry-level (Schneider 1987, Roach 1987, 1991), and firm-level (Harris and Katz 1991). However, the results of these studies were inconclusive.

Given the equivocal results of the productivity approach, researchers have investigated IT value from other angles. One of these angles is to examine how IT improves firm performance. In particular, IT value could be proved as the increase of the firms' market value. The innovative research in this theme is by Dos Santos et al. (1993) and Im et al. (2001). They used the event study methodology to provide evidence that IT investments can increase the market value of firms. Both of them, however, got negative results.

Most previous studies of IT value were limited to U.S. data. However, with the rise of Asia in recent years, the value of IT in Asia has attracted much attention (Amsden 2001, Enos et al. 1997, Hobday 1995, Kim 1997, Lall 2000, Mathews and Cho 2000).

Some scholars believe that IT plays an important role in the rise of Asian firms. In contrast, other researchers are skeptical about the efficiency of IT adoption and diffusion in developing countries. Compared with developed countries, developing countries are believed to have inadequate IT infrastructures, ineffective policy and lack of communication (Sauvant 1984, Dasgupta et al. 1999, Dewan and Kraemer 2000). All these obstacles could slow down IT adoption in developing countries. As a result, IT investment in the firms in developing countries may not be as efficient as that in developed countries.

Because of these contradictive expectations, I conducted a comparative study of IT investment value to firms in developing countries vis-à-vis developed countries, to provide a better understanding of IT value in different contexts. This study tries to answer the following questions: (1) Whether IT can increase the firms' value in developing countries and developed countries respectively; (2) Whether IT investment in firms in developing countries is as efficient as that in developed countries; (3) How does IT value vary with respect to various features such as the firm size and firm type in different countries?

1.2.3. Advertising and Signaling in eBay

The third essay aims to study advertising and signaling effects in online auction markets. Major online auction markets, such as eBay and Yahoo auction, provide optional features, such as Gallery (inserting a large picture of the items being sold), for sellers to promote their items. The research question arises: What is the function of these optional features? One possibility is that these features are advertising which attracts buyers' attention and increases sellers' profit. Another possibility is that these features could be quality signals, which mitigate the information asymmetry between buyers and sellers.

To distinguish between the advertising and the signaling effects, I collected field data from eBay to test the sales-response function and sellers' selection of the Gallery feature. It was found that auctions with the Gallery feature exhibit more intense competition and end with a higher price. Such results indicate that the Gallery feature serves as an advertising tool. Moreover, for high-priced products, high quality sellers are more likely to choose the Gallery feature than low quality sellers. Hence, for high-priced products, Gallery is a quality signal, which helps sellers credibly communicate the private information and establish trust with buyers.

This study has two empirical implications: firstly, these optional features are proved to be profitable advertising tools. Hence, sellers can use them to earn price premia. Secondly, for high-priced products, these optional features may help buyers to get more information about sellers' quality and reduce the risk in online transactions.

1.3. Contribution

More and more proprietary software producers must compete with open source software. However, there have been few studies of the compatibility choices of proprietary software producers. The first essay in this thesis addresses this issue and provides theoretical support for the managers of the proprietary software regarding the compatibility strategies. Furthermore, the results shed light on the impact of the open source software on the proprietary software producer and on society. Moreover, the welfare analysis suggests to governments that the move to open source software may lower social welfare. Thus, the governments should be careful to promote the open source movement.

How to measure the value of IT has been discussed for decades in the field of IS. Most research in this field was limited to U.S. data. Moreover, previous studies could not find positive evidence that IT investments can increase the market value of the firms. The second essay in this thesis provides a comparative study of IT investment value in China with that in the U.S. It showed that IT investments have a positive impact on the firms in China, but not in the U.S. Thus, IT could be a bigger opportunity for the firms in developing countries compared with those in developed countries. This essay provides empirical evidence for the IT value in developing counties, and hence enriches the limited research in this stream.

Signaling has a solid theoretical foundation, but limited empirical support. In the third essay in this thesis, I conduct an empirical test, which examines whether the optional features used in eBay are quality signals or advertising tools. Such a test provides empirical support for the signaling theory. Furthermore, the Gallery feature is proved to serve advertising and signaling functions, which can smooth transactions and establish trust between transaction parties. E-commerce providers can apply these findings in their service design.

This thesis is organized as follows: Chapter 2 presents the essay “Open Source vs. Proprietary Software: Competition and Compatibility”; Chapter 3 presents “The Value of IT to Firms in a Developing Country in the Catch-up Process: an Empirical Comparison of China and the Untied States”; while Chapter 4 presents the essay “Gallery Feature in eBay: Advertising or Signaling”. In the last chapter, I briefly summarize the results of these three essays and propose a few possible directions for future research.

References

Akerlof, G. 1970. The market for “lemons”: Quality under uncertainty and the market mechanism. *Quarterly Journal of Economics*, 84, 488-500.

Amsden, A. 1989. *Asia’s Next Giant: South Korea and Late Industrialization*. NY: Oxford University Press.

Avgerou, C., Cornford, T. 1995. Limitations of information systems theory and practice: A case for pluralism. in Falkenberg et al., *Information Systems Concepts: Towards a Consolidation of Views*, London: ChapmanandHall, 130-143.

Baily, M. N. 1986. What has happened to productivity growth?. *Science*, 234 (4775), 443-451.

Benbasat, I., Weber, R. 1996. Research commentary: rethinking ‘Diversity’. *Information Systems Research,* 7(4), 389-399.

Boulding, W., Kirmani, A. 1993. A Consumer-Side Experimental Examination of Signaling Theory: Do Consumers Perceive Warranties as Signals of Quality. *The Journal of Consumer Research*, 20(1), 111-123.

Conner, K. 1995. Obtaining Strategic Advantage from Being Imitated: When Can Encouraging ‘Clones’ Pay?. *Management Science*, 42(2).

Culnan, M. 1987. Mapping the Intellectual Structure of MIS, 1980-85: A Co-Citation Analysis. *Management Information Systems Quarterly,* 11(3), 340-353.

Culnan, M., Swanson, E.B. 1986. Research in management information systems 1980-1984: Points of work and reference. *Management Information Systems Quarterly,* 10(3), 289-301.

Cushing, B.E. 1990. Frameworks, Paradigms, and Scientific Research in Management Information Systems. *The Journal of Information Systems*, 4(2), 38-59.

Dasgupta, S., Agarwal, D., Ioannidis, A., Gopalakrishnan, S., 1999. Determinants of Information Technology Adoption: An Extension of Existing Models to Firms in a Developing Country. *Journal of Global Information Management*, 7(3), 41-49.

Davis, G.B., Gorgone, J.T., Couger, J.D., Feinstein, D.L, Longnecker, Jr., H.E. 1997. IS'97: Model Curriculum and Guidelines for Undergraduate Degree programs in Information Systems. The DATA- BASE for Advances in *Information Systems*, Vol.28, No. 1, Winter.

Dewan, S., Kraemer, K. L., 2000. Information technology and productivity: Evidence from country-level data. *Management Science*, 46(4), 548-562.

Dos Santos, B.L., Peffers, K., Mauer, D.C. 1993. The impact of information technology investment announcements on the market value of the firm. *Information Systems Research,* 4(1), 1-23.

Enos, J., Lall, S., Yun, M., 1997. Transfer of technology: An update. Asian-Pacific *Economic Literature*, 11 (1), 56-66.

Gosain, S., Lee, Z., Im, L. 1997. Topics of interest in IS: Comparing academic journals with the practitioner press. *Proceedings of the International Conference on Information Systems*, Atlanta, Georgia, December 15-17, 263-284.

Harris, S. E., Katz, J.L. 1991. Firm Size and the Information Technology Investment Intensity of Life Insurers. *MIS Quarterly*, 15(3), 333-352.

Hobday, M. 1995. *Innovation in East Asia: The Challenge to Japan.* Aldershot, UK: Edward Elgar.

Im K.S., Dow, K.E., Grover, V. 2001. A reexamination of IT investments and the market value of the firm: an event study methodology. *Information Systems Research,* 12(1), 103-117.

Jorgenson, D. W., Stiroh, K. J. 2000. Raising the speed limit: U. S. economic growth in the information age. Brookings Papers on Economic Activity, 1, 125-235.

Katz, M., Shapiro, C. 1985. Network externalities, competition and compatibility. *American Economic Review*. 75(3) 424-440.

Katz, M., Shapiro, C. 1986, Technology Adoption in the Presence of Network Externalities. *Journal of Political Economy*, 94, pp. 822-841.

Katz, M., Shapiro, C. 1994. Systems Competition and Network Effects. *Journal of Economic Perspectives*, 8(2).

Keen, P. G. W. 1980. MIS research: Reference disciplines and cumulative tradition. in *Proceedings of the First international Conference on Information Systems*, E. R. McLean (ed.), Philadelphia, 9-17.

Kim, L., 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Boston: Harvard Business School Press.

Lall, S., 2000. Technological change and industrialization in the Asian newly industrializing economies: Achievements and challenges. In L. Kim, and R.R.

Nelson, Technology, *Learning, and Innovation: Experiences of Newly Industrializing Economies.* Cambridge, UK: Cambridge University Press.

Mathews, J. A., Cho, D. S. 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia.* Cambridge, UK: Cambridge University Press.

Milgrom, P., Roberts, J. 1982. Limit Pricing and Entry under Incomplete Information: An Equilibrium Analysis. *Econometrica*, 50(2), 443-460.

Nelson, P. 1970. Information and Consumer Behavior. *The Journal of Political Economy*. 78(2), 311-329.

O'Reilly, T. 1999. Lessons from open-source software development. *Communications of the ACM*. 42(4) 33-37.

OSI. 2001. The Open Source Definition. http://opensource.org/docs/definition_plain.html.

Roach, S. S. 1987. America's Technology Dilemma: A profile of the information economy. *Morgan Stanley Special Economic Study*. April.

Roach, S. S. 1991. Services under siege: the restructuring imperative. *Harvard Business Review,* 60(5), 82-92.

Sauvant, K.P. 1984. The growing dependence on transborter Data Flows. *Computerworld,* 18(26).

Schneider, K. 1987. Services hurt by technology: productivity is declining. *The New York Times,* June 29.

Solow, R. M. 1987. We'd better watch out. *New York Times Book Review.* July 12.

Spence, M. 1973. Job marketing Signaling. *The Quarterly Journal of Economics*, 87(3), 355-374.

Swanson, E.W., Ramiller, N.C. 1993. Information systems research thematic: submissions to a new journal, 1987-1992. *Information Systems Research,* 4(4), 299-358.

Wolinsky, A. 1983. Prices as Signals of Product Quality. *The Review of Economics Studies*, 50(4), 647-658.

CHAPTER 2 OPEN SOURCE VS. PROPRIETARY SOFTWARE: COMPETITION AND COMPATIBILITY

2.1. Introduction

Recent years have seen the striking success of open source software, which allows software developers to use shared source codes, identify and correct errors, and redistribute the source codes (OSI 2001, O'Reilly 1999). One of the most famous and successful open source software projects is Linux, which commands a third market share within the server operating system market, and whose share is expected to grow to 41 percent by 2005 (International Data Corporation IDC 2002). Another well-known example is Apache, which supports 67 percent of web sites on the Internet (Netcraft Web Server Survey 2004). Other successful open source software products have had significant market shares in their product categories. For instance, Sendmail, an open source email transfer program, carries an estimated 80% of the entire world's e-mail traffic (Weber 2004).

Open source software threatens proprietary software producers.[3] Amazon reported that adopting open source software has reduced 25 percent of its technology expenses. The European city Munich is switching from Windows to Linux, and from Internet Explorer (IE) to Mozilla browser (CNet News 2004a).

[3] I use the term 'proprietary software' as non-free software (Working Group on Libre Software 2000).

To survive and win the maximum profit in the battle with the open source software, proprietary software producers may adopt one of four different compatibility strategies: incompatibility; two-way compatibility; inward compatibility; and outward compatibility.[4] These four compatibility strategies can be understood through the following examples:

- Windows, a proprietary software product, is incompatible with Linux, an open source software product.

- In the case of web browsers, Internet Explorer (IE), a proprietary software product, is two-way compatible with Mozilla, an open source product. Files created for IE users can be used without any difficulty by Mozilla users and vice versa.

- In the web server market, Microsoft IIS (a proprietary web server) is inward compatible: it can support both PHP and ASP, server side programming languages. Thus, the programs designed for Apache (an open source web server) using PHP language can be executed in IIS. However, since ASP belongs to Microsoft and cannot execute on Apache, the programs designed for IIS using ASP are not usable in Apache.

- Finally, outward compatibility means that the files or programs designed for the proprietary software can be used by the open source software while files or programs

[4] Katz and Shapiro (1998) defined compatibility as follows: "When two programs can communicate with one another and/or be used with the same complementary system components, they are said to be compatible".

designed for the open source software are not usable by the proprietary software. Realistically, outward compatibility is seldom observed.

These different compatibility strategies present a series of research questions: why would a proprietary software producer choose different strategies of compatibility when facing competition from open source software? How would the choices of compatibility affect the profitability of a proprietary software producer? Furthermore, what are the welfare implications?

Another series of questions relate to the impact of open source software. If the open source software pursues maximum market share rather than reacts passively, should the proprietary software producer change the compatibility strategy? How would the proprietary producer's profit, price and market share be affected if its rival changes from providing proprietary to open source software? Does such a switch benefit society or not?

This essay addresses these research questions using the Hotelling model of competition between the open source and proprietary software. In contrast with the conventional Hotelling model, only one party – the proprietary software producer – aims at maximizing profit, and the open source software is passive.

The different compatibility choices of the proprietary software result in different network externalities for the open source and proprietary software. Thus, the price and profit of the proprietary software vary correspondently. I compare the maximum profit of the proprietary software under different compatibility strategies, and propose the best compatibility strategy for the propriety software producer.[5]

The main findings in this part are: when the market is fully covered, i.e., when all the consumers purchase one of the two products, inward compatibility is the best strategy. However, when the market is partly covered, two-way compatibility is the best strategy. Furthermore, the welfare analysis provides some implications on how the welfare would be affected by different parameters, such as the network externality intensity and software quality.

Next, I relax the conditions of the basic model to investigate competition between open source and proprietary software under different scenarios. Firstly, I suppose that the open source software aims at maximizing the market share rather than reacts passively. In such a case, two-way compatibility is a Nash Equilibrium in both fully covered market and partly covered market.

Secondly, I examine the impact of open source software on proprietary software and on society. It is found that a proprietary software producer does not favor its proprietary rival changing to open source software because such change will lower its market share, price and profit. Furthermore, contrary to the general belief that the change from proprietary software to open source software will benefit society, I find that under certain conditions, such a change will decrease social welfare.

[5] In the following context, by default, the best compatibility strategy means the best compatibility strategy for a proprietary software producer.

The rest of this essay is organized as follows. Section 2.2 reviews the literature on open source software. Section 2.3 introduces the basic Hotelling model of asymmetric competition between open source and proprietary software. In sections 2.4, I compare the market results under different compatibility choices when the base-level qualities of the open source and proprietary software are the same. Section 2.5 presents market results when open and proprietary software have different base-level qualities. Section 2.6 proposes the best compatibility strategy under different market coverage conditions. Section 2.7 investigates the implication for welfare. Section 2.8 extends the basic model to investigate competition between open source and proprietary software under different scenarios. Section 2.9 discusses the results and suggests possible directions for future work.

2.2. Literature Review

The most widely investigated research question in past literature on open source software is to identify the economic and non-economic motivations for individual developers to contribute to open source software (Lerner and Tirole 2002, Lakhani and Wolf 2003, Hann et al. 2002). Currently, researchers classify the possible reasons into intrinsic motivation, such as intellectual stimulation (Lakhani and Wolf 2003), and extrinsic motivation, including career concerns (Lerner and Tirole 2002) and peer recognition (Raymond 1999, Vostroknutov 2002).

Another theme of prior research focuses on the quality of open source software and competition between open source and proprietary software. An important conclusion is that open source software is not necessarily inferior in quality to proprietary software (Mishra et al. 2002, Dalle and Jullien 2002, Kuan 2001, Johnson 2001, and Bessen 2002). This conclusion is derived from models of different aspects: Mishra et al. (2002) compared the quality of software under open source and closed environments; Kuan (2001) demonstrated that open source software has a higher rate of quality improvement than proprietary software; Johnson (2001) modeled open source software as the private provision of public goods; Dalle and Jullien (2002) presented organizational structure and compatibility as key factors to the quality of open source software.

Within the research theme outlined above, one strand has been to consider competition between open source and proprietary software. Casadesus-Masanell and Ghemawat (2003) modeled the competition between Windows and Linux as a dynamic "mixed duopoly", where a not-for-profit competitor interacts with a for-profit competitor. What the study named mixed duopoly differs from the well-investigated mixed oligopoly competition, where one party pursues profit maximization while the other (most probably a public producer) aims at welfare maximization (Cremer et al. 1989, 1991, DeFraja and Delbono 1989, Fershtman 1990, Fjell and Pal 1996, White 1996). Casadesus-Masanell and Ghemawat (2003) showed that, as long as Windows' pricing decision is not myopic, the result of the competition would be either the coexistence of the two products or Linux being driven out of the market.

This essay takes a similar approach but differs from Casadesus-Masanell and Ghemawat (2003) in two aspects. The main difference is in the research questions. This work focuses on strategic choices for compatibility – a topic seldom investigated in previous studies on open source software. I seek to find the best compatibility strategy rather than predict the results of competition. Secondly, I model the consumers' heterogeneous preferences for products. Software users differ in their technology sophistication. Open source software is often appealing to sophisticated users while proprietary software is usually more user-friendly and more likely to be adopted by less sophisticated users. Furthermore, software users differ in their past experiences. Different users have different extent of 'lock-in' to certain kind of software. Thus, the switching cost and adopting cost are heterogeneous among the users. Moreover, software users' preferences are affected by their different environments. For instance, most conferences in computer science department provide LeTax (open source file compiler software) file style for authors, which greatly encourages the adopting of LeTax in the academic area. Concerning these factors, I believe that consumers have different tastes for the products. The consumers who have lower taste for the open source software would rather choose the proprietary software even though the open source software is free of charge. The difference in the consumers' taste allows rich intuitive interpretations for real-world software competition.

2.3. Basic Model

Consider a software market where two software products are located at the ends of a unit line, i.e., the open source software (O) is located at $x=0$ and the proprietary software (P) is located at *x=1* (see Figure 2.1). Consumers are uniformly distributed along the unit interval and they have unit demand for the software. Consumers differ in their taste for the products. Specifically, for a consumer located at $x \in [0, 1]$, she incurs utility cost *tx* if she uses the open source software because of the difference between her ideal preference and the product specifications. Similarly, she incurs utility cost *t(1-x)* if she chooses the proprietary software, where *t* measures the consumers' taste difference. I assume that the marginal costs of both the open source and proprietary software products are zero. Following Katz and Shapiro (1985), the network externalities are a linear function of the number of users who adopt the same or compatible software products.

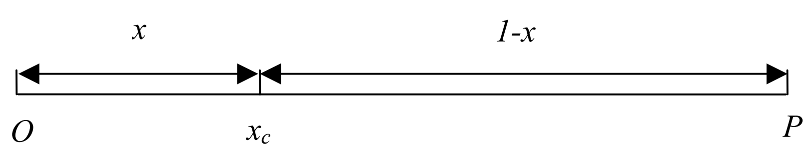

Figure 2.1: Basic Hotelling Model

In the basic model, I assume that the two products have the same inherent quality *s* and are incompatible. Furthermore, I assume that the market is fully covered, i.e., all the consumers choose to use one of the two software products. This is always true when the benefit of the product is sufficiently large. If a consumer located at *x* adopts the open source software, her net utility U_o would be $U_o = s + kq_o - tx + \gamma q_o$, where q_o is the number of open source users and *k* measures the degree of contribution of each consumer to the quality of the open source software. The parameter γ is to the network externality that a software user receives from other users of same or compatible software. I assume that the open source software product is freely available, and there is no price component in the net utility. Similarly, if the consumer located at *x* adopts the proprietary software, her net utility U_p is $U_p = s - t(1-x) + \gamma q_p - p$, where q_p denotes the number of proprietary software users and *p* is the price of the proprietary software.

Suppose the consumer at $x_c \in [0,1]$ is indifferent between the open source and proprietary software products, then from $U_o = U_p$, it can be derived that:

$$x_c = \frac{p+t-\gamma}{2t-2\gamma-k}, q_o = \frac{p+t-\gamma}{2t-2\gamma-k}, q_p = 1 - \frac{p+t-\gamma}{2t-2\gamma-k}.$$

The profit for the proprietary software producer is:

$$\pi(p) = pq_p = p(1-x_c) = p[1 - \frac{p+t-\gamma}{2t-2\gamma-k}].$$

By solving the profit maximization problem with respect to *p*, it can be derived:

$$p^* = \frac{t-\gamma-k}{2},$$

$$\pi^* = \frac{(t-\gamma-k)^2}{4[2(t-\gamma)-k]},$$

where p^* and π^* denote the equilibrium price and profit respectively.

Using M_p^* to represent the market share of the proprietary software under the equilibrium price and M_o^* to denote that of the open source software, we have:

$$M_p^* = \frac{t-\gamma-k}{2[2(t-\gamma)-k]},$$

$$M_o^* = \frac{3t-3\gamma-k}{2[2(t-\gamma)-k]}.$$

The proprietary software producer will choose positive market share and profit. We have:

$$t-\gamma-k > 0$$
$$2t-2\gamma-k > 0$$

The base-level qualities of proprietary and open source software are identical. However, the quality of the open source software increases with the number of users, and the price of open source software is zero. Hence, in equilibrium, the open source software has a bigger market share than the proprietary software.

2.4. Compatibility and Profits

In the basic model, I assumed that the open source and proprietary software were incompatible. However, the proprietary software producer may also choose for its product to be compatible to some degree with the open source software. Which is the best strategy? How does this compatibility decision change the profitability of proprietary software? To answer these questions, I extend the basic model to consider different degrees of compatibility. In common with the Hotelling model, the analysis depends on whether the market is fully covered.

2.4.1. Fully Covered Market

I firstly present how the utility functions of the open source and proprietary software consumers change according to different compatibility strategies when the market is fully covered. Next, I summarize the net utilities of the open source and proprietary software consumers and the equilibrium outcomes under different compatibility strategies in Table 2.1.

- **Two-way compatibility**

Two-way compatibility is the case where the open source and proprietary software are compatible with each other. In this case, users of the two software products share the same network externality.[6] Since the market is fully covered, the total number of software users is *1*. Thus, the network externality is $\gamma(q_o + q_p) = \gamma$.

- **Inward compatibility**

I define inward compatibility as the case where the proprietary software is compatible with the open source software, but the open source software is incompatible with the proprietary software. In this case, the network externality for users of the proprietary software is $\gamma(q_o + q_p) = \gamma$, and the network externality for users of the open source software is γq_o .

- **Outward compatibility**

Outward compatibility is defined as the case where the proprietary software is incompatible with the open source software, but the open source software is compatible with the proprietary software. In this case, the network externality for users of the proprietary software is γq_p , and the network externality for users of the open source software is $\gamma(q_o + q_p) = \gamma$.

Table 2.1 reports the net utilities of the open source and proprietary software consumers and the equilibrium outcomes under different compatibility strategies.[7]

[6] Following the previous literature (Farrell and Saloner 1992), I suppose the network externality intensity γ is the same for all the networks.

[7] In this and following tables, U_o and U_p indicate the net utilities of open source and proprietary software consumers respectively; $p*$ and $\pi*$ are the equilibrium price and profit of the proprietary software; M_o^* and M_p^* represent the equilibrium market share of open source and proprietary software respectively.

	Two-way Compatibility	Inward Compatibility	Outward Compatibility	Incompatibility
U_o	$s+kq_o-tx+\gamma$	$s+kq_o-tx+\gamma q_o$	$s+kq_o-tx+\gamma$	$s+kq_o-tx+\gamma q_o$
U_p	$s-t(1-x)+\gamma-p$	$s-t(1-x)+\gamma-p$	$s-t(1-x)+\gamma q_p-p$	$s-t(1-x)+\gamma q_p-p$
$p*$	$\frac{t-k}{2}$	$\frac{t-k}{2}$	$\frac{t-\gamma-k}{2}$	$\frac{t-\gamma-k}{2}$
$\pi*$	$\frac{(t-k)^2}{4(2t-k)}$	$\frac{(t-k)^2}{4(2t-\gamma-k)}$	$\frac{(t-\gamma-k)^2}{4(2t-\gamma-k)}$	$\frac{(t-\gamma-k)^2}{4[2(t-\gamma)-k]}$
M_o^*	$\frac{3t-k}{2(2t-k)}$	$\frac{3t-2\gamma-k}{2(2t-\gamma-k)}$	$\frac{3t-\gamma-k}{2(2t-\gamma-k)}$	$\frac{3t-3\gamma-k}{2\left[2(t-\gamma)-k\right]}$
M_p^*	$\frac{t-k}{2(2t-k)}$	$\frac{t-k}{2(2t-\gamma-k)}$	$\frac{t-\gamma-k}{2(2t-\gamma-k)}$	$\frac{t-\gamma-k}{2[2(t-\gamma)-k]}$

Table 2.1: Fully Covered Market: Equilibrium Outcomes

2.4.2. Partly Covered Market

Suppose the market is partly covered. Some consumers use neither the open source software nor the proprietary software. This may happen when the benefit provided by the software is small compared with users' cost. The basic model is thus changed as follows:

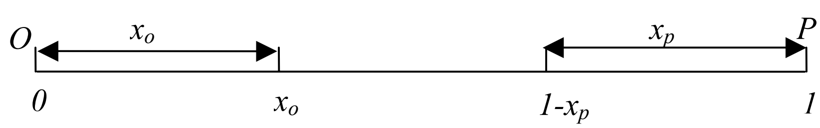

Figure 2.2: Competition: Partly Covered Market

The consumers at $x \in [0, x_o]$ would choose the open source software, where x_o is the location of the marginal consumer who is indifferent between using and not using the open source software. On the other hand, the consumers at $x \in [1-x_p, 1]$ would choose the proprietary software, where $1-x_p$ is the location of the marginal consumer who is indifferent between buying and not buying the proprietary software. The third group of consumers at $x \in [x_o, 1-x_p]$ will choose neither the open source software nor the proprietary software.

The net utilities of the open source and proprietary software consumers under different compatibility strategies are reported in Table 2.2. By setting $U_o = 0$ and $U_p = 0$, we can get the equilibrium outcomes, which are also summarized in Table 2.2.

	Two-way Compatibility	Inward Compatibility	Outward Compatibility	Incompatibility
U_o	$s+kq_o-tx_o+\gamma(q_o+q_p)$	$s+kq_o-tx_o+\gamma q_o$	$s+kq_o-tx_o+\gamma(q_o+q_p)$	$s+kq_o-tx_o+\gamma q_o$
U_p	$s-tx_p+\gamma(q_o+q_p)-p$	$s-tx_p+\gamma(q_o+q_p)-p$	$s-tx_p+\gamma q_p-p$	$s-tx_p+\gamma q_p-p$
p^*	$\frac{s(t-k)}{2(t-k-\gamma)}$	$\frac{s(t-k)}{2(t-k-\gamma)}$	$\frac{s}{2}$	$\frac{s}{2}$
π^*	$\frac{(t-k)^2 s^2}{4(t^2-2t\gamma-tk+\gamma k)(t-\gamma-k)}$	$\frac{s^2(t-k)^2}{4(t-\gamma)(t-\gamma-k)^2}$	$\frac{s^2}{4(t-\gamma)}$	$\frac{s^2}{4(t-\gamma)}$
M_o^*	$\frac{(2t^2-3t\gamma-2tk+\gamma k)s}{2(t^2-2t\gamma-tk+\gamma k)(t-\gamma-k)}$	$\frac{s}{t-\gamma-k}$	$\frac{s(2t-\gamma)}{2(t-\gamma)(t-\gamma-k)}$	$\frac{s}{t-\gamma-k}$
M_p^*	$\frac{(t-k)s}{2(t^2-2t\gamma-tk+\gamma k)}$	$\frac{s(t-k)}{2(t-\gamma)(t-\gamma-k)}$	$\frac{s}{2(t-\gamma)}$	$\frac{s}{2(t-\gamma)}$

Table 2.2: Partly Covered Market: Equilibrium Outcomes

2.5. Quality Differences

In section 2.4, the base-level qualities of the open source software and proprietary software are assumed to be equal. Since the open source software will increase in quality corresponding to the number of users, the market share of the open source software is higher than that of the proprietary software. In some situations, however, this condition may not be true. In this section, I extend the model and give the equilibrium outcomes when the base-level quality of the proprietary software is different from that of the open source software.

Suppose the open source software and the proprietary software products have different qualities, denoted by s_o and s_p respectively. With similar procedures in section 2.4, I can get the net utilities of open source and proprietary software consumers and the equilibrium outcomes under different market coverage conditions, which are reported in Table 2.3 and Table 2.4.

Fully Covered Market

	Two-way Compatibility	Inward Compatibility	Outward Compatibility	Incompatibility
U_o	$s_o + kq_o - tx + \gamma$	$s_o + kq_o - tx + \gamma q_o$	$s_o + kq_o - tx + \gamma$	$s_o + kq_o - tx + \gamma q_o$
U_p	$s_p - t(1-x) + \gamma - p$	$s_p - t(1-x) + \gamma - p$	$s_p - t(1-x) + \gamma q_p - p$	$s_p - t(1-x) + \gamma q_p - p$
$p*$	$\frac{s_p - s_o + t - k}{2}$	$\frac{s_p - s_o + t - k}{2}$	$\frac{s_p - s_o + t - \gamma - k}{2}$	$\frac{s_p - s_o + t - \gamma - k}{2}$
$\pi*$	$\frac{(s_p - s_o + t - k)^2}{4(2t-k)}$	$\frac{(s_p - s_o + t - k)^2}{4(2t-\gamma-k)}$	$\frac{(s_p - s_o + t - \gamma - k)^2}{4(2t-\gamma-k)}$	$\frac{(s_p - s_o + t - \gamma - k)^2}{4[2(t-\gamma)-k]}$
M_o^*	$\frac{3t - k - s_p + s_o}{2(2t-k)}$	$\frac{3t - 2\gamma - k - s_p + s_o}{2(2t-\gamma-k)}$	$\frac{3t - \gamma - k - s_p + s_o}{2(2t-\gamma-k)}$	$\frac{3t - 3\gamma - k - s_p + s_o}{2[2(t-\gamma)-k]}$
M_p^*	$\frac{s_p - s_o + t - k}{2(2t-k)}$	$\frac{s_p - s_o + t - k}{2(2t-\gamma-k)}$	$\frac{s_p - s_o + t - \gamma - k}{2(2t-\gamma-k)}$	$\frac{s_p - s_o + t - \gamma - k}{2[2(t-\gamma)-k]}$

Table 2.3: Quality Differences: Fully Covered Market

Partly Covered Market

	Two-way Compatibility	Inward Compatibility	Outward Compatibility	Incompatibility
U_o	$s_o + kq_o - tx_o + \gamma(q_o + q_p)$	$s_o + kq_o - tx_o + \gamma q_o$	$s_o + kq_o - tx_o + \gamma q_o + \gamma q_p$	$s_o + kq_o - tx_o + \gamma q_o$
U_p	$s_p - tx_p + \gamma(q_o + q_p) - p$	$s_p - tx_p + \gamma(q_o + q_p) - p$	$s_p - tx_p + \gamma q_p - p$	$s_p - tx_p + \gamma q_p - p$
p^*	$\frac{s_p}{2} + \frac{\gamma s_o}{2(t-k-\gamma)}$	$\frac{s_p}{2} + \frac{\gamma s_o}{2(t-k-\gamma)}$	$\frac{s_p}{2}$	$\frac{s_p}{2}$
π^*	$\frac{[\gamma s_o + s_p(t-k-\gamma)]^2}{4[(t-\gamma)(t-\gamma-k)-\gamma^2](t-\gamma-k)}$	$\frac{(s_p t - s_p\gamma - s_p k + \gamma s_o)^2}{4(t-\gamma)(t-\gamma-k)^2}$	$\frac{s_p^{\,2}}{4(t-\gamma)}$	$\frac{s_p^{\,2}}{4(t-\gamma)}$
M_o^*	$\frac{\gamma^2 s_o}{2[(t-\gamma)(t-\gamma-k)-\gamma^2](t-k-\gamma)} + \frac{s_o}{t-k-\gamma} + \frac{\gamma s_p}{2[(t-\gamma)(t-\gamma-k)-\gamma^2]}$	$\frac{s_o}{t-k-\gamma}$	$\frac{\gamma s_p}{2(t-\gamma)(t-k-\gamma)} + \frac{s_o}{t-k-\gamma}$	$\frac{s_o}{t-k-\gamma}$
M_p^*	$\frac{\gamma s_o + s_p(t-k-\gamma)}{2[(t-\gamma)(t-\gamma-k)-\gamma^2]}$	$\frac{s_p(t-\gamma-k)+\gamma s_o}{2(t-\gamma)(t-\gamma-k)}$	$\frac{s_p}{2(t-\gamma)}$	$\frac{s_p}{2(t-\gamma)}$

Table 2.4: Quality Differences: Partly Covered Market

2.6. Best Compatibility Strategy

I have examined the best compatibility strategy under different market coverage conditions by comparing the equilibrium outcomes in section 2.4 and section 2.5, and derived the following results:

Proposition 1 A proprietary software producer should never choose incompatibility or outward compatibility.

<proof> Please see the Appendix 2.1.

Under all conditions, the proprietary producer should not choose incompatibility or outward compatibility. Intuitively, to the proprietary software producer, inward compatibility can bring more profit than incompatibility by allowing proprietary software users to share the network benefits from open source users. Furthermore, incompatibility is always better than outward compatibility, in that it prevents open source software users from sharing the network benefits of proprietary software users. Therefore, incompatibility and outward compatibility would never be the best strategy. Consistent with these results, in reality, outward compatibility can hardly be observed. Incompatibility is also rare.

Proposition 2 When the market is partly covered, a proprietary software producer earns the highest profit from two-way compatibility, followed by inward compatibility, and last, incompatibility or outward compatibility.

<proof> Please see the Appendix 2.1.

When the market is partly covered, one additional open source software user does not decrease the number of proprietary software users. In this case, an increase in open source software users can benefit proprietary software users through the network externality, without decreasing the market share of the proprietary software. Therefore, two-way compatibility is a win-win strategy: it increases the proprietary producers' profit while enhancing the user base of the open source software, which generates positive externalities for the users of the proprietary software.

Realistically, most software markets are not fully covered. Thus, two-way compatibility is common. Typical examples include IE vs. Mozilla and Microsoft Outlook vs. Mozilla Thunderbird. Furthermore, some proprietary software producers are improving the compatibility with open source software. For instance, Microsoft has committed in perpetuity to offering a royalty-free license of Office-related XML document formats, which encourages other open source software, such as Open Office, to create "filters" to read the files created in Microsoft Office (CNet News, 2004 b).

Proposition 3.1 When the market is fully covered, the proprietary software producer earns the highest profit from inward compatibility, and the lowest from outward compatibility. However, the profitability of two-way compatibility and incompatibility depends on the quality difference between the open source software and the proprietary software.

<proof> Please see the Appendix 2.1.

Proposition 3.2 When the market is fully covered and the quality difference between proprietary software and open source software is sufficiently small that $s_p - s_o < \frac{k + \sqrt{(2t-k)(2t-k-2\gamma)}}{2}$, the proprietary software producer earns the highest profit from inward compatibility, followed by two-way compatibility, incompatibility, and last, outward compatibility.

<proof> Please see the Appendix 2.1.

Proposition 3.3 When the market is fully covered and the quality difference between proprietary software and open source software is sufficiently large that $s_p - s_o > \frac{k + \sqrt{(2t-k)(2t-k-2\gamma)}}{2}$, the proprietary software producer earns the highest profit from inward compatibility, followed by incompatibility, two-way compatibility, and last, outward compatibility.

<proof> Please see the Appendix 2.1.

A covered market indicates that the two products are in severe competition, i.e., one product can gain a user only if the other product loses one user. Thus, the proprietary software producer should adopt a strategy which promotes the increase of its users while restraining the growth of open source software. Inward compatibility allows proprietary software users to share the network externality of open source users, while preventing open source software users from sharing the network externality of the proprietary software. Therefore, it becomes the best compatibility strategy.

In a covered market, the profit ranking of the incompatibility and two-way compatibility varies according to the quality difference between the open source and proprietary software. On the one hand, the price of the proprietary software with two-way compatibility is higher than that with incompatibility (see Table 2.3). On the other hand, the market share of the proprietary software with two-way compatibility may be lower than that with incompatibility. This could happen when the proprietary software has sufficiently higher quality and becomes the dominating software in the market. Combining the price and market share factors together, it can be concluded that once the quality of the proprietary software is high enough and the market share factor dominates the price factor, the proprietary software producer will choose incompatibility rather than two-way compatibility.

Such results provide theoretical explanations for the actual behavior of proprietary software producers. For instance, the Windows Update website denies access by Firefox, the new open source browser. This shows that Microsoft refuses to be compatible with Firefox, and thus restrains its growth.

The change of the profit ranking of incompatibility and two-way compatibility is consistent with the argument of Katz and Shapiro (1985). They develop a static model of oligopoly and conclude that the firms with large existing network externalities will tend to be against compatibility. In contrast, firms with small existing network externalities will tend to favor product compatibility. In the case of proprietary vs. open source software, when the proprietary software has sufficiently high quality, its existing network externalities are large. Hence, the proprietary software producer favors incompatibility over two-way compatibility. In contrast, when the quality of the proprietary software is sufficiently small, proprietary software has small existing network externalities. Therefore, two-way compatibility is more profitable than incompatibility.

Moreover, I extend the conclusion of Katz and Shapiro (1985) by adding the inward and outward compatibility, which they did not discuss. I show tdhat in both fully covered and partly covered markets, inward compatibility is always superior to incompatibility. Hence, their conclusion that incompatibility can be the best strategy may not hold if inward compatibility can be realized.

2.7. Welfare

In this section, I calculate the social welfare and investigate how the parameters γ, s, k and t affect the social welfare. Social welfare in this model is the sum of sellers' profit and consumers' surplus. Since the open source software is freely distributed, I deem that sellers' profit from the open source software is zero. For tractability, I assume that the base-level qualities of proprietary and open source software are equal.

I investigate the case where the market is fully covered. The proprietary software producer is assumed to adopt the best strategy: inward compatibility. The welfare is denoted as W and presented as follows:

$$W = \int_0^{x_c} U_o dx + \int_{x_c}^{1} U_p dx + \pi_p$$
$$= \frac{(k+\gamma-t)(3t-2\gamma-k)^2}{4(2t-\gamma-k)^2} + s - \frac{(t-\gamma)(t-k)}{2(2t-\gamma-k)} + \frac{t}{2}$$

For the detailed calculations, please refer to Appendix 2.2.

I next investigate how the changes in the parameters *s*, *γ*, *k* and *t* affect the welfare. The results of the comparative statics are summarized in Table 2.5.[8]

	Increase in *s*	Increase in *γ*	Increase in *k*
Welfare	+	+	+

Table 2.5: Social Welfare

Firstly, it is intuitive that the increase in quality will raise the social welfare. Secondly, with the increase of the network externality intensity γ, the consumer surplus of both the open source users and the proprietary software users will increase. Thus, the social welfare will increase. Thirdly, higher *k* increases the quality of the open source software. Hence, consumer surplus increases. However, the increase in *k* reduces sellers' profit. From the comparative statics, it can be seen that the increase in consumer surplus dominates the decrease in sellers' profit, and welfare increases with the increase in *k*.

Moreover, the first order derivative of *W* with respect to *t* is:

$$\frac{\partial W}{\partial t} = \frac{(\gamma-k)(k+\gamma-t)(3t-2\gamma-k)}{2(2t-\gamma-k)^3} - \frac{(3t-2\gamma-k)^2 - 2(t-\gamma)(\gamma-k)}{4(2t-\gamma-k)^2} - \frac{(t-k)}{2(2t-\gamma-k)} + \frac{1}{2}.$$

8 I also calculated welfare with two-way compatibility when the market is fully covered. The results of comparative statics are the same.

It is complicated to determine the sign of this equation analytically. Thus, I plot a figure to show how welfare changes according to *t*. In Figure 2.3, I fix $s = 0$ and $\gamma = 0.5$, and show that with the increase of taste difference *t*, the social welfare will decrease.[9] On the one hand, higher *t* binds consumers to the proprietary software and increases the monopoly power of the proprietary software. Thus, the sellers' profits will increase. On the other hand, higher *t* lowers the consumer surplus. From Figure 2.3, one can see that the latter impact dominates the former one and social welfare decreases with the increase in *t*.

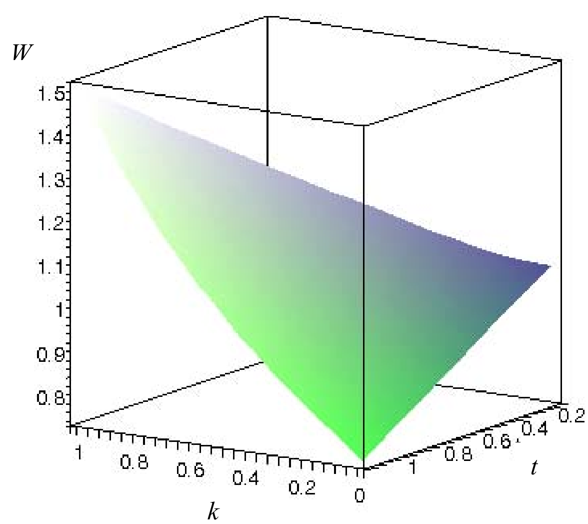

Figure 2.3: Welfare when $\gamma = 0.5$ and $s = 0$

[9] I have tried other values of *s* and γ. The results are quite similar.

2.8. Extension

2.8.1. Open Source Software Aiming at Increasing the Market Share

In previous chapters, I have assumed that the proprietary software producer seeks profit maximization while open source software reacts passively. For certain open source software, however, maximizing market share could be the aim. For instance, Sun uses StarOffice to battle with Microsoft Office and has won over 10 percent total market share (PC World News 2002).

In the above case, the competition changes to an asymmetric duopoly, where the proprietary software pursues the profit maximization and the open source software aims at maximizing market share. What would the best compatibility strategy be? I use a one-period game model to analyze this situation and derive the following proposition:

Proposition 4 When open source software aims at maximizing market share and proprietary pursues maximum profit, the competition between open source and proprietary software results in two-way compatibility in both fully covered and partly covered markets.

<proof> Please see the Appendix 2.3.

The different aims of the open source software will affect the compatibility choices of the proprietary software. As mentioned previously, when the market is partly covered, two-way compatibility is a win-win strategy for both open and proprietary software, and therefore, a Nash Equilibrium. Moreover, when the market is fully covered and both parties have their maximization aims, if either party chooses incompatibility, the other will choose compatibility to benefit from network externality. Therefore, two-way compatibility will be a Nash Equilibrium.

2.8.2. 'Proprietary vs. Open' and 'Proprietary vs. Proprietary'

Today, opening the source code has become a trend that more and more proprietary software products are adopting. For instance, IBM has offered the source code of Cloudscape, a Java-based relational database software worth $85 million, to the Apache Software Foundation. The goal is to spur Java application development (IDG News Service 2004). Microsoft .Net, the rival of Java, will be seriously affected by such move of IBM. Similarly, Sun opened the source code of Solaris to better compete with Microsoft Windows OS (Computer Weekly News 2005).

Lerner and Tirole (2002) analyze the economic motivation of a proprietary software vendor opening its source code. The software vendor expects that the opening of the source code will boost its profit on a proprietary complementary segment. If the increase in profit in the proprietary complementary segment is large enough to offset the loss from opening source code, it is profitable for software vendor to release its source code.

How does the competition with open source software change the behavior of the proprietary software producer compared with the case where the rival is another proprietary producer? Will the change to open source software increase social welfare? I investigate these questions by comparing market outcomes of the basic model with those of the "proprietary vs. proprietary" case.

- **Comparison of price, market share and profit**

Let us consider a covered duopoly market where two proprietary software producers compete. I consider two extreme cases: incompatibility and two-way compatibility. It is assumed that the compatibility strategies chosen by two software producers are symmetric. Here, I do not go through the details of the procedures because the results of two symmetric producers under Hotelling model are well known. I simply provide the following propositions.

Proposition 5 When the competitor is an open source software product, the proprietary software developer faces lower price, lower market share, and lower profit compared with the case when the rival is another proprietary software developer.

<proof> Please see the Appendix 2.4.

As Proposition 5 indicates, it is better for a proprietary software product to compete with another proprietary software product than contend with open source software. When its rival changes from providing proprietary to open source software, the proprietary software producer is worse off in every aspect. Such results explain why Microsoft executives have publicly decried that the open-source movement is, at minimum, bad for competition, and, at worst, a "cancer" to everything it touches (CNet News 2001). Furthermore, my results are consistent with Microsoft's sensitivity to Netscape or Sun opening up some parts of their products.

- **Comparison of the social welfare**

Proposition 6 When two proprietary software products are compatible and the market is fully covered, the change of one proprietary software to open source software will increase social welfare if and only if $t^3 < k(3t-k)^2$.

<proof> Please see the Appendix 2.5.

Such results are counterintuitive. Generally, it is believed that the open source software will benefit social welfare by providing free high quality software. However, the results indicate that this is not always the case. The change of the proprietary software to open source software may lower social welfare under the condition that the consumers taste difference *t* is sufficiently high.

To get a better understanding of the results, I draw Figure 2.4 and show how the value of $W_{op} - W_{pp} = \dfrac{-t^3 + k^3 + 9kt^2 - 6tk^2}{4(2t-k)^2}$ changes in term of *t* and *k*, where W_{pp} represents the social welfare with competition between two compatible proprietary software products and W_{op} indicates the social welfare when one of the proprietary software changes to open source software.

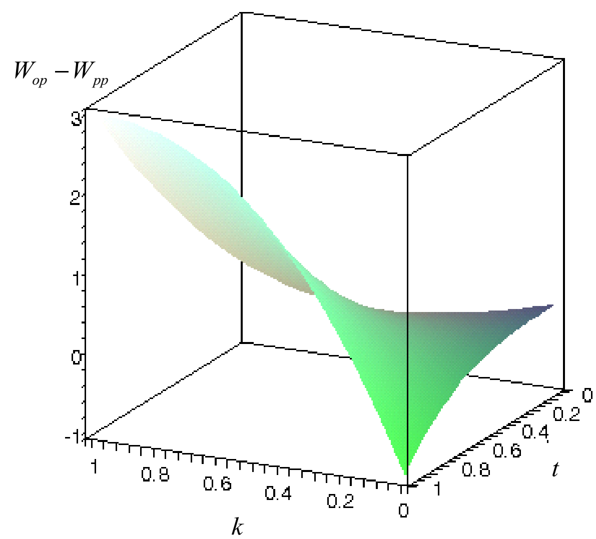

Figure 2.4: Picture of $W_{op} - W_{pp}$

From Figure 2.4, it can be seen that when k is small and t is large, the welfare of "proprietary vs. open" is smaller than that of "proprietary vs. proprietary", which means that social welfare is worse off when one of the proprietary software products changes to open source software. In contrast, when k is large and t is small, the change of the proprietary software to open source software benefits the social welfare.

The reason is that the change to open source software increases the software quality, which has two opposite impacts on the social welfare. On the one hand, higher quality increases the consumer surplus and raises the social welfare. On the other hand, the higher quality of the open source software drives the marginal consumers to switch from proprietary software to open source software. Since open source software covers more than half of the whole market share (see section 2.3), these marginal consumers move from the nearer software to the further one, and the consumer surplus decreases. In Figure 2.4, one can see that when t is large and k is small, the reduction in consumer surplus is the dominating factor and the social welfare will be lower.

Such results suggest that governments should not encourage the open source movement unconditionally. For instance, following Munich's decision to switch from Microsoft software to open source software, Paris postponed a similar move in light of the incompatible problem and high migration cost (ZDNet news, 2004).

2.9. Conclusions

I used the Hotelling model to investigate competition between open source and proprietary software. Firstly, I focused on the compatibility choices of the proprietary software. It was shown that the best compatibility strategy depends on the market coverage degree. When the market is fully covered, inward compatibility is the best strategy. When the market is partly covered, however, two-way compatibility is the best strategy. Moreover, the welfare analysis implied that the increase of t (the taste difference of consumers) may decrease the social welfare, although it can increase the profit of the proprietary software producer.

Next, I relaxed the conditions in the basic model and investigated competition between open source and proprietary software in different scenarios. Firstly, I assumed that the open source software provider begins to maximize market share rather than react passively. The results showed that two-way compatibility is the best choice for both the proprietary and the open source software.

Secondly, I investigated the impact of the open source software from two aspects. From the aspect of a proprietary software producer, I found that it does not favor its proprietary rival changing to open source software. When the rival changes from providing proprietary to open source software, both the market share and the profit of the proprietary software producer will decease. From the aspect of social welfare, I found that when the rival of a proprietary software product changes from providing proprietary to open source software, social welfare may be lower if the consumers' taste difference is sufficiently high.

It is important to consider how the model's simplifying assumptions may affect the conclusions. Firstly, I have assumed that the compatibility strategies are chosen by the proprietary software producer. However, in the software market, the compatibility choice is decided not only by software producers but also by the software architecture. Sometimes, compatibility may not be feasible because the architecture of the two software products is quite different, while other times, it may be difficult to technically implement the inward compatibility. The results may not be applicable in such cases.

Secondly, I have assumed there is no installed user-base for both open source and proprietary software. However, realistically, the open source software and the proprietary software may not enter the market simultaneously. The software which enters earlier will grab the consumers and have large existing network externalities. Therefore, the best compatibility strategy may change. Such limitation of the analysis suggests directions for future study. In the further work, it would be interesting to consider how the installed user-base affects the compatibility choices of the proprietary software.

Finally, for tractability, I have assumed consumers' taste difference is larger than the network externality intensity. If this assumption is violated, the equilibrium results are unstable. The switch of the marginal consumer from one software to the other makes every consumer follows the switch. Such a tipping market needs further investigation.

References

Bessen, J. 2002. Open Source Software: Free Provision of a Complex Public Good. Working paper. http://www.researchoninnovation.org/opensrc.pdf.

Casadesus-Masanell, R., Ghemawat, P., 2003. Dynamic Mixed Duopoly: A Model Motivated by Linux vs. Windows. Working paper. Harvard Business School.

CNet News 2001. Why Microsoft Is Wary of Open Source. http://news.com.com/2100-1001-268520.html?legacy=cnet.

CNet News. 2004a. *In* Europe, Microsoft Aims to Mute Open-Source 'Noise'. http://zdnet.com.com/2100-1104_2-5252994.html.

CNet News. 2004b. Microsoft commits to XML docs for long term. http://techrepublic.com.com/5100-22_11-5442396.html..

Computer Weekly News. 2005. Sun Make Solaris Open Source. http://81.144.183.106/Articles/2005/06/15/210410/SunmakesSolarisopensource.ht m

Cremer, H., Marchand, M., Thisse, J. 1989. The public firm as an instrument for regulating an oligopolistic market. *Oxford Economic Papers.* 41 283-301.

Cremer, H., Marchand, M., Thisse, J. 1991. Mixed oligopoly with differentiated products. *International Journal of Industrial Organization*. 9 43-53.

Dalle, J., Jullien, N. 2002. Open-source vs. proprietary software. Working paper. http://opensource.mit.edu/papers/dalle2.pdf.

DeFraja, G., Delbono, F.1989. Alternative strategies of a public enterprise in oligopoly. *Oxford Economic Papers.* 41 302-311.

Fershtman, C. 1990. The interdependence between ownership status and market structure: The case of privatization. *Economica*. 57 319-328.

Fjell, K., Pal, D. 1996. A mixed oligopoly in the presence of foreign private firms. *Canadian Journal of Economics.* 29 737-743.

Halloween Documents. 1998. http://www.opensource.org/Halloween.

Hann, I-H., Roberts, J., Slaughter, S., Fielding, R. 2002. Economic incentives for participating in open source software projects. in *Proceedings of the Twenty-Third International Conference on Information Systems*. 365-372.

IDG News Service 2004. IBM offers Cloudscape as open source code. http://open.itworld.com/4923/040803cloudscape/page_1.html

International Data Corporation IDC. 2002. Linux Market Share within Web Server Section to Grow. http://thewhir.com/features/linux-market-share.cfm.

Johnson, J. P. 2001. Economics of Open Source Software. Working paper. Cornell University.

Katz, M., Shapiro, C. 1985. Network externalities, competition and compatibility. *American Economic Review.* 75(3) 424-440.

Katz, M., Shapiro, C. 1998. Antitrust in Software Markets. Working paper. University of California at Berkeley.

Kuan, J. 2001. Open Source Software as Consumer Integration Into Production. Working paper. University of California at Berkeley.

Lakhani, K. R., Bates, B.W.J., DiBona, C. 2002. The Boston Consulting Group Hacker *Survey.* http://www.osdn.com/bcg/BCGHACKERSURVEY-0.73.pdf.

Lakhani, K. R., Wolf, R. G. 2003. Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open Source Software Project. Working paper. MIT Sloan School of Management/The Boston Consulting Group.

Lerner, J., Tirole, J. 2002. Some simple economics of open source. *The Journal of Industrial Economics*. 50(2), 197-234.

Mishra, B., Prasad, A., Raghunathan, S. 2002. Quality and profits under open source versus closed source. *in Proceedings of the Twenty-Third International Conference on Information Systems.* 349-363.

Netcraft Web Server Survey. 2004. *May 2004 Netcraft web server survey.* http://news.netcraft.com/archives/ 2004/05/index.html.

O'Reilly, T. 1999. Lessons from open-source software development. *Communications of the ACM.* 42(4) 33-37.

OSI. 2001. The Open Source Definition, http://opensource.org/docs/definition_plain.html.

PC World News 2002. StarOffice Set to Challenge Microsoft's Office http://www.pcworld.com/news/article/0,aid,99643,00.asp.

Raymond, E.S. 1999. The Cathedral and the Bazaar. Working paper. http://www.tuxedo.org/~esr/writings/cathedral-bazaar/ .

Vostroknutov, A. 2002. Economics of Open Source: A Brief Literature Overview. Working paper.

Weber, S. 2004. *The success of open source*. Harvard University Press.

White, M. 1996. Mixed oligopoly, privatization and subsidization. *Economics Letters.* 53 189-95.

ZDNet News 2004. Paris shrugs off open-source plans. http://news.zdnet.co.uk/software/linuxunix/0,39020390,39170365,00.htm.

Appendix 2.1. Best Compatibility Strategy

2A.1.1. Fully Covered Market

In the proof procedures, strategy I denotes two-way compatibility. Also, strategy II denotes inward compatibility. Strategy III and Strategy IV means the outward and incompatibility respectively.

- **Equal base-level qualities**

Table 2.1 reports the equilibrium outcomes of the fully covered market when open source and proprietary software have equal base-level qualities. From Table 2.1, we have:

$$p^*(III) = p^*(IV) < p^*(I) = p^*(II)\,, \qquad \text{(A-1)}$$

$$M_p^*(III) < M_p^*(IV) < M_p^*(I) < M_p^*(II)\,. \qquad \text{(A-2)}$$

By (A-1) and (A-2), we have $\pi^*(III) < \pi^*(IV) < \pi^*(I) < \pi^*(II)$.

- **Different base-level qualities**

When the market is fully covered and the base-level qualities of the open source and proprietary software are different, from the Table 2.3, we have:

$$p^*(III) = p^*(IV) < p^*(I) = p^*(II)\,,$$

$$M_p^*(III) < M_p^*(IV)\,, M_p^*(I) < M_p^*(II)\,,$$

$$\pi_p^*(III) < \pi_p^*(IV)\,, \pi_p^*(I) < \pi_p^*(II)\,. \qquad \text{(A-3)}$$

To guarantee $M_p^*(IV) < 1$, we have

$$s_p - s_o < 3t - 3\gamma - k\,. \qquad \text{(A-4)}$$

Compare $\pi_p^*(IV)$ with $\pi_p^*(I)$:

$$\pi_p^*(IV)=\pi_p^*(I) \Rightarrow \frac{(s_p-s_o+t-\gamma-k)^2}{(s_p-s_o+t-k)^2}=\frac{2t-2\gamma-k}{(2t-k)}$$

$$\Rightarrow s_p-s_o=\frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2} \qquad \text{(A-5)}$$

, where $t-\gamma<\frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2}<t$.

Therefore, it can be derived that:

$$s_p-s_o<\frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2} \Rightarrow \pi_p^*(IV)<\pi_p^*(I) \qquad \text{(A-6).}$$

Combining A-6 with A-3, we have

$$s_p-s_o<\frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2} \Rightarrow \pi_p^*(III)<\pi_p^*(IV)<\pi_p^*(I)<\pi_p^*(II).$$

Proposition 3.2 is thus proved.

From (A-5), it can also be derived:

$$s_p-s_o>\frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2} \Rightarrow \pi_p^*(IV)>\pi_p^*(I). \qquad \text{(A-7)}$$

Under such a case, to decide the sequence of the profit under different strategies, we need to compare $\pi_p^*(I)$ with $\pi_p^*(III)$, and compare $\pi_p^*(IV)$ with $\pi_p^*(II)$.

First, compare $\pi_p^*(I)$ with $\pi_p^*(III)$:

$$\pi_p^*(I)=\pi_p^*(III) \Rightarrow s_p-s_o=t+\sqrt{(2t-k)(2t-k-\gamma)}$$

Thus, we know that:

$$s_p-s_o>t+\sqrt{(2t-k)(2t-k-\gamma)} \Rightarrow \pi^*(III)>\pi^*(I). \qquad \text{(A-8)}$$

Since $t+\sqrt{(2t-k)(2t-k-\gamma)} > 3t-\gamma-k > 3t-3\gamma-k$, we can know that (A-8) contradict with (A-4). Therefore, we have:

$\pi^*(III) < \pi^*(I)$. (A-9)

Secondly, compare $\pi_p^*(IV)$ with $\pi_p^*(II)$:

$\pi_p^*(IV) = \pi_p^*(II)$ ➔ $s_p - s_o = t-\gamma+\sqrt{(2t-\gamma-k)(2t-\gamma-k-\gamma)}$

We can get that

$s_p - s_o > t-\gamma+\sqrt{(2t-\gamma-k)(2t-\gamma-k-\gamma)}$ ➔ $\pi^*(IV) > \pi^*(II)$. (A-10)

Since $t-\gamma+\sqrt{(2t-\gamma-k)(2t-\gamma-k-\gamma)} > 3t-3\gamma-k$, we know that (A-10) contradict with (A-4). Therefore, it can be derived that

$\pi^*(IV) < \pi^*(II)$. (A-11)

Combining (A-3), (A-7), (A-9) and (A-11), it can be derived that

$s_p - s_o > \frac{k+\sqrt{(2t-k)(2t-k-2\gamma)}}{2}$ ➔ $\pi_p^*(III) < \pi_p^*(I) < \pi_p^*(IV) < \pi_p^*(II)$.

Proposition 3.3 is thus proved.

Proposition 3.2 and proposition 3.3 lead to proposition 3.1 spontaneously.

2A.1.2. Partly Covered Market

- **Equal base-level qualities**

Table 2.2 reports the equilibrium outcomes of the partly covered market when open source and proprietary software have equal base-level qualities. From Table 2.2, we have:

$p^*(III) = p^*(IV) < p^*(II) = p^*(I)$, (A-12)

$M_p^*(III) = M_p^*(IV) < M_p^*(II) < M_p^*(I)$. (A-13)

By (A-12) and (A-13), it can be derived that $\pi^*(III) = \pi^*(IV) < \pi^*(II) < \pi^*(I)$.

- **Different base-level qualities**

Table 2.4 reports the equilibrium outcomes of the partly covered market when open source and proprietary software have different base-level qualities. From Table 2. 4, we have:

$$p^*(III) = p^*(IV) < p^*(II) = p^*(I), \qquad \text{(A-14)}$$

$$M_p^*(III) = M_p^*(IV) < M_p^*(II) < M_p^*(I). \qquad \text{(A-15)}$$

By (A-14) and (A-15), it can be derived that $\pi^*(III) = \pi^*(IV) < \pi^*(II) < \pi^*(I)$.

Such results are the same as those when open source and proprietary software products have equal base-level quality. Therefore, the proposition 2 is proved.

Proposition 2 and proposition 3.1 prove proposition 1 spontaneously.

Appendix 2.2. Calculation of the Welfare

When the market is fully covered, the proprietary software producer will choose inward compatibility. Under such a scenario, the welfare denoted as W is calculated as:

$$
\begin{aligned}
W &= \int_0^{x_c} U_o dx + \int_{x_c}^1 U_p dx + \pi_p \\
&= \int_0^{x_c} (s + kq_o - tx + \gamma q_o) dx + \int_{x_c}^1 [s - t(1-x) + \gamma - p] dx + \pi_p
\end{aligned} \qquad \text{(A-16)}
$$

By substituting $q_o = \dfrac{3t - 2\gamma - k}{2(2t - \gamma - k)}$, $p = \dfrac{t-k}{2}$ and $x_c = \dfrac{3t - 2\gamma - k}{2(2t - \gamma - k)}$ into (A-16), we have:

$$
\begin{aligned}
W &= \int_0^{\frac{3t-2\gamma-k}{2(2t-\gamma-k)}} \left(s + k\frac{3t - 2\gamma - k}{2(2t-\gamma-k)} - tx + \gamma \frac{3t - 2\gamma - k}{2(2t-\gamma-k)}\right) dx \\
&\quad + \int_{\frac{3t-2\gamma-k}{2(2t-\gamma-k)}}^1 [s - t(1-x) + \gamma - p] dx + \frac{(t-k)^2}{4(2t-\gamma-k)} \\
&= \frac{(k+\gamma-t)(3t-2\gamma-k)^2}{4(2t-\gamma-k)^2} + s - \frac{(t-\gamma)(t-k)}{2(2t-\gamma-k)} + \frac{t}{2}
\end{aligned}
$$

Appendix 2.3. Proof of Proposition 4

2A.3.1. Fully Covered Market

Suppose the open source software aims at maximizing market share and the proprietary software pursues the maximum profits. And suppose that they choose the compatibility strategy simultaneously. The payoffs under each strategy are listed in Table 2A.1. The first number in each cell is the market share of the open source software, and the second number is the profit of the proprietary software.

Proprietary software

Open Source Software		Incompatibility	Compatibility
	Incompatibility	$M_o^* = \frac{3t-3\gamma-k}{2\left[2(t-\gamma)-k\right]}$, $\pi_p^* = \frac{(t-\gamma-k)^2}{4[2(t-\gamma)-k]}$	$M_o^* = \frac{3t-2\gamma-k}{2(2t-\gamma-k)}$, $\pi_p^* = \frac{(t-k)^2}{4(2t-\gamma-k)}$
	Compatibility	$M_o^* = \frac{3t+2\gamma-k}{2(2t+\gamma-k)}$, $\pi_p^* = \frac{(t-\gamma-k)^2}{4(2t-\gamma-k)}$	$M_o^* = \frac{3t-k}{2(2t-k)}$, $\pi_p^* = \frac{(t-k)^2}{4(2t-k)}$

Table 2A.1: Fully Covered Market: Competition Outcomes

The Nash equilibrium can be solved as (Compatible, Compatible). Therefore, when the market is fully covered, both open source and proprietary software will choose to be compatible with the rival, which leads to two-way compatibility.

2A.3.2. Partly Covered Market

Similarly, when the market is not fully covered, the payoffs under each strategy are listed in Table 2A.2.

Proprietary Software

Open Source Software		Incompatibility	Compatibility
	Incompatibility	$M_o^* = \frac{s}{t-\gamma-k}$, $\pi_p^* = \frac{s^2}{4(t-\gamma)}$	$M_o^* = \frac{s}{t-\gamma-k}$, $\pi_p^* = \frac{s^2(t-k)^2}{4(t-\gamma)(t-\gamma-k)^2}$
	Compatibility	$M_o^* = \frac{s(2t-\gamma)}{2(t-\gamma)(t-\gamma-k)}$, $\pi_p^* = \frac{s^2}{4(t-\gamma)}$	$M_o^* = \frac{(2t^2-3t\gamma-2tk+\gamma k)s}{2(t^2-2t\gamma-tk+\gamma k)(t-\gamma-k)}$, $\pi_p^* = \frac{(t-k)^2 s^2}{4(2t\gamma-\gamma k-t^2+tk)(\gamma+k-t)}$

Table 2A.2: Partly Covered Market: Competition Outcomes

The Nash equilibrium can be solved as (compatible, compatible). Therefore, when the market is not fully covered, both open source and proprietary software will choose to be compatible with their rival, which leads to two-way compatibility.

Appendix 2.4. Proof of Proposition 5

2A.4.1. Incompatibility

When two software products are incompatible, the equilibrium outcomes of the proprietary software are listed in the following table, where the second row is the case of open vs. proprietary software and the third row is the case of proprietary vs. proprietary software.

Incompatibility	Equilibrium Price	Market Share	Profit
Case1: Open vs. Proprietary	$\frac{t-\gamma-k}{2}$	$\frac{t-\gamma-k}{2[2(t-\gamma)-k]}$	$\frac{(t-\gamma-k)^2}{4[2(t-\gamma)-k]}$
Case 2: Proprietary vs. Proprietary	$t-\gamma$	$\frac{1}{2}$	$\frac{t-\gamma}{2}$

Table 2A.3: The Comparison of Two Cases Where Two Products Are Incompatible

First, comparing the equilibrium price under two cases, it can be derived that:

$$\frac{t-\gamma-k}{2} < t-\gamma \,. \qquad \text{(A-17)}$$

Second, comparing the market share under two cases, it is obtained:

$$\frac{t-\gamma-k}{2[2(t-\gamma)-k]} < \frac{1}{2} \,. \qquad \text{(A-18)}$$

From (A-17) and (A-18), we can get:

$$\frac{(t-\gamma-k)^2}{4[2(t-\gamma)-k]} < \frac{t-\gamma}{2} \,.$$

Therefore, the equilibrium profit of the "proprietary vs. proprietary" case is higher than that of the "open vs. proprietary" case.

2A.4.2. Two-way Compatibility

Table 2A.4 shows the equilibrium price, market share and the profit of the proprietary software when two products are two-way compatible.

Compatibility	Equilibrium Price	Market Share	Profit
Case1: Open vs. Proprietary	$\frac{t-k}{2}$	$\frac{t-k}{2(2t-k)}$	$\frac{(t-k)^2}{4(2t-k)}$
Case2: Proprietary vs. Proprietary	t	$\frac{1}{2}$	$\frac{t}{2}$

Table 2A.4: The Comparison of Two Cases Where Two Products Are Compatible

It is straightforward that the equilibrium profit under the "proprietary vs. proprietary" case is higher than that under "open vs. proprietary" case.

Appendix 2.5. Proof of Proposition 6

2A.5.1. Social Welfare: Proprietary vs. Proprietary

Suppose that the market is fully covered and two software products are two-way compatible. The equilibrium price, market share and profits are shown as follows:

$p_1^* = p_2^* = t$,

$\pi_1^* = \pi_2^* = \dfrac{t}{2}$,

$M_1^* = M_2^* = \dfrac{1}{2}$,

where the footnote 1 and 2 denotes the first proprietary and the second proprietary software respectively.

Using W_{pp} to denote the welfare when two proprietary software products compete together, we have:

$$
\begin{aligned}
W_{pp} &= \int_0^{\frac{1}{2}} U_1 dx + \int_{\frac{1}{2}}^{1} U_2 dx + \pi_1^* + \pi_2^* \\
&= \int_0^{\frac{1}{2}} (s - tx + \gamma - p)dx + \int_{\frac{1}{2}}^{1} [s - t(1-x) + \gamma - p]dx + t \qquad \text{(A-19)} \\
&= s + \gamma - \frac{t}{4}
\end{aligned}
$$

2A.5.2. Social Welfare: Open vs. Proprietary

When two proprietary software compete together and one of them changes to open source software, we suppose that it aims at market share maximization. Therefore, the best strategy is two-way compatibility. Using W_{op} to denote the welfare, we have:

$$\begin{aligned} W_{op} &= \int_0^{x_c} U_o dx + \int_{x_c}^{1} U_p dx + \pi_p \\ &= \int_0^{x_c} (s + kq_o - tx + \gamma)dx + \int_{x_c}^{1} [s - t(1-x) + \gamma - p]dx + \pi_p \end{aligned} \qquad \text{(A-20)}$$

By substituting $q_o = \frac{3t-k}{2(2t-k)}$, $p = \frac{t-k}{2}$ and $x_c = \frac{3t-k}{2(2t-k)}$ into (A-20), we have:

$$\begin{aligned} W_{op} &= \int_0^{\frac{3t-k}{2(2t-k)}} (s + k\frac{3t-k}{2(2t-k)} - tx + \gamma)dx + \int_{\frac{3t-k}{2(2t-k)}}^{1} [s - t(1-x) + \gamma - \frac{t-k}{2}]dx + \frac{(t-k)^2}{4(2t-k)} \\ &= s + \gamma - \frac{t(t-k)}{2(2t-k)} + \frac{(2k-t)(3t-k)^2 + t(7t-3k)(t-k)}{8(2t-k)^2} \end{aligned} \qquad (A-21)$$

2A.5.3. Social Welfare: "Open vs. Proprietary" vs. "Proprietary vs. Proprietary"

From A-19 and A-21, we can get:

$$\begin{aligned} W_{op} - W_{pp} &= s + \gamma - \frac{t(t-k)}{2(2t-k)} + \frac{(2k-t)(3t-k)^2 + t(7t-3k)(t-k)}{8(2t-k)^2} - s - \gamma + \frac{t}{4} \\ &= \frac{-t^3 + k(3t-k)^2}{4(2t-k)^2} \end{aligned} \qquad \text{(A-22)}$$

Therefore, we have:

$t^3 > k(3t-k)^2 \Rightarrow W_{op} < W_{pp}$,

$t^3 < k(3t-k)^2 \Rightarrow W_{op} > W_{pp}$

CHAPTER 3 THE VALUE OF IT TO FIRMS IN A DEVELOPING COUNTRY IN THE CATCH-UP PROCESS: AN EMPIRICAL COMPARISON OF CHINA AND THE UNITED STATES

3.1. Introduction

With the coming of the information age, information technology (IT) investments are becoming increasingly important to firms' survival and growth (Bharadwaj 2000). In particular, Asian firms have grown successfully with the help of IT (Amsden 2001, Enos et al. 1997, Hobday 1995, Kim 1997, Lall 2000, Mathews and Cho 2000). Such successes have obviously boosted the confidence of firms in developing countries. Indeed, many developing countries have turned to IT as a way to propel economic growth (Song 2000, Splettstoesser 1996, Talero 1994, Thong, 1999).

The catch-up theory (Gerschenkron 1962) explains the successes of firms in developing countries: developing countries can skip several stages of development and directly adopt advanced technologies. In particular, technologies are "short cuts" by which developing countries may "catch up" with developed countries.

Information technology could act as the shortcut suggested in the catch-up theory. By adopting IT that has been proven to be successful in developed countries, firms in developing countries may grow faster than those in developed countries.

Many researchers believe that the rise of Asian firms is related to the development of IT. However, some scholars have been skeptical about the role of IT in the catch-up process. They argued that IT adoption and implementation in developing countries face a broad range of obstacles, such as inadequate IT infrastructure, lack of communication, and ineffective policies (Dasgupta et al. 1999, Dewan and Kraemer 2000, Sauvant 1984). Homer-Dixon (1991) even reported that the gap between developing countries and developed countries is widening, owing to slow IT adoption and diffusion.

Puzzled by these arguments, researchers and practitioners are struggling to collect empirical evidence to determine whether IT propels the catch-up processes of firms in developing countries, and if so, to find out which factors may affect IT value. Although some studies have documented successful cases of latecomer firms in Asia (Amsden 2001, Kim 1995, 1997, Lall 2000), little literature in the field has focused on the role of IT in the catch-up process. Besides, most of the previous studies on IT value were limited to US cases (Dos Santos et al. 1993, Im et al. 2001). We do not know whether their results are applicable to developing countries, especially those in the catch-up process.

China has maintained rapid economic growth, especially in the IT industry, in spite of the Asian financial crisis of the late 1990s, and the subsequent global economic slowdown. IT growth in China may therefore represent the rapid adoption of IT by latecomer firms in developing countries. In contrast, US firms are leaders of the market. They would have profited from first-mover advantages (Shapiro and Varian 1998) through high research and development (R&D) expenditure. Hence, the comparative studies of IT value to firms in these two countries can offer insight on whether IT plays a significant role in the latecomer firms' catch-up process or not.

This study aims to assess the value of IT investments to firms in China, a developing country actively engaged in the catch-up process. I employ the event study methodology and compare the empirical impact of IT investments in China with that in the US. I shall investigate the following questions: (1) Can IT increase firms' value in a developing country (China) and in a developed country (US) respectively? (2) Does IT really provide an opportunity for firms in a developing country to catch up with those in a developed one? (3) How do various context factors (such as industry, size and type) affect the catch-up process?

The rest of the essay is organized as follows: I present four hypotheses about the market value of IT investments in Section 3.2. Section 3.3 briefly explains the methodology of event study. Section 3.4 describes the data collection procedure. The empirical results follow in Section 3.5. Section 3.6 discusses the findings. Section 3.7 concludes the essay with a summary of its contributions and a discussion of directions for future work.

3.2. Hypotheses

3.2.1. Overall IT Investment Effect

IT is believed to automate processes (Zuboff 1988), change business strategies (Malone et al. 1987), and smooth the daily operation of firms (Dos Santos et al. 1993). Given the tangible and intangible value of IT, IT investments should bring benefits to firms. Yet previous empirical studies in the US have failed to support such a claim (Dos Santos et al. 1993, Im et al. 2001). One possible reason is the high risk of IT investments in the US. It is reported that over 80% of IT projects in the US failed (The Standish Group 1995). Another possible reason is the high competitive pressure. Dos Santos et al. (1993) posited that only early adopters of IT applications can reap first-mover benefits. For the other firms, IT investments become necessities rather than value creators (Clemons and Row 1991).

The disadvantages that US firms seem to face in IT adoption may not apply to firms in China for a number of reasons. Firstly, the catch-up theory indicates that technology development in developing countries lags behind that in developed countries. This gives a good opportunity for firms in developing counties to identify which is the most effective technology to adopt, and at which stage they should enter IT adoption. Therefore, the risk of failure may be significantly lower for firms in developing countries. For instance, firms in the US implemented material requirement planning (MRP) to manage resources in the early 1960s. This technology subsequently developed into manufacturing resource planning (MRP II), and finally evolved into enterprise resource planning (ERP). While US firms would have implemented MRP, MRPII, and eventually, ERP over the years, most firms in China could simply leap over MRP and MRPII and implement ERP directly.

Secondly, although the technologies learnt and adopted by firms in developing countries may not be the most advanced in developed countries, they would be new and innovative in the local market of the adopting firm. It has been noted that competitive pressure is statistically significant for firms in the US but not for those in China (Zhu and Kraemer 2005, Xu et al. 2004). This indicates that in China, firms adopt IT not to avoid competitive decline but to gain the competitive advantage. Thus, I propose the following hypotheses:

Hypothesis 1(a): Announcements of IT investments cause positive abnormal returns for firms in China.

Hypothesis 1(b): Announcements of IT investments do not cause positive abnormal returns for firms in the U.S.

3.2.2. Industry Effect

Prior studies have shown that IT investments do not exhibit significant difference between the manufacturing and financial industries in the US (Dos Santos et al. 1993, Im et al. 2001) [10]. However, industry effect should be expected in China because the catch-up process is more intense in the manufacturing sector (Amsden 1989, Hobday 1995, Kim 1997, Lall 1982).

A series of research shows that the catch up process of Central and Eastern European countries and Asian countries present unbalanced growth (Ark and Timmer 2003, Ark

[10] In the US stock market, SIC codes are used to indicate the industry type of firms. China has a similar classification in the market index portfolio.

and Piatkowski 2003). The manufacturing sector continues to drive much more of the overall productivity growth than non-manufacturing sector.

Furthermore, structural change is a key factor for productivity growth (Lucas 1993 and Versepagen 1993). When there is a transition from socialist centrally planned to a market economy, the major restructuring happens in the manufacturing sector (Ark and Piatkowski 2003). In contrast, the restructuring in the non-manufacturing sector is more complicated and requires bigger changes in the economic environment (Ark et al. 2002).

The problem is more pronounced in China. The Chinese government is changing the structure of the finance industry gradually. A few big issues are delaying the development of the whole financial services industry. For instance, China lacks a social credit system. The information asymmetry in the China financial market is more severe than that in the US, which directly affects trust building in transactions. Concerning the cross-country and cross-industry difference, I propose the following hypotheses:

Hypothesis 2(a): In China, the reaction of stock prices to the announcements of IT investments is greater for manufacturing firms than for financial firms.

Hypothesis 2(b): In the US, the reaction of stock prices to the announcements of IT investments is no greater for manufacturing firms than for financial firms.

3.2.3. Firm Size Effect

The relationship between firm size[11] and IT has been investigated from different aspects in the IS field (Dewan et al. 1998, Brynjolfsson 1994, Richardson and Zmud 2001, Im et al. 2001). Theoretically, firm size may affect the adoption of IT in opposite ways. On the one hand, IT influences the scale and scope of economies, which favors large-sized firms because large-sized firms usually have ample resources (Dewan et al. 1998). This is defined as resource advantage (Zhu et al. 2004). On the other hand, Richardson and Zmud (2001) state that the competitive advantage brought by IT is more likely sustained in small-sized firms since they are more agile. The greater structural inertia associated with large-sized firms requires more effort to implement IT (Nohria and Gulati 1996).

In the US market, I expect firm size effect to be a mix of resource advantage and structural inertia and, in balance, the two factors may cancel each other out. China, however, was a socialist economy for several decades, and began changing into a market economy in recent years. Most large firms are still state-owned, and the structural inertia is more distinct in these firms (Xu et al. 2004). As a result, small-sized firms would benefit more from IT investments. Thus, I posit the following hypotheses:

Hypothesis 3(a): In China, the reaction of stock prices to the announcements of IT investments is greater for small-sized firms than for large-sized firms.

Hypothesis 3(b): In the US, the reaction of stock prices to the announcements of IT investments is no greater for small-sized firms than for large-sized firms.

[11] Based on prior studies (Im et al. 2001), firm size is measured by market capitalization.

3.2.4. Firm Type Effect

The value of IT in the IT-using industry and the IT-producing industry[12] has been investigated separately in prior studies for developed countries (Dedrick et al. 2003). Some studies have observed the positive value of IT in the IT-producing industry (Gordon 2000, Jorgenson and Stiroh 2000) while others acknowledged the value of IT in the IT-using industry (Triplett and Bosworth 2003). I thus expect that IT value has no significant difference in these two sub-samples in the US.

In contrast, I expect piracy to seriously affect IT value in the IT-producing industry in China. Unlike the US, China faces rampant piracy of intellectual property. Although the Chinese government recognizes the importance of protecting intellectual property and has developed copyright laws, the implementation of these laws has proven lacking, due largely to difficulties in enforcement. Compared with IT-using firms, IT-producing firms are more undermined by piracy as they are technology-oriented and operate in higher technology intensity. Without effective enforcement of copyright laws, leading technologies can be easily duplicated, and leader firms would lose their first-mover advantages in the local Chinese market. Therefore, the impact of IT investments in IT-producing firms may not be as significant as that in IT-using firms in China, leading to the following hypotheses:

Hypothesis 4(a): The reaction of stock prices to announcements of IT investments for IT-using firms is larger than that for IT-producing firms in China.

---

[12] Here, the IT-producing industry includes software and hardware producing firms, and IT service providers. All other firms belong to the IT-using industry.

Hypothesis 4(b): The reaction of stock prices to announcements of IT investments for IT-using firms is no larger than that for IT-producing firms in the US.

3.3. Methodology

Consistent with prior studies on the United States (Dos Santos et al. 1993, Im et al. 2001), the methodology applied in this paper is event study methodology. Changes in stock prices associated with IT investment announcements are deemed the discounted value of future net cash flow, which is the true contribution of IT investments to firms. By linking market value directly to IT investments, we can eliminate the effect of other factors that cannot be properly measured (Dos Santos et al. 1993, Im et al. 2001).

First, I construct a model of share price relative to market index, which is specified as an equation (3.1). The parameters in the model are estimated by historical data. The market model is specified as follows:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + \varepsilon_{i,t} \qquad (3.1)$$

$R_{i,t}$ is the rate of return for firm i on day t and $R_{i,t} = (Price_{i,t} - Price_{i,(t-1)}) / Price_{i,(t-1)}$; $R_{m,t}$ is the average of returns for all firms in the stock market; α_i and β_i are the intercept and the slope parameters for firm i; and $\varepsilon_{i,t}$ represents the error term for firm i on day t. α_i and β_i are estimated over T days, where T(=200) begins 230 days before the announcement day (event day) and ends 30 days before the announcement day[13].

[13] The 30 days' data before event window day are deleted in case there is information leakage.

Second, I choose a three-day event window (beginning on the event day and ending two days after the event day). I assume that any abnormal returns in the event window days are the result of the announcement. The abnormal returns of firm *i* on event day *t* are computed as:

$$AR_{i,t} = R_{i,t} - (\hat{\alpha}_i + \hat{\beta}_i R_{m,t}) \qquad (3.2)$$

Finally, I check whether the average abnormal returns in the event window days are statistically significant; I proceed as follows:

Cumulative abnormal returns (*CAR*) are computed as:

$$CAR_i = \sum_{t=0}^{2} AR_{i,t} \qquad (3.3)$$

Thus, for a sample of *N* firms, the average announcement effect equals:

$$\overline{CAR} = \frac{1}{N}\sum_{i=1}^{N} CAR_i \qquad (3.4)$$

The standard variance of *AR* is calculated as:

$$Var(AR) = S_i^2 \left[1 + \frac{1}{T} + \frac{(R_{m,\tau} - \overline{R}_m)^2}{\sum_{t=1}^{T}(R_{m,t} - \overline{R}_m)^2} \right] \qquad (3.5)$$

(Judge et al. 1988), where S_i^2 is the residual return variance from the estimation of the market model over the T days before the announcement period, $\overline{R}_m$ represents the mean return of the whole market over the estimation period, $R_{m,t}$ is the return of the market on day t during the estimation period, and $R_{m,\tau}$ is the market return on day τ in the event window.

Then, I can derive:

$$Var(CAR_{s,i}) = \sum_{i=0}^{2} \text{var}(AR_{s,i}) \tag{3.6}$$

Based on equation (3.6), I calculate the variance of $\overline{CAR}$ across all firms with the following equation:

$$Var(\overline{CAR_{\tau}}) = \frac{1}{N^2} \sum_{s=1}^{N} VAR(CAR_{s,\tau}) \tag{3.7}$$

To test whether $\overline{CAR}$ is different from zero, t-statistic is defined as:

$$t = \frac{\overline{CAR_{\tau}}}{\sqrt{Var(\overline{CAR_{\tau}})}} \tag{3.8}$$

with *T-1(=199)* degree of freedom (Campbell et al. 1997, Subramani and Walden 2001).

3.4. Data Collection

To compare US firms and China firms, I consider data from the same period of 1999 to 2002 for both countries. In the US, there are many available databases carrying news of IT investments. I use Factiva as the main database. To collect news on IT investment announcements of firms traded on the US stock exchanges (such as NYSE, AMEX and NASDAQ), I searched the Factiva database from 1999 to 2002. The target news sources were Business Wire, PR Newswire, Dow Jones Business News and Dow Jones International News. A full text search was done using the keywords: “computer”, “software”, “hardware”, “investment” and “purchase”, which yielded more than 4,000 items of news. I selected the data by reading the details of the news. Having done that, historical stock prices were collected from finance.yahoo.com. To find out the SIC codes and past assets of the firms, I further conducted a search in the CRSP/COMPUSTAT Merged database. I used the S&P 500 index to calculate the return of the market portfolio.

For China, news of IT investment announcements were collected from five of the most well-known Chinese stock news web sites (www.p5w.net, www.stocknews.com.cn, finance.eastday.com, www.cs.com.cn, and www.my0578.com). These five web sites cover all core news related to China's stock market. Using the keyword, "IT investments", I found more than 3,300 matches of IT announcement news. Then, I examined the titles to ensure that the news item was actually related to IT investments. After this, I checked the event date by comparing the dates from different sources. If a piece of news appeared in different sources, I used the earliest one as the event date. The return of the market was calculated by the simple average returns of all 943 companies in the stock market. I obtained the historical stock prices of the firms from the Daily Stock Returns File of China.

In the process of computation, I needed at least 233 days of stock prices to predict the returns during the event window. Some stocks were too new to have enough historical prices. These stocks were eliminated. Next, firms with more than one announcement on the event day were excluded, which left 63 firms for the US stock market and 65 firms for the China market.

3.5. Results

3.5.1 Overall Effects of IT Investment Announcements

Table 3.1 reports the *CAR* and test results of the 65 samples from China and the 63 samples from the US. From the table, one can see that *CAR* is positive for both China and the US. However, *CAR* was significantly different from zero for China but insignificant for the US. This implies that IT investment announcements can significantly increase firms' value in China, a developing country in the catch-up processes, but not in the US. Thus, both Hypothesis 1(a) and Hypothesis 1(b) are accepted.

Full Sample	$\overline{CAR}$	$VAR(\overline{CAR})$	*t*-statistics
China (n=65)	1.077815	0.117171	3.148728**
The United States (n=63)	0.003701	6.45096E-05	0.460805

**significant at the 1% level

Table 3.1: Test Results: Overall Effect

3.5.2 Industry Effect

To test for industry effect, I divided the samples of each country into two groups: manufacturing firms and financial firms. Table 2 reports the *CAR* of manufacturing firms and financial firms in the two countries. One can see that IT investment announcements can significantly increase the market value of manufacturing firms but not financial firms in China, although the *t*-statistic of the difference between the manufacturing firms and financial firms is insignificant. In contrast, for the US, both sub-samples show insignificant results, indicating that industry effect cannot be observed in the sample of the US at all. As a result, Hypothesis 2(a) is rejected and Hypothesis 2(b) is accepted.

Sample Category	$\overline{CAR}$	$VAR(\overline{CAR})$	*t*-statistics
Manufacturing firms in China (n=41)	1.347909	0.172963	3.24104**
Non-manufacturing firms in China(n=24)	0.616405	0.354679	1.035019
Difference between two sub-samples In China	0.731504	0.52764	1.007
Manufacturing firms In the United States (n=32)	0.00454	0.000143	0.379268
Non-manufacturing firms In the United States (n=31)	0.002835	0.000114	0.265826
Difference between two sub-samples In the United States	0.00171	0.000257	0.10667

**significant at the 1% level

Table 3.2: Test Results: Industry Effect

3.5.3 Firm Size Effect

The test results for firm size effect are reported in Table 3. For China, the *CAR* of small-sized firms is statistically significant while that of large-sized firms is insignificant. However, the *t*-statistic of the difference between small-sized firms and large-sized firms is insignificant. In contrast, large-sized firms in the US show significantly negative abnormal returns while small-sized firms show insignificantly positive abnormal returns. The difference between these two sub-samples is significant. Such results show that IT investments can trigger opposite reactions for different firm sizes in different countries. Both Hypothesis 3(a) and Hypothesis 3(b) are rejected.

Sample Category	$\overline{CAR}$	$VAR(\overline{CAR})$	*t*-statistics
Large-sized firms in China (n=22)	-0.3385	2.348401	-0.22089
Small-sized firms in China (n=43)	1.398489	0.137648	3.769419**
Difference between two sub-samples in China	-1.736989	2.486049	-1.10164
Large-sized firms In the United States (n=15)	-0.02713	0.000154	-2.18326*
Small-sized firms In the United States (n=48)	0.013336	9.60465E-05	1.360801
Difference between two sub-samples In the United States	-0.040466	0.00025	-2.55929**

**significant at the 1% level   *significant at the 5% level

Table 3.3: Test Results: Firm Size Effect

3.5.4 Firm Type Effect

To test for firm type effect, I divided the samples into IT-producing firms and IT-using firms. The *CAR* and *t*-statistic value of these two types of firms are reported in Table 4.

In China, the *CAR* for IT-using firms is significantly positive while the *CAR* for IT-producing firms is statistically insignificant. The difference between these two sub-samples is statistically significant. In contrast, in the US, I cannot infer significant reactions in either sub-sample; the difference is also insignificant. This implies that both Hypothesis 4(a) and Hypothesis 4(b) are accepted.

Sample Category	$\overline{CAR}$	$VAR(\overline{CAR})$	*t*-statistics
IT-using firms in China (n=39)	1.572932	0.20841	3.44549**
IT-producing firms in China (n=26)	0.335141	0.263394	0.653017
Difference between two sub Samples in China	1.237791	0.471804	1.80204*
IT-using firms in the United States (n=33)	0.000187	9.699E-05	0.019035
IT-producing firms in the United States (n=30)	0.007566	0.000252	0.476427
Difference between two sub-samples in the United States	-0.007753	0.00034899	-0.415

**significant at the 1% level   *significant at the 5% level

Table 3.4: Test Results: Firm Type Effect

All the results of testing the hypotheses are summarized in Table 3.5

Hypotheses	Supported
H1(a): Announcements of IT investments cause positive abnormal returns for firms in China.	Yes
H1(b): Announcements of IT investments do not cause positive abnormal returns for firms in the U.S.	Yes
H2(a): In China, the reaction of stock prices to the announcements of IT investments is greater for manufacturing firms than for financial firms.	No
H2(b): In the US, the reaction of stock prices to the announcements of IT investments is no greater for manufacturing firms than for financial firms.	Yes
H3(a): In China, the reaction of stock prices to the announcements of IT investments is greater for small-sized firms than for large-sized firms.	No
H3(b): In the US, the reaction of stock prices to the announcements of IT investments is no greater for small-sized firms than for large-sized firms.	No
H4(a): The reaction of stock prices to announcements of IT investments for IT-using firms is larger than that for IT-producing firms in China.	Yes
H4(b): The reaction of stock prices to announcements of IT investments for IT-using firms is no larger than that for IT-producing firms in the US.	Yes

Table 3.5: Summary: Test Results of the Hypotheses

3.6. Discussion

The main finding is that IT investment announcements significantly increase firms' market value in China but not in the US. The increase in market value can be deemed as the net present value that has resulted from the expected profits of IT investments (Dos Santos et al. 1993). In other words, IT investments can benefit firms in China but not in the US, which could explain the successful catch-up process of China.

China clearly lags behind the US in IT development. The US began research on the Internet in the 1960s, and constructed the first generation of the Internet in 1986. In contrast, China set up its Internet structure in 1994. Firms in the US began using MRP to plan enterprise resources in the 1960s while firms in China began implementing ERP in the 1990s. The US e-government was established in the early 1990s while the e-government in China has been developed only in the past five years. These lags indicate the technological gaps between developed countries and developing countries.

Early adoption of new technologies may provide certain opportunities to leader firms – the so-called first-mover advantages. It enables leader firms to lock in consumers before competitors enter the market (Shapiro and Varian 1998). It allows leader firms to establish the technology standard, and using the installed consumer bases, to maximize network externalities so that latecomer firms may have serious difficulties in competing against them. However, the problem for early comers is that it is very difficult to be a winner and enjoy the advantages. As I have noted, over 80% of IT projects in the US failed.

Latecomer firms in developed countries can reduce the risks of IT investments by adopting mature technologies rather than new technologies. However, mature technologies invariably mean strong incumbents who are enjoying first-mover advantages in the market. Therefore, latecomer firms in developed countries would face difficulties competing against early comer firms.

However, latecomer firms in China may not necessarily compete against leader firms in the US directly. Therefore, the disadvantages as latecomers may not so serious because the firms can adopt the technologies that have been proven successful in the US for their business in China. Compared with the big traditional firms in China which mainly rely on manpower, those China firms investing in IT can use IT as leverage to enhance their performance and increase productivity, and thus win the competitive advantage in the China market.

The catch-up process can be more easily observed among manufacturing firms than among financial firms in China, although there is no evidence that industry difference exists. The possible reason is that compared with manufacturing firms, financial firms require comparatively more communication, coordination and dependence with others. The developing status of the whole China financial services industry may affect the results of individual firms' IT investments.

In China, IT investments can increase the market value of small-sized firms but not that of large-sized firms. Surprisingly, in the US, large-sized firms have significantly negative abnormal returns. Combining with the results of prior research – Im et al. (2001) who posited insignificant negative abnormal returns of large-sized firms, and Xu et al. (2004) who demonstrated that firm size slows e-business adoption in the US – I may expect that structural inertia dominates the resource advantage of large-sized firms in the US.

I have found strong evidence that the value of IT varies with respect to type of firm. IT-using firms in China are more likely to catch up successfully with leader firms in developed countries, but the outlook may not be so optimistic for IT-producing firms. Rampant piracy seriously affects the growth of IT-producing firms in China. The US software industry reported that up to 98% of copies of US software products sold in China were unlicensed or pirated copies. A big proportion of gains from IT products in China are cannibalized by illegal copies, which affects the profits of IT investments. This serves as a reminder that, for China, the enactment of laws protecting intellectual property is only the first step to keeping its long-term growth. How to enforce these laws and protect the technology investment environment is key to the success of the catch-up process.

3.7. Conclusions

I have studied IT payoff from the perspective of the catch-up process. Using actual data of firm performance, I have compared IT value in two big economies (China vs. the US). The difference in the pattern of IT value in China and the US indicates that IT could be the technology shortcut through which firms in developing countries could grow more quickly. Thus, the gap between developing and developed counties could narrow with technology. The result could serve as a good explanation of the fast growth of the China economy in recent years. It is also of empirical implication for other developing countries in the aspect of IT investments. The low efficiency of IT investments in the financial services industry compared with the manufacturing industry, and that in the IT-producing industry compared with that in the IT-using industry, may also serve as a reminder to policy makers in China that a more healthy IT investment environment is needed.

This study contributes to the current research in advancing a theory on IT value to firms by incorporating the country dimension. It is interesting that contextual factors, such as industry, firm size, and firm type, affect IT value in different ways in developing countries and developed countries. Empirically, such results are of useful implications for firms operating in various types of countries. Academically, it implies the necessity to check whether the conclusions of IT value research derived from US data are also applicable to developing countries.

As a final note, I acknowledge that this study provides only one successful example of the catch-up theory. Gaps remain between developing countries and developed countries, and they may not always be good for the developing countries.

References

Amsden, A. 1989. *Asia's Next Giant: South Korea and Late Industrialization***.** NY: Oxford University Press.

Amsden, A. 2001. *The Rise of "The Rest": Challenges to the West from Late-Industrializing economies.* New York and Oxford: Oxford University Press.

Ark, B. V., Inklaar, R., McGuckin, R.H. 2002. "Changing Gear": Productivity, ICT and Services: Europe and the United States. Research Memorandum GD-60. Groningen Growth and Development Centre.

Ark, B. V., Piatkowski, M. 2004. Productivity, Innovation and ICT in Old and New Europe. Working paper. Leon Kozminski Academy of Entrepreneurship and Management, Warsaw, Poland.

Ark, B. V., Timmer, M. 2003. Asia's Productivity Performance and Potential: The Contribution of Sectors and Structural ChangeInnovation and ICT in Old and New Europe. Working paper. University of Groningen, the Netherlands.

Baily, M. N. 1986. What has happened to productivity growth?. *Science*, 234 (4775), 443-451.

Baily, M. N., Lawrence, R. Z. 2001. Do we have a new e-conomy?. *American Economic Review*, 91(2), 308–312.

Banz, R. W. 1981. The relationship between return and market value of common stocks. *Journal of Financial Economics*, 9(1), 3-18.

Barua, A., Kriebel, C. H., Mukhopadhyay, T. 1995. Information technologies and business value: An analytic and empirical investigation. *Information Systems Research*, 6(1), 3-23.

Benston, G. J. 1982. Accounting numbers and economic values. *Antitrust Bulletion*, 27, pp. 161-215.

Bharadwaj, A. S. 2000. A resource-based perspective on information technology capability and firm performance: an empirical investigation. *MIS Quarterly*, 24(1), 169-197.

Bresnahan, T. F. 1997. Computerization and wage dispersion: An analytical reinterpretation. Working paper 97031, Stanford University, Department of Economics.

Brynjolfsson, E. 1993. The productivity paradox of information technology. *Communications of the ACM*, 36(12), 66-77.

Brynjolfsson, E. 1994. Information assets, technology and organization. *Management Science*, 40 (12), 1645-1662

Campbell, J. Y., Andrew, W. L., MacKinlay, A. C. 1997. *Event-Study Analysis*. Princeton University Press, NJ, 149-180.

Carr, N. G. 2003. IT doesn't matter. Harvard Business Review, 81(5), 41-50.

China Internet Network Information Center. 2002. Semiannual survey report on the development of China's Internet. http:// www.cnnic.net.cn.

Council of Economic Advisor. 2001. The annual report of the council of economic advisors. In *The Economics of the President*. U.S. Government Printing Office, Washington, D.C.

Crowston, K., Treacy, M. E. 1986. Assessing the impact of information technology on enterprise level performance. *Proceedings of 6th International Conference on Information Systems*. Indianapolis, 299-310.

Dahlman, C. J., Ross-Larson, B., Westphal, L. E. 1987. Managing Technological Development: Lessons from the Newly Industrial Countries. *World Development*, 15(6), 759-775.

Dasgupta, S., Agarwal, D., Ioannidis, A., Gopalakrishnan, S. 1999. Determinants of Information Technology Adoption: An Extension of Existing Models to Firms in a Developing Country. *Journal of Global Information Management*, 7(3), 41-49.

Dasgupta, S., Laplante, B., Mamingi, N. 1998. Capital market responses to environmental performance in developing countries. World Bank Policy Research Working paper, No.1909.

Dedrick, J., Gurbaxani, V., Kraemer, K. L. 2003. Information technology and economic performance: A critical review of the empirical evidences. *ACM Computing Surveys*, 36(1).

Dedrick, J., Kraemer, K. 1995. National technology policy and computer production in Asia-Pacific countries. *The Information Society*, 11(1), 29-58.

DeLone, W. H. 1981. Firm size and characteristics of computer use. *MTS Quarterly*, 5(4), 65-77.

Dewan, S., Kraemer, K. L. 2000. Information technology and productivity: Evidence from country-level data. *Management Science*, 46(4), 548-562.

Dewan, S., Michael, S. C., Min, C. 1998. Firm Characteristics and investments in Information Technology: scale and scope effects. *Information Systems Research*, 9(3), 219-232.

Dewar, R. D., Dutton, J. E. 1986. The adoption of radical and incremental innovations: an empirical analysis. *Management Science*, 32(11), 1422-1433.

Dos Santos, B. L., Peffers, K., Mauer, D. C. 1993. The impact of information technology investment announcements on the market value of the firm. *Information Systems Research*, 4(1), 1-23.

Durlauf, S. N., Quah, D. T. 1998. The new empirics of economic growth. NBER. Working paper, No. 6422.

Ein-Dor, P., Segev, E. 1978. Organizational context and the success of management information systems. *Management Science*, 24(10), 1064-1077.

Enos, J., Lall, S. Yun, M. 1997. Transfer of technology: An update. *Asian-Pacific Economic Literature*, 11 (1), 56-66.

Fama, E. F. French, K. R. 1995. Size and book-to-market factors in earnings and returns. *Journal of Finance*, 50(1), 131-155.

Fang, X. 2004. Intel Versus Microsoft: who is the biggest IT monopoly in China. http://www.blogchina.com/new/display/24010.html.

Gerschenkron, A. 1962. *Economic Backwardness in Historical Perspective*. Cambridge MA: Harvard University Press

Gordon, R. J. 2000. Does the "New Economy" measure up to the great inventions of the past? Journal of Economic Perspectives, 14(4), 49-74.

Gremillion, L. L. 1984. Organization Size and Information System Use: An Empirical Study. *Journal of Management Information Systems*, 1(2), 4-17.

Harris, S. E., Katz, J. L. 1991. Firm Size and the Information Technology Investment Intensity of Life Insurers. *MIS Quarterly*, 15(3), 333-352.

Hobday, M. 1995. Innovation in East Asia: The Challenge to Japan. Aldershot, UK: Edward Elgar.

Homer-Dixon, T. F. 1991. Environmental changes as causes of ascetic conflict. *International Security*, 16(2), 76-116.

Im K. S., Dow, K. E., Grover, V. 2001. A reexamination of IT investments and the market value of the firm – an event study methodology. *Information Systems Research*, 12(1), 103-117.

Jia, X. 2000. Ji yu gong chuang ruan jian lian meng. People's Daily, March 17.

Jorgenson, D. W., Stiroh, K. J. 2000. Raising the speed limit: U. S. economic growth in the information age. Brookings Papers on Economic Activity, 1, 125-235.

Judge, G. G., Hill, R. C., Griffiths, W. E., Lütkepohl, H., Lee, T. C. 1998. *Introduction to the Theory and Practice of Econometrics*. John Wiley and Sons, New York.

Kim, L. 1995. Absorptive Capacity and Industrial Growth: A Conceptual Framework and Korea's Experience. In B.H. Koo and D. Perkins, *Social Capability and Economic Growth*. London: Macmillan.

Kim, L., 1997. Imitation to Innovation: *The Dynamics of Korea's Technological Learning*. Boston: Harvard Business School Press.

Kowtha, N. R., Choon, T. M. I. 2001. Determinants of website development: A study of electronic commerce in Singapore. *Information and Management*, 39(3), 227-242.

Kraemer, K. L., Dedrick. J. 2001. The productivity paradox: Is it resolved? Is there a new one? What does it all mean for managers? CRITO, University of California.

Lall, S. 1982. Developing Countries as Exporters of Technology. London: Macmillan.

Lall, S. 2000. Technological change and industrialization in the Asian newly industrializing economies: Achievements and challenges. In L. Kim, and R.R. Nelson, *Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies*. Cambridge, UK: Cambridge University Press.

Lieberman, M. B., Montgomery, O. B. 1988. First-mover advantages. *Strategic Management Journal*, 9, 41-58.

Lieberman, M. B., Montgomery, O. B. 1998. First-mover (dis)advantages: Retrospective and link with the resource-based view. *Strategic Management Journal*, 19(12), 1111-1126.

Malone, T. W., Smith, S. A. 1987. Modeling Coordination in Organizations and Markets. *Management Science*, 33(10), 1317-1332.

Malone, T. W., Yates, J., Benjamin, R. J. 1987. Electronic markets and electronic hierarchies. *Communication of the ACM*, 30(6), 484-497.

Malone, T. W., Yate, J., Benjamin, R.I. 1989. The logic of electronic markets. *Harvard Business Review*, 67(3), 166–172.

Mathews, J. A., Cho, D. S. 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*. Cambridge, UK: Cambridge University Press.

Oliner, S. D., Sichel, O. E. 2000. The resurgence of growth in the late 1990s: Is information technology the story?. *Journal of Economic Perspective*, 14(4), 3-22.

Richardson, V. J., Zmud, R. W. 2001. The Value Relevance of Information Technology Investment Announcements: Incorporating Industry Strategic IT Role. *Proceedings of the 35th Hawaii International Conference on Systems Sciences*.

Sauvant, K. P. 1984. The growing dependence on transborter Data Flows. *Computerworld*, 18(26).

Song, J. 2000. Technological Catching-Up of Korea and Taiwan in the Global Semiconductor Industry: A Study of Modes of Technology Sourcing. Working paper, Columbia Business School.

Splettstoesser, D. 1996. Development decision centers – A strategy to improve development decision-making. In B.Glasson, D.R.Vogel, J.F.Nunamaker, and P.W.Bots, *Information Systems and Technology in the International Office of the Future*. London: Chapman and Hall, 299-315.

Strassmann, P. A. 1990. The *business value of computers: An executive's guide.* New Canaan, Coon. : Information Economics Press.

Subramani, M., Walden, E. A. 2001. The impact of E-Commerce announcements on the market value of firms. *Information Systems Research*, 12(2), 135-154.

Talero, E. 1994. Demand-Driven Approach to National Informatics Policy, Linkage Developing Countries. *Proceedings of the IFIP 13th World Computer Congress*, Hamburg, Germany, Vol. III, Amsterdam et al. 17-25.

Tam K. Y. 1998. The Impact of Information Technology Investments on Firm Performance and Evaluation: Evidence form Newly Industrialized Economies. *Information Systems Research*, 9(1), 85-98.

The Standish group, 1995. The Chaos Report. http://www3.uta.edu/faculty/reyes/teaching/general_presentations/chaos1994.pdf.

Thong, J. Y. L. 1999. An Integrated Model of Information Systems Adoption in small Business. *Journal of Management Information Systems*, 15(4), 187-214.

Triplett, J., Bosworth, B. P. 2003. Productivity measurement issues in services industries: "Baumol's disease" has been cured. *Economic Policy Review*, 9(3), 23-33.

Turner, J. A. 1982. Firm Size, Performance, and Computer Use. *Proceedings of Third International Conference on Information Systems*, Ann Arbor, MI, 109-120.

Westphal, L. E., Kim, L., Dahlman, C. J. 1985. Reflections on the Republic of Korea's Acquisition of Technological Capability. In N. Rosenberg, and C. Frischtak, *International Transfer of Technology: Concepts, Measures, and Comparison*. New York: Praeger.

Whelan, K. 2000. Computers, obsolescence, and productivity. Finance and Economic Discussions Services, 2000-06, Board of Governors of the Federal Reserve System.

Zhu, K., Xu, S., Dedrick, J. 2003. Assessing drivers of e-business value: results of a cross-country study. *Twenty-Fourth International Conference on Information System*s, Seattle, Washington, USA.

Zuboff, S. 1988. In *the age of the Smart Machine: the future of work and power*. New York: Basic Books.

CHAPTER 4 GALLERY FEATURE IN EBAY: ADVERTISING OR SIGNALING

4.1. Introduction

Founded in 1995, eBay describes itself as “The World's Online Marketplace”. EBay has now grown to 135.5 million registered members from around the world, with annual sales of $34.2 billion in 2004.[14] Other large U.S. online auction services include Yahoo Auction (founded in 1999) and Amazon Auction. Online auction services outside the U.S. include eBid in the UK, QXL Ricardo in Europe, and Taobao in China.

Online auction markets have been in existence for sufficiently long that business practices among buyers and sellers should now be quite mature. Since these markets are very transparent, they are a good context in which to measure the impact of the various elements of the marketing mix.

EBay and Yahoo Auctions apply a second price auction. Upon paying an insertion fee, a seller can list auction items for a fixed period with a public start bid price and, possibly, a secret reserve price. Sellers also have the option of setting a fixed price at which the items may be bought without bidding. If the auction is successful, eBay will collect a commission of about 5.25% of the closing value from the seller.

Both eBay and Yahoo Auctions offer various optional features with which sellers may promote their items. In eBay, these features include: “Gallery”, which inserts a large picture of the items being sold; “Highlight”, which emphasizes the seller’s listing

[14] Source: EBay. Announces Fourth Quarter and Full Year 2004 Financial Results, 2004

with an eye-catching purple colored band; “Bold”, which uses different fonts for the titles of the items; and “Border”, which adds a gray frame around the seller’s listing.

Generally, the objective of advertising is to increase demand and hence enable the seller to increase profit. Accordingly, a key tool in advertising strategy is the sales-response function, which measures the impact of advertising expenditure on sales revenue.

In this essay, I focus on sellers’ use of the Gallery feature in eBay auctions for several consumer products to gauge the sales-response function, and to explore what underlies the sales-response function. The hedonic method is applied to examine Gallery’s impact on the sales-response function. I recorded sellers’ information and auction results for 12 products and 6148 individual auctions. It was found that the auctions with Gallery feature attract more bids and achieve a higher final auction price than those without. Hence, Gallery can be an effective advertising tool and bring benefit to sellers.

Furthermore, I examine whether the Gallery feature serves as signal. In the online context, sellers have private information about the items that they sell, and buyers are uninformed. Signaling is a way by which informed parties can credibly communicate their information to uninformed parties. It was found that sellers’ quality is related to the Gallery feature for high-priced products.

The rest of the essay is organized as follows: section 4.2 provides the theoretical background. Section 4.3 proposes the hypotheses. In section 4.4, I describe the data collection procedures. The test results are presented in section 4.5. Finally, I discuss the results and implications of this study in section 4.6.

4.2. Theory

Generally, advertising raises the demand for an item and also causes buyers to be less price-sensitive. Accordingly, if the Gallery feature serves an advertising function, auctions with the Gallery feature should attract more bids and exhibit more intense competition. If the competition is more intense, the likelihood that the highest bid will fall below the seller's reserve price will be lower, and hence the probability that the item will be sold would be higher. Further, the closing price should be higher. Thus, if the Gallery feature serves an advertising function, auctions with the Gallery feature should:

- Exhibit more intense competition;
- Be more likely to succeed; and
- End with a higher price.

Another possible explanation for sellers' use of the Gallery feature is to signal their attributes. Asymmetry of information between buyers and sellers is more serious in online markets than conventional markets. In an online context, buyers cannot inspect the item for sale and do not meet the seller in person. Accordingly, a key issue in online markets is how to resolve the information asymmetry and establish trust between buyers and sellers.

A key way by which eBay mitigates this asymmetry of information is the feedback mechanisms. In eBay, after each transaction, both the buyer and seller are required to provide an assessment (positive, negative or neutral) of the trading partner. They even can leave detailed comments, such as "Fast delivery and great seller". These assessments comprise the permanent feedback record of each seller, which is presented just beside each person's eBay ID. The feedback record includes the Positive Score, Negative Score, Feedback Score and Positive Ratio.[15] These feedback mechanisms induce trust and provide reputable sellers with a price premium (Ba and Pavlou 2002, Lucking-Reiley et al. 2000, Melnik and Alm 2002).

But, what if the seller's feedback record does not fully resolve the informational asymmetry? This would be particularly true considering that hundreds of sellers list side by side in eBay. It is costly for buyer to check the feedback record for each seller. Signaling is a way by which an informed party may credibly communicate its private information. Various practices have been explained in terms of signaling – these include advertising (Nelson 1970), branding (Erdem and Swait 1998), warranties (Grossman 1981) and product pricing (Wolinsky 1983). Could the seller's use of the Gallery feature serve to signal seller quality?

For something to be a credible signal of seller quality, the signal must be more costly for sellers with lower quality. In eBay, sellers with inferior feedback record should attract less intense bidding, and hence be less likely to sell their item, and would attract a lower price. Since the fee for the Gallery feature is not refundable, lower quality sellers have less incentive to use the feature. Thus, it is possible to assume that sellers use Gallery as a signal.

---

[15] Feedback Score=Positive Score-Negative Score; Positive Ratio=Positive Score/(Positive score + Negative score). In eBay, Feedback Score and Positive Ratio are listed just beside each ID. By clicking the ID, trading parties can see the Positive Score and Negative Score with detailed comments.

If the Gallery feature serves a signaling function, auctions with the Gallery feature should attract more bidders. Consequently, the empirical implications of the Gallery feature are similar to those arising if Gallery serves an advertising function.

How can the advertising and signaling theories be distinguished? The distinction relates to the necessary condition for signaling. Relatively more high-quality than low-quality sellers should use the signal.

4.3. Hypotheses

The first hypothesis addresses the use of the Gallery feature for either advertising or signaling.

Hypothesis 1. Auctions with the Gallery feature should:

(a) Exhibit more intense competition;

(b) Be more likely to succeed; and

(c) End with a higher price.

The predictions underlying Hypothesis 1 are consistent with both the advertising and signaling theories.

In the above theoretical section, I have argued that, Gallery may serve as an effective quality signal. If so, the Gallery feature should be used by relatively more high-quality than low-quality sellers. This prediction can be operationalized through the seller's

“Positive Ratio”, which is the seller’s Positive Score divided by the sum of the seller’s Positive Score and Negative Score. Using the Positive Ratio to measure the seller’s quality, the signaling theory predicts:

Hypothesis 2. Sellers with higher Positive Ratio are more likely to use Gallery compared with those with lower Positive Ratio.

The seller’s quality can also be operationalized by the Feedback Score (Positive Score minus Negative Score), which represents seller’s experience and reputation. Thus, the signaling theory expects:

Hypothesis 3. Sellers with higher Feedback Score are more likely to use Gallery compared with those with lower Feedback Score.

4.4. Data

The hypotheses were tested using field data collected from eBay. I chose 12 consumer products, whose closing prices range from around $2 to around $400. In addition to the variables used to operationalize the hypotheses, various other factors might influence the intensity of bidding, success of the auction and closing price. These include the nature of the product, starting bid price, and shipping fee.

Accordingly, for each product, the detailed information of the auction was recorded, including the seller’s feedback records, start bid price, whether the Gallery feature was used, whether the item was sold, final auction price and shipping fee.

The total sample size was 6148, which was collected over a period of four months (October 2004 to January 2005). The detailed descriptions of the data are presented in Tables 4.1.1 and 4.1.2.

Product	Aladdin VHS (1993)	Under my skin	The day after tomorrow	Cinderella	Fable	Nintendo
Condition	Used	New	New	Used	Used	Used
No. of Observation	243	201	286	283	257	294
Deal items	87	150	194	240	214	230
No. of Using Gallery within All the Observation	51	49	28	93	80	124
No. of Using Gallery within the Deal Items	22	39	20	85	71	100
Ratio of Using Gallery within all the Observation	20.98%	24.38%	9.79%	32.86%	31.28%	42.18%
Ratio of Using Gallery within the Deal Items	25.28%	26%	10.30%	35.42%	33.18%	43.48%
Average Positive Ratio of all the Observation	99.48%	99.54%	98.64%	99.62%	99.2%	98.90%
Average Auction Price	2.89	7.23	7.92	17.28	31.00	37.53

Table 4.1.1: Data Descriptions

Product	LG TM510	Grand theft	Halo (1994)	LG VX600	Sony Play station	Sony Cyber Shot
Condition	Used	New	New	New	new	New
No. of Observation	531	1329	1197	372	886	269
Deal items	428	1143	894	252	624	192
No. of Using Gallery within All the Observation	348	643	609	205	551	169
No. of Using Gallery within the Deal Items	259	537	491	140	331	105
Ratio of Using Gallery within all the Observation	65.54%	48.38%	50.88%	55.11%	62.19%	62.83%
Ratio of Using Gallery within the Deal Items	60.51%	46.98%	54.92%	55.56%	53.04%	54.69%
Average Positive Ratio of all the Observation	98.83%	98.52%	98.199%	97.76%	95.73%	98.55%
Average Auction Price	44.2560	45.0292	46.82	133.39	190.77	398.31

Table 4.1.2: Data Descriptions

A few measures were taken to improve the accuracy of data collected. Firstly, the descriptions of the selling items were checked to ensure they were homogeneous. Secondly, auctions in which sellers used features other than Gallery were excluded. As a result, the analysis of the effect of Gallery excluded the possible influence of other features, such as Bold or Highlight. Thirdly, each record was of a unique seller. This ensured that there was no duplication of information about a particular seller.

4.5. Results

4.5.1. Advertising Effect

Hypotheses 1(a)-1(c) focus on the impact of the Gallery feature on demand for the item. I set up equations 4.1-4.3 to analyze the impact of the Gallery feature. By Hypotheses 1(a)-1(c), the coefficient α_3 in equation 4.1- 4.3 should be positive and significant.

$$\text{No. of bids} = \alpha_0\text{Constant} + \alpha_1\text{Start bid price} + \alpha_2\text{Shipping fee} + \alpha_3\text{Gallery} + \alpha_4\text{Feedback score} + \varepsilon \quad (4.1),$$

$$\text{Success} = \alpha_0\text{Constant} + \alpha_1\text{Start bid price} + \alpha_2\text{Shipping fee} + \alpha_3\text{Gallery} + \alpha_4\text{Feedback score} + \varepsilon \quad (4.2),$$

$$\text{Price} = \alpha_0\text{Constant} + \alpha_1\text{Start bid price} + \alpha_2\text{Shipping fee} + \alpha_3\text{Gallery} + \alpha_4\text{Feedback score} + \varepsilon \quad (4.3).$$

The results are summarized in Table 4.2.

	No. of bids		Success		Price	
	(i) Gallery	(ii) Feedback Score	(iii) Gallery	(iv) Feedback Score	(v) Gallery	(vi) Feedback Score
Aladdin	2.344*** (.588) t=3.983	.000 (.000) t=1.243	.352 (.330) t=1.133	.000 (.000) t=.312	1.478** (.632) t=2.338	.000 (.000) t=.941
Under my skin	1.146** (.495) t=2.316	.000 (.000) t=1.561	-.207 (.472) t=.192	.000*** (.000) t=28.823	.494 (.261) t=1.893	.000 (.000) t=1.793
The Day After Tomorrow	2.658*** (.786) t=3.382	.000 (.000) t=.765	.064 (.461) t=.019	.000 (.000) t=.868	3.548*** (.556) t=6.384	5.51E-005 (.000) t=.889

Cinderella	2.285*** (.677) t=3.372	.000 (.000) t=-.349	.892** (.433) t=4.242	.000** (.000) t=4.606	3.191*** (.880) t=3.625	2.18E-005 (.000) t=.111
Fable	.258 (.664) t=.388	.000 (.001) t=-.875	.665 (.450) t=2.178	.001 (.001) t=2.842	1.275** (.537) t=2.375	.000 (.000) t=-.292
Nintendo	1.781 (1.079) t=1.651	-.002 (.001) t=-2.162	.113 (.357) t=.101	.000 (.000) t=.115	4.234 (2.840) t=1.490	-.005** (.002) t=-2.211
LG TM510	1.259 (.723) t=1.741	.001 (.001) t=1.940	-.179 (.400) t=.199	.000 (.000) t=1.566	-2.227 (1.565) t=-1.423	.000 (.001) t=.172
Grand theft	1.053*** (.365) t=2.882	.000 (.000) t=1.763	-.412** (.176) t=.019	.000*** (.000) t=13.603	.316 (.295) t=1.070	.000*** (.000) t=6.922
Halo	1.343*** (.370) t=3.626	.000 (.000) t=2.435	.666*** (.154) t=18.633	.000*** (.000) t=19.132	.844** (.394) t=2.142	.000** (.000) t=2.482
LG VX600	3.121*** (1.071) t=2.916	.001 (.001) t=.610	.268 (.262) t=1.042	-.001*** (.000) t=17.001	.119*** (.027) t=4.415	11.469*** (3.116) t=3.680
Sony Play station	1.151 (.746) t=1.543	.000 (.000) t=.334	.346 (.215) t=2.590	.000 (.000) t=.494	5.760** (2.620) t=2.198	.001 (.002) t=.646
Sony Cyber Shot	3.130*** (1.205) t=2.597	.001 (.001) t=.457	-.250 (.376) t=.440	.000*** (.000) t=13.152	-1.003 (4.043) t=-.248	-.002 (.004) t=-.558

***significant at the 0.01% level **significant at the 1% level

Table 4.2: Advertising Effect: each product category

Firstly, I use the number of bids to measure the intensity of the competition. If Gallery is effective in advertising, the auctions with Gallery feature should attract more bidders, and hence more bids. Table 4.2, columns (i)-(ii), reports OLS estimates of equation 4.1. In 8 out of 12 products, the Gallery feature was associated with a significantly higher number of bids, which is consistent with Hypothesis 1(a).

Secondly, I test whether the Gallery feature increases the likelihood of the item being sold. Table 4.2, columns (iii)-(iv), reports logit estimates of equation 4.2. In only 2 out of 12 products was the coefficient of Gallery positive and significant. Therefore, H1(b) is rejected.

Thirdly, I examine whether Gallery can raise seller profits. Table 4.2, columns (v)-(vi) reports OLS estimation of equation 4.3 on the sub-sample in which the item was sold. In 7 out of 12 products, the Gallery feature was associated with a significantly higher final auction price. More importantly, for most products, the increase in the final auction price exceeds the cost of the Gallery feature ($0.35). For instance, Gallery can increase the final auction price of Sony Playstation by $5.76. Therefore, Gallery is a profitable advertising tool.

After testing hypotheses 1(a)-1(c) in each product category, I further check them for the sample of the total 12 product categories, using dummy variables for the various products. The results are summarized in Table 4.3.

	No. of bids		Success		Price	
	(i) Gallery	(ii) Feedback Score	(iii) Gallery	(iv) Feedback Score	(v) Gallery	(vi) Feedback Score

Whole Sample	.000*** (.000) t=2.706	1.827*** (.194) t=9.443	.000 (.000) p=.460	.142 (.128) p=.268	2.667*** (.143) t=18.699	.000*** (.000) t=3.161

***significant at the 0.01% level

Table 4.3: Advertising Effect: whole sample

Firstly, I examine the impact of Gallery on the intensity of the competition for the whole sample. Table 4.3, column (i), showed that the coefficient of Gallery feature was significant and positive. Hence, the above finding that the Gallery feature is associated with a higher number of bids is strengthened.

Next, the relationship between the Gallery feature and the likelihood of the item being sold is tested for the whole sample. In Table 4.3, column (iii), the insignificant coefficient of the Gallery feature indicated that the Gallery feature was not correlated to the likelihood of the item being sold. Again, H1(b) is rejected.

Finally, I check how the Gallery feature affects the final auction price for the whole sample. The result in Table 4.3, column (v), showed that the coefficient of Gallery feature was significant and positive. Such results reconfirm that Gallery feature was associated with a higher final auction price.

From the above results, I conclude that Gallery does serve as an advertising function. By attracting the attention of buyers, auctions with the Gallery feature attract more intense competition, which increases the final auction price. For most products, the increased final auction price is higher than the cost of the Gallery feature. Thus, it is profitable for sellers to invest in the Gallery feature. Surprisingly, I do not find evidence that Gallery increases the probability that the item will be sold.

4.5.2. Signaling Effect

Having proved the advertising effect of Gallery, I further examine whether the Gallery feature serves as an effective quality signal. If Gallery is a quality signal, as inferred by Hypothesis 2, sellers with a higher Positive Ratio should be more likely to use Gallery feature than those with lower Positive Ratio. Therefore, the coefficient in the logit model 4.4 should be positive and significant.

$$\text{Gallery} = \alpha_0 \text{Constant} + \alpha_1 \text{Start bid price} + \alpha_2 \text{Shipping fee} + \alpha_3 \text{Positive Ratio} + \varepsilon \qquad (4.4).$$

The regression results are reported in Table 4.4. Column (ii) showed that in only 2 out of 12 products is the coefficient of Positive Ratio negative and significant. Hence, Gallery is not associated with the Positive Ratio. H2 is rejected.

	Regression Function 4.4 Sample: all	
	(i) Start Bid Price	(ii) Positive Ratio
Aladdin	.014 (.085) t=.029	-.063 (.086) t=.528
Under my skin	.083 (.058) t=2.086	.007 (.214) t=.001
The Day After Tomorrow	.004 (.053) t=.006	.012 (.050) t=.060
Cinderella	-.036 (.019) t=3.769	-.070 (.229) t=.092
Fable	-.006 (.013) t=.226	-.046 (.088) t=.270
Nintendo	-.005 (.009) t=.280	.082 (.076) t=1.166
LG TM510	.035 (.007) t=25.429	.021 (.056) t=.139
Grand theft	.006 (.003) t=3.072	-.053*** (.018) t=8.934
Halo	-.022*** (.003) t=49.304	.020 (.014) t=2.099
LG VX600	-.001 (.002) t=.154	.023 (.021) t=1.145
Sony Play station	-.004*** (.001) t=12.230	-.070*** (.026) t=7.149
Sony Cyber Shot	-.001 (.001) t=.479	-.071 (.058) t=1.525

***significant at the 0.01% level

Table 4.4: Signaling Effect: Positive Ratio

A possible reason is that Positive Ratio is not a good measure to differentiate seller quality. To establish trust in the community, eBay checks the users' transaction history regularly and bans those with low Positive Ratio. As a result, most sellers in eBay have high Positive Ratio. From Table 4.1.1 and 4.1.2, one can observe that the average Positive Ratio of sellers is above 98%. Buyers may not be sensitive to small differences in sellers' Positive Ratio. Consequently, Positive Ratio may not affect sellers' choice of using Gallery feature.

Hypothesis 3 uses the Feedback Score as a proxy for seller quality and predicts that sellers with higher Feedback Score have more incentive to use the Gallery feature. By hypothesis 3, the coefficient α_3 in the equation 4.5 should be positive and significant.

$$\text{Gallery} = \alpha_0 \text{Constant} + \alpha_1 \text{Start bid price} + \alpha_2 \text{Shipping fee} + \alpha_3 \text{Feedback Score} + \varepsilon \qquad (4.5).$$

Table 4.5, column (ii), reports logit estimations of equation 4.5. In 7 out of 12 products, the Gallery feature was associated with a higher Feedback Score. Moreover, 5 of them were high-priced products.[16] As a result, I infer that H3 can be accepted in the high-priced product categories.

[16] Since the coefficient of the Feedback Score is too small, the regression results using Spss and Eviews are different. Here I report the results by Spss. For the results by Eviews, please refer to the Table 4A.1 in the Appendix 4.1.

	Regression Function 4.5 Sample: all	
	(i) Start Bid Price	(ii) Feedback Score
Aladdin	.021 (.086) p=.803	.000 (.000) p=.370
Under my skin	.063 (.057) p=.268	.000** (.000) p=.026
The Day After Tomorrow	0.010 (0.056) p=.858	0.000 (0.000) p=.738
Cinderella	-0.031 (0.020) p=.106	0.000** (0.000) p=.032
Fable	-0.006 (0.013) p=.620	0.000 (0.000) p=.691
Nintendo	-0.003 (0.009) p=.674	0.000 (0.000) p=.716
LG TM510	0.033*** (0.007) p=.000	0.001*** (0.000) p=.000
Grand theft	-0.007** (0.004) p=.045	0.000*** (0.000) p=0.000
Halo	-0.018*** (0.003) p=.000	0.000*** (0.000) p=.001
LG VX600	-0.001 (0.002) p=.704	0.001*** (0.000) p=.001
Sony Play station	-0.003*** (0.001) p=.002	0.000 (0.000) p=.324
Sony Cyber Shot	-.002 (0.001) p=.078	.000** (0.000) p=.035

***significant at the 0.01% level **significant at the 1% level

Table 4.5: Signaling Effect: Feedback Score (Spss)

4.6. Discussion and Conclusions

This study provides an interpretation of the advertising and signaling behavior in eBay. The Gallery feature was examined to investigate the function of the optional features in online auction markets. There are two main sets of findings: firstly, Gallery serves as an advertising function, which intensifies competition among buyers, and thus increases the final auction price. In a way, these features act as value-added indications for buyers. However, there is no evidence that Gallery is related to the probability that the item will be sold.

Secondly, for high-priced products, I observe that sellers with a higher Feedback Score are more likely to choose Gallery feature than those with lower Feedback Score. Using Feedback Score as an indicator of seller quality, I conclude that Gallery is more likely to be chosen by high quality sellers, and thus, serves as a quality signal.

Such results provide practical implications for the trading parties in eBay. Sellers can be reminded to get an insight into the buyers' psychology, and thus invest in the optional features to win the price premia. Buyers can be informed that the Gallery feature serves as a quality signal for the high-priced products. It is thus wiser for them to choose the auctions with Gallery. Furthermore, the Gallery feature can help to mitigate the information asymmetry and establish trust between trading parties.

There are a few puzzles, which need further investigation. Firstly, the Gallery feature can bring extra payoff which exceeds the cost. Since sellers can easily get past transaction information in eBay, sellers should invest in the Gallery feature until the market equilibrium is reached, where the profit of Gallery is equal to the cost. However, this is not the case I observed.

The possible reason is that it is hard or too costly for any individual buyer or seller to predict the market outcome precisely. Far from having perfect or common information, subjects know only their own circumstances. Therefore, their behaviors may deviate from the prediction of the economic theory.

Such results challenge the claim that Internet can remove market frictions, and will bring about a nearly perfect market (Kuttner 1998). Although eBay provides a more transparent market than the conventional one, the efficient market or frictionless market has not been realized yet.

The second puzzle is that signaling effect is observed in high-priced products rather than low-priced products. Since the cost of the Gallery feature is fixed for all the products, the possible loss from a fake signal is comparatively higher for low-priced products than high-priced products. It is thus expected that signal effect should be more widespread in low-priced products. However, the real data show the opposite pattern.

A possible explanation, as according to Smith and Szidarovszky (1999) is that individuals' behavior will more closely match the prediction of rational-behavior theories when the stakes of the decision increase, and the decision costs decrease. With the increase of the product price, the decision cost of choosing Gallery or not is comparatively low. Hence, it is expected that sellers' behavior will be consistent with the prediction of the signaling theory. Such results indicate that the prediction of the signaling theory and the empirical testing has discrepancy, which need to be reconciled by further study.

References

Akerlof, G. 1970. The Market for ‘Lemons’: Quality Uncertainty and the Market Mechanism. *The Quarterly Journal of Economics,* 84(3), 488-500.

Ba, S., Pavlou, P. 2002. Evidence of the Effect of Trust Building Technology in Electronic Markets: Price Premiums and Buyer Behavior. *MIS Quarterly,* 26(3), 243-269.

Bain, J. S. 1956. *Barriers to New Competition*. Cambridge: Harvard University Press.

Bonifield, C., Cole, C., Schultz, R. L. 2002. Product Returns on the Internet: A Case of Mixed Signals?. Working paper, School of Business, University of Vermont.

Brynjolfsson, E., Smith, M.D. 2000. The Great Equalizer? Consumer Choice Behavior at Internet Shopbots. Working Paper, Sloan School of Management, MIT.

Chinabyte News. 2004. Interview with the CEO of eBay. http://e.chinabyte.com/homepage/219001898546495488/20040423/1791012.shtml.

Comanor, W. S., Wilson, T. A. 1967. Advertising, Market Structure and Performance. *This Review,* XLIX, 423-440.

Erdem, T., Swait, J. 1998. Brand Equity as a Signaling Phenomenon. *Journal of Consumer Psychology* , 7(2), 131-158.

Grossman, S. 1981. The Role of Warranties and Private Disclosure about Product Quality. *Journal of Law and Economics,* 24(3), 461-483.

Kahneman, D. 1994. New Challenges to the Rationality Assumption. *Journal of Institutional and Theoretical Economics*, 150(1), 18-36.

Kahneman, D. Tversky, A. 1979. Prospect Theory: An Analysis of Decision under Risk. *Econometrics,* 47(2), 263-292.

Kahneman, D., Slovic P., Tversky A. 1982. *Judgment Under Uncertainty: Heuristics and Biases*. Cambridge University Press.

Kuttner, R. 1998. in Business Week, May 11.

Lohse, G. L. 1993. Consumer Eye Movement Pattern on Yellow Pages Advertising. *Journal of Advertising,* 26(1), 1-13.

Lohse, G. L., Rosen, D. L. 2001. Signaling Quality and Credibility in Yellow Pages Advertising: The Influence of Color and Graphic Choice. *Journal of Advertising*, 30(2), 73-85.

Lucking-Reily, D., Bryan, D., Prasa, N., Reeves, D. 2000. Pennies from eBay: The Determinants of Price in Online Auctions. Working Paper, Vanderbilt University.

Melnik, M. I., Alm, J. 2002. Does a Seller's Ecommerce Reputation Matter? Evidence from eBay Auctions. *The Journal of Industrial Economics,* L(3), 337-349.

Rothschild, M., Stiglitz, J. E. 1976. Equilibrium in Competitive Insurance Markets: The economics of markets with imperfect information. *Quarterly Journal of* Economics, (90:4), 629-649.

Sena, M., Braun, G. 2004. A Picture is Worth $84: An Examination of Consumer Behavior on EBay Motors. *Proceedings of the Tenth Americas Conference on Information Systems*, New York, New York.

Smith, V., Szidarovszky, F. 1999. Monetary Rewards and Decision Cost in Strategic Interactions. Working paper, University of Arizona.

Spence, M. 1973. Job marketing Signaling. *The Quarterly Journal of Economics,* 87(3), 355-374.

Simon, H. A. 1955. A Behavioral Model of Rational Choice. *The Quarterly Journal of Economics*, 69, 99-118.

Telser, L. G. 1964. Advertising and Competition. *Journal of Political Economy*, LXXII, 537-562.

Tversky, A., Edwards, W. 1996. Information versus Reward in Binary Choices. *Journal of Experimental Psychology*, 71, 608-683.

Wolinsky, A. 1983. Prices as Signals of Product Quality. *The Review of Economics Studies*, 50(4), 647-658.

Appendix 4.1. Signaling Effect (Eviews)

	Regression Function (8) Sample: all	
	(i) Start Bid Price	(ii) Feedback Score
Aladdin	0.005 (0.016) t=0.29	-0.000 (0.000) t=-0.68
Under my skin	0.062 (0.056) t=1.11	-0.000** (0.000) t=-1.99
The Day After Tomorrow	0.010 (0.056) t=0.18	-0.000 (0.000) t=-0.33
Cinderella	-0.031 (0.020) t= -1.56	-0.000 (0.000) t =-1.18
Fable	-0.006 (0.013) t= -0.50	0.000 (0.000) t=0.40
Nintendo	-0.003 (0.009) t=-0.42	0.000 (0.000) t=0.36
LG TM510	0.033*** (0.007) t=4.76	0.001*** (0.000) t=3.81
Grand theft	-0.007** (0.004) t=-2.01	0.000*** (0.000) t=7.86
Halo	-0.018*** (0.003) t=-5.62	0.000*** (0.000) t=3.31
LG VX600	-0.001 (0.002) t=-0.37	0.001*** (0.000) t=3.38
Sony Play station	-0.003 (0.001) t=-0.14	-0.000 (0.000) t=-0.98
Sony Cyber Shot	-0.001 (0.001) t= -1.56	0.001** (0.000) t=2.06

***significant at the 0.01% level **significant at the 1% level

Table 4A.1: Signaling Effect: Feedback Score (Eviews)

CHAPTER 5 CONCLUSIONS AND FUTURE WORK

In this chapter, I will briefly review the results of these three essays, and propose a few possible directions for future research.

5.1. Competition between Open Source and Proprietary Software

In the second chapter, I focused on competition between open source and proprietary software. When facing an open source competitor, the producer of the proprietary software must decide on compatibility. On the one hand, compatibility with the open source software allows users of the proprietary software to share the network externality from the open source users. On the other hand, incompatibility enables the proprietary producer to maintain monopoly power.

I applied a Hotelling linear city model to study the choice between compatibility and no compatibility by the producer of the proprietary software. Competition was asymmetric in that proprietary software aims at maximizing its profit, while open source software reacts passively. The model was analyzed under two scenarios, where the market is fully covered and where the market is not fully covered.

I found that the proprietary producer's choice of compatibility strategy depends on the market coverage condition. When the market is fully covered, two products are in severe competition. Inward compatibility allows proprietary software users to share the network externality of open source users, while preventing open source software users from sharing the network externality of the proprietary software. This is the best strategy.

When the market is partly covered, an increase in open source software users can benefit proprietary software users through the network externality, without decreasing the market share of the proprietary software. Therefore, two-way compatibility is a win-win strategy: it increases the proprietary producer's profit, while enhancing the user base of the open source software, which generates positive externalities for the users of the proprietary software.

Furthermore, the extension of the basic model showed that when the providers of the open source software maximize market share rather than react passively, two-way compatibility would be the best choice for both the proprietary software and the open source software.

Moreover, in a scenario where initially, both providers are proprietary, and then, one provider changes from providing proprietary to open source software, both the market share and the profit of the remaining proprietary software producer will decrease. Such a change may lower social welfare.

Future studies may focus on three possible directions. Firstly, the open source software and the proprietary software may not enter the market simultaneously. The software that enters earlier will grab the consumers and have large existing network externalities. It would be interesting to investigate how the installed user base affects the compatibility choices of the proprietary software.

Secondly, I assumed that consumers' taste difference is greater than the network externality intensity. If this assumption is violated, the equilibrium results are unstable. The switch of the marginal consumer from one software to the other makes every consumer follows the switch. Such a tipping market might have different implications regarding the compatibility strategies, which need further investigation.

Thirdly, users of the open source software may contribute to its quality. In turn, the increased quality attracts more users to switch from proprietary software to open source software. These two steps may feed on another. Another competition model, which focuses on the quality increase of the open source software, might be built to investigate how the compatibility strategies of the proprietary software and network externality influence the quality of the open source software.

5.2. IT Investment Value

In the third chapter, I applied an event study methodology to provide a better understanding of IT value to firms in a developing country. By comparing the impact of IT investment announcements on the firms' stock price in China and that in the U.S., I found that IT investment could significantly increase the firms' market value in China, while such an effect was not observed in the U.S.

Furthermore, the value of IT investment varied with respect to various factors. For instance, in China, IT value was more likely to create value in manufacturing than non-manufacturing industries, and, in IT-using firms than IT-producing firms.

Previous studies applied the event study methodology to study the value of IT investment in the U.S. However, all yielded negative results (Dos Santos et al. 1993, Im et al. 2001). This essay is the first one to report positive evidence of the value of IT investment, but for a sample of Chinese rather than U.S. businesses. The difference in results between China and the U.S. strongly suggests that IT investments may have different impacts in developing countries as contrasted with developed countries.

This essay enriches the limited research of IT value in developing counties. IT is proved to bring a better payoff in a developing country than in a developed country, and thus could be a bigger opportunity in developing countries.

5.3. Advertising and Signaling Behavior in eBay

In the fourth chapter, I studied advertising and signaling behavior on eBay. Major online auction markets provide optional features, such as Gallery and Bold, for sellers to promote the items for sale. These optional features have two possible functions. One is advertising, which attracts the attention of potential bidders. The other is a signal of quality, by which sellers can communicate private quality information.

To distinguish these two possible functions, field data were collected from eBay on sales and sellers' use of the Gallery feature. The results showed that the Gallery feature serves as an advertising tool. Auctions with the Gallery feature exhibited more intense competition and ended with a higher price. Moreover, for relatively high-priced products, sellers with higher feedback score were more likely to choose the Gallery feature than those with lower feedback score. Thus, Gallery can be deemed as a quality signal, which helps to establish trust between buyers and sellers.

This study has several empirical implications: firstly, these optional features are proved to be profitable advertising tools. Hence, sellers can use them to win price premia. Secondly, for the relatively high-priced product, these optional features may help buyers to get more information about sellers' quality and reduce the risk in online transaction. Thirdly, online market managers could be aware of the advertising and signaling functions of these optional features. Hence, they may provide more effective features, such as video clips, to smooth the transaction in the online market.

The results present a few puzzles, which need further investigation: firstly, the increased final auction price due to the Gallery feature exceeds the cost. Hence, it might be interesting to study the reason why some sellers do not invest in the Gallery feature to get the price premium. Secondly, the signal effect is more likely to be observed in relatively high-priced product categories than low-priced ones. Such an observation contradicts the theoretical prediction that signals with a relatively higher cost are more credible, and thus, needs to be reconciled by further research.

There are two other possible directions for future study. Firstly, the signaling behavior could be further investigated by using more expensive optional features, such as Bold or Highlight. As mentioned in the essay, the condition for an effective signal is that the signaling cost should be high enough to deter the low quality seller. Hence, with the increase of the cost of optional features, sellers' behavior should be more likely to fit with the prediction of the signaling theory.

However, in eBay, few sellers choose high-priced features. Thus, I need a comparatively longer time period to collect sufficient data for valid statistical tests. Because of the time limitation, in the essay, I choose the Gallery feature, which is cheap and chosen by quite a few sellers. The result showed that the signaling effect can only be observed in high-priced product categories. Future work could focus on features that are more expensive and may get better results.

The second possible future work is related to the bidders' behavior. During the data collection process, I found an interesting phenomenon: early bidding for each auction always exists. EBay applies the second price auction, which lasts for a fixed period, normally 3 or 5 days. The auction theory predicts that the optimal strategy for each bidder is to bid the true value. In such an auction, early bidding will disclose the bidder's private information to the competitors without bringing any extra payoff. Moreover, last minute bidding, which is called "sniffing", may successfully deter the other bidders from increasing their bids, and hence, bring benefits. It would be interesting to find the underlying economic or psychological reasons for the early bidding behavior.

One possible explanation is proposed by Klemperer (2003). He believes that the early bidding can be the result of collusion among bidders. In ascending auctions, bidders can use the early rounds, when prices are still low, to signal their views about who should win which objects, and then, when consensus has been reached, tacitly agree to stop bidding the price up. However, considering the vast number of the potential bidders in eBay, it would be surprising if collusion could work, especially for the common consumer products. Future study should investigate whether the early bidder is the final winner of the auction, which would then test Klemperer's collusion theory.

5.4. Conclusions

This thesis has provided three studies, that applied economic theory, modeling and empirical methods to study issues associated with IT and its application in electronic markets. The economic methods provide prediction and explanation for various phenomena. These are effective tools for IS scholars in addressing challenging research questions. It can be expected that economics will continue to play a key role in the development of IS research.

References

Dos Santos, Peffers, B.L., K., Mauer, D.C. 1993. The impact of information technology investment announcements on the market value of the firm. *Information Systems Research,* 4(1), 1-23.

Im K.S., Dow, K.E., Grover, V. 2001. A reexamination of IT investments and the market value of the firm: an event study methodology. *Information Systems Research,* 12(1), 103-117.

Klemperer, P. 2004. *Auction: Theory and Practice*. Princeton: Princeton University Press.